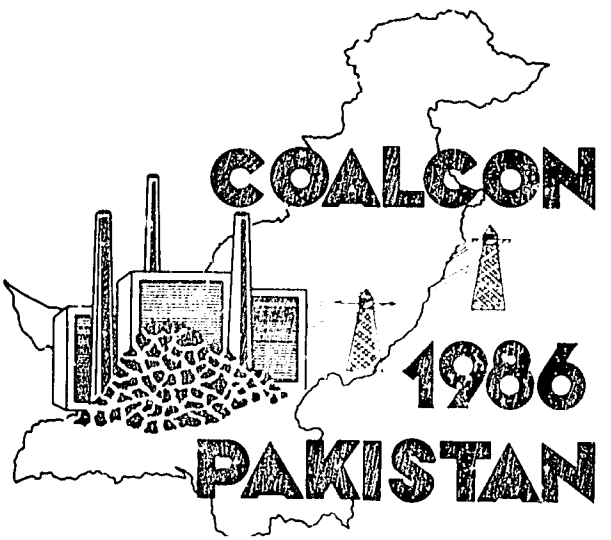
COAL DEVELOPMENT POTENTIAL IN PAKISTAN



Proceedings of
The First Pakistan National Coal Conference
Feb. 22 - 26, 1986

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Ministry of Planning & Development and Ministry of Petroleum and Natural Resources,
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COAL DEVELOPMENT POTENTIALS IN PAKISTAN

This publication contains a compilation of papers presented at
The First Pakistan National Coal Conference
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The First Pakistan National Coal Conference attracted over 600 people representing industry, government, financial and educational institutions from 23 countries. The Conference Goal and objectives, as set forth by the sponsors, were successfully achieved because of the positive spirit, goodwill and cooperation on the part of all Conference participants. In particular the success is due to the valuable guidance of the Steering Committee, the constant effort of the Organizing Committee, and dedication of Sadaqat Hasan Mir, Izharul Haque and the staff of ENERPLAN, Nawaz Khan of the Mineral Coordination Board; Charles Bliss, Asrarullah and staff of USAID; and Arnold and Loretta Pelofsky of AER Enterprises.

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EXECUTIVE SUMMARY

Sadaqat Hasan Mir
Managing Director, ENERPLAN and
Secretary General of Conference

Pakistan has extensive resources of lignitic and sub-bituminous coals, estimated (1985) by the Geological Survey of Pakistan to be around 800 million tonne. Indigenous coal however has a meagre share of 5% in the national energy supplies, primarily due to subsidized price of other competing fuels and partly on account of its high sulphur and ash contents requiring additional investment for its use as industrial fuel.

The Goal of this Conference was to provide a multi-disciplinary forum for constructive exchange of information that reinforces Pakistan's commitment to rely on coal resources as a major future energy supply.

The objectives were to review and evaluate the present situation in Pakistan with respect to the development and utilization of coal resources and the policies that have been responsible for this development and utilization; to review and evaluate precedents established by other nations which are undergoing coal development and utilization; to identify technological developments with respect to coal exploration, extraction, handling, transportation and utilization that could accelerate future development of Pakistan's coal; to identify and evaluate potentially attractive business opportunities associated with further coal development in Pakistan; and to determine whether institutional, infrastructural, and policy changes are needed to encourage such coal development and utilization.

Using these objectives as the basis, the following conclusions can be drawn from the sessions of the Conference:

Overview

The Conference unanimously agreed that immediate action must be taken for the development and use of the available coal resources, not only in the power generating sector, but in the industrial sector as well. The appropriate technology to achieve these goals must be utilized.

Government policy must be implemented and monitored to encourage substitution of coal for various fuels presently used.

Indigenous coal resources should be developed to reduce the import energy bill, increase dependence on domestic supplies and to provide power generating diversification.

Coal Resources Development and Utilization Policies and Procedures

The experience of Australia, China, Greece, Thailand and the United States, in the exploitation and use of lignite coal, can help us to develop our coal resources.

Exploration and Mining

Coal mine development should be treated on par with development in other industries by providing tax concessions and financing facilities. Each Province should establish a Department of Mines to focus attention on coal mine development. The highest priority should be given to develop the Sonda-Thatta coalfield due to its potential to supply low-cost coal for power generation.

Power Generation

The Conference demonstrated that the private sector has a role in power generation. There is also potential for public and private joint efforts in the areas of coal mine development for power and other industrial uses.

Industrial Applications

Coal briquetting offers great potential and should be given priority attention. New cement plants should be designed to use local coal and existing cement plants, along with other industries, should be exposed to the utilization of indigenous coal.

Manpower Development and Training

A comprehensive manpower development program is needed in the areas of coal mining and coal utilization techniques. Local expertise is also needed to consult on coal exploitation, mine development and coal utilization.

Mobilizing Financial Resources

Joint ventures between public and private sectors and by local and foreign entrepreneurs should be encouraged to provide the financial resources for coal mine development and utilization.

Views of Lending Agencies

ADB has committed to assist in coal development as it has in other countries, but emphasized the need for government support, institutional changes and a definite role for the private sector. The World Bank, ADB and USAID have all expressed their willingness to consider support for the Lakhra Coal Mine Development Project.

ADDRESS AT THE INAUGURAL SESSION BY MR. SADAQAT HASAN MIR, SECRETARY GENERAL, FIRST PAKISTAN NATIONAL COAL CONFERENCE

Justice (Retd) Syed Ghous Ali Shah, Chief Minister of Sind, Mr. V. A. Jafarey, Deputy Chairman, Planning Commission, Excellencies, distinguished guests, Ladies and Gentlemen!

I am extremely thankful to Justice (Retd) Syed Ghous Ali Shah, Chief Minister Sind for having graced this occasion with his presence inspite of his very pressing engagements.

As Secretary General of the First Pakistan National Coal Conference I welcome you all.

I would also like to extend my sincere thanks to His Excellency Mr. Deane R. Hinton, the Ambassador of United States of America, for being among us this morning.

I would like to provide a brief background before opening this Conference. The revival of the coal sector, which has been dormant for the past three decades, is a very important component of the policy of the Government of Pakistan for developing the energy sector. The present day energy crisis in which load shedding has become a common but devastating feature inhibits sustained economic growth. We are also faced with a large energy imbalance, resulting in annual import bills ranging from between 1.5 to 1.7 billion dollars.

The Sixth Plan emphasizes, the development of indigenous energy resources. Coal can play a very important role in this effort particularly for thermal generation and other industrial uses. ENERPLAN and the Energy Planning and Development Project, co-sponsored by the Government of Pakistan and the United States of America, has been launched for long term energy planning and also covers the development of coal.

The financial burden of the needed expansion of the energy sector already exceeds public sector resources. The Government is therefore promoting private investment in this important sector. The Conference is designed to create an awareness of the policies of the Government for private sector investment which cover coal mines development and thermal power generation, as well as extensive exploration and exploitation under the General Coal Assessment Programme. Coal has also been earmarked as a substitute for present day fuels such as gas and subsidised kerosene oil for domestic, commercial and industrial use.

As you will note during the next four days the Conference will discuss many aspects related to the development of the coal sector, from exploration to utilisation and financing possibilities. I am sure both the expatriates and Pakistani participants will benefit from the exchange of information which this Conference will provide on investment possibilities. This forum will also give private entrepreneurs an opportunity to explain their difficulties so that viable solutions can be considered and placed before the Government for policy decisions.

ADDRESS AT THE INAUGURAL SESSION BY MR. DEANE R. HINTON AMBASSADOR OF THE UNITED STATES OF AMERICA TO THE ISLAMIC REPUBLIC OF PAKISTAN

Mr. Chief Minister, Syed Ghous Ali Shah; Mr. Jafarey; Mr. Mir; Ladies and Gentlemen:

This First Pakistan National Coal Conference is important and I am delighted to participate.

Pakistan needs additional energy desperately. Coal can make a significant contribution.

Pakistan today produces less than 70 percent of the energy it consumes. The foreign exchange cost of imported energy last year alone amounted to more than 1.5 billion dollars. The indirect costs to industry, agriculture and human welfare of power load-shedding now and for years to come are incalculably greater. And energy demand at current uneconomically low prices will continue to grow faster than supply.

In short, unless systemic changes are made in existing policies, Pakistan's energy problems, already cricitical, will worsen. Even with substantial policy improvements, years of well-directed effort would be essential just to catch up. Additional energy is essential for the rapid economic growth required just to maintain the quality of life in Pakistan. To improve per capita incomes, taking into account Pakistan's high population growth rate, would require an even greater effort.

An attack on all fronts is needed. On the demand side, realistic pricing to reduce waste and conservation measures are indespensable. On the supply side, realistic pricing to induce production, reduction of scandalous power distribution and transmission losses, efficient-honest billing, and new generating facilities — nuclear, hydro, oil, gas, and coal-fired are all urgently needed for optimal economic progress in Pakistan.

Pakistan's sixth five year development plan proposes to respond to this challenge by targeting 40 percent of all new public sector investment for the energy sector. Four-fifths of this new investment is to go for power generation. This would help. However, much more would remain to be done.

The U.S. is assisting Pakistan in the critical energy sector. About 450 million dollars -- a quarter of our current economic assistance program to Pakistan -- is dedicated to helping meet energy objectives. Our energy assistance in support of Pakistan's efforts aims at the:

- eventual elimination of electricity and natural gas loadshedding,
- increasing private sector investment in energy development;
- strengthening the energy sector's institutional, management, and manpo[illegible] base; and,
- reducing Pakistan's energy related balance of payments deficits.

U.S. assisted energy projects now include expansion of the thermal power plant at Guddu, improvements in Pakistan's electricity distribution system and creation of energy planning and conservation offices in the Ministry of Planning. Incidentally, I must pay tribute to the lead role played by ENERPLAN in organizing this conference.

Additional thermal power capacity is critical for Pakistan because energy and agriculture compete directly for water resources which are seasonally limited. Pakistan — fortunately — has considerable coal reserves which could fuel new power generation plants. These reserves, primarily lignite, may exceed one billion tons. This could be as large as two billion tons. There are at least 300 million tons in the Lakhra coal field alone and perhaps 500 million more tons is the nearby Sondha Thatta area. The Geological Survey of Pakistan — in collaboration with the U.S. Geological Survey — is developing a national program to assess the quality and quantity of Pakistan's coal.

U.S. experience highlights the key role coal can play in achieving energy security. Even in the 1960's and the early 1970's, when oil was cheap, coal served as an important energy source. Coal fueled 44 percent of the U.S. electricity generated in 1974. Today, twelve years after the 1973-74 oil price increases, coal's share of total electricity generated has increased to nearly 56 percent. Coal in the U.S. today produces more electricity than oil, gas, hydro, and nuclear sources combined.

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The United States has used "brown coal" or lignite for many years as a fuel for power generation. Seventy American lignite fired power plants are currently in operation; 16 more will be constructed between now and 1995. Many of the new mining, transportation, power, and environmental technologies that will be discussed at this conference are based on our long practical experience with lignite.

As most of you know, the United States and other donor agencies are assisting WAPDA in evaluating the possibilities for Lakhra coal. If the project proves out, we will help fund the first of several large lignite fired power plants to be constructed there. Most of the feasibility studies are complete. Many investors and coal suppliers are showing interest in the project. I hope those businessmen present will take note that several coal related projects in Pakistan offer investment opportunities. The Lakhra power project is one good example, the cement industry and coal briquetting are others.

Let me conclude by urging this first coal conference to produce useful technical exchanges and thoroughly to explore opportunities for increased private sector investment in Pakistan's coal development. I am convinced that coal can play a large, economically sound and environmentally acceptable role in Pakistan's energy future. I am confident your discussion will contribute to a better energy outlook for Pakistan.

Thank you.

INAUGURAL ADDRESS BY JUSTICE (RETD) SYED GHAUS ALI SHAH CHIEF MINISTER OF SIND

Mr. V. A. Jafarey, Deputy Chairman, Planning Commission, Mr. Sadaqat Hasan Mir, Excellencies, Distinguished guests, Ladies and Gentlemen:

I am honoured and pleased at being asked to inaugurate the FIRST PAKISTAN NATIONAL COAL CONFERENCE. The Conference is being held at a time when the country is facing serious problems in the field of energy, with load shedding at peak hours in most parts of the country and heavy reliance on imported energy. The 6th Plan addressed itself to many of these critical issues and in particular emphasised the development of indigenous energy resources. There has been appreciable success in the development of petroleum resources and our production has increased four fold in less than three years. However, we have not yet been able to make a significant beginning in the utilisation of the vast resources of coal with which our country is endowed. In the past, fuel pricing policies, particularly in the case of gas, and shortage of capital funds in the Public Sector have contributed to the slow development of indigenous coal resources.

A start has now been made to rationalise the prices of energy supplies. At the same time, action needs to be taken to expeditiously explore and exploit local resources, particularly for power generation and for use in industry.

The holding of this Conference under joint sponsorship of the Ministries of Planning & Development and Petroleum & Natural Resources and USAID, is a very timely step. I am very happy to note that the Conference will address itself to many important issues, including private sector involvement in coal development and utilization, particularly in thermal power generation. The government will lend all possible support in this effort to the Private Sector. I understand that vast untapped coal resources exist not only at Lakhra but elsewhere in Sind, and also in other provinces, thus providing a challenge to private sector entrepreneurs and Government institutions to discharge their responsibilities.

I wish this Conference all success and do hope that the deliberations will lead to positive conclusions and recommendations.

I declare the Conference opened.

Thank you.

COAL UTILIZATION AND POLICIES

Jawaid Ahmed Mirza
Chairman
Pakistan Mineral Development Corporation

The phenomenal increase in the oil prices in the later part of 1973 made it clear that the era of cheap energy had gone forever. The steep hike in oil prices and the fear for shortfall in supplies focused attention on the replacement of oil with cheaper fuels, as well as diversification and broadening of the energy supply base. This was also the only viable strategy for Pakistan, which is deficient in energy resources. Unfortunately, no diverse energy supply program could be launched and the country continued to rely on imported fuel and natural gas. This resulted in a balance of payment problem and depletion of gas reserves at a faster pace. Consequently, the country is today faced with a serious energy crisis which, if aggravated, is likely to hold back economic growth if concrete measures are not taken to alleviate the energy shortage.

The pattern of economic growth set by the Sixth Five Year Plan is essentially energy intensive. This shows that the Government is fully conscious of the crying need of the hour and is prepared for a quantum jump in energy supply to meet and sustain the targeted economic growth. With the expanding economic base, the energy requirements of the country are expected to increase considerably, with the domestic supplies lagging behind and with consequent adverse affects on economic development and on the balance of payment situation. Without suitable reorientation and adjustment of policies with regard to energy development, it may not be possible either to sustain an economic growth rate or to bridge a growing balance of payment gap.

Oil, natural gas and coal constitute the most important sources of conventional energy and supply about 90% of the total energy needs of the world. The output of oil and gas is on the decline due to depletion of reserves. It is, therefore, being considered highly imperative to restrict the consumption of these resources to prolong their subsequent decline and coal is being increasingly considered as the main source of energy and is regaining its position as such all over the world.

The international trends in energy development supplies have to be kept in view while evolving a strategy for the development of indigenous resources. Although a diverse set of energy resources is available in the country, there is no single major resource that could supply the energy needed to support the economic development. This necessitates balanced development and utilization of all the indigenous resources. As in other parts of the world, the emphasis should be on optimum utilization of coal to conserve the natural gas and for import substitution.

The need for extensive coal exploration was not felt earlier as the available proven reserves were sufficient to cater to the existing limited demand for coal in the country. Systematic and intensive exploration will make a significant contribution to the present reserves estimates. Based on the available data, International Energy Development Consultants estimated the coal reserves in 1983 at 1176 million tonnes, while according to the latest estimates of the GSP, the coal reserves in the known coal fields are of the order of 1200 mil-

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lion tonnes. These estimates are based on surface geological evidence and the geological data available from the mine workings. The detailed geological investigations to evaluate the coal reserves in all the coal fields have not been carried out and as a result only 102 million tonnes of deposits have been placed in the proven category. Chemical Consultants, Lahore, assessed the total coal reserves in 1985 at 764 million tonnes, including 84 million tonnes in proven reserves. The estimates of Chemical Consultants, however, are conservative, which is evident from the fact that the proven reserves in the entire Lakhra coal field covering an area of 500 sq. kms. are estimated at 40 million tonnes, whereas the mineable proven reserves in PMDC leased area alone measuring 58 sq. kms. are of the order of 110 million tonnes. These estimates are more reliable as these are based on intensive drilling carried out by GSP, PMDC, Japanese and American consultants. The indigenous coal resources thus have a large energy potential and could play a significant role in bridging the widening gap between energy supply and demand.

IED Consultants, who were commissioned to prepare an Energy Development Plan after analyzing all fuel prospects of the country, concluded that only domestic coal can be developed expeditiously at a comparatively modest level of investment and provide an important contribution towards alleviating Pakistan's power crisis. They suggested, among other things, fixing of coal production and utilization targets for the Sixth Five Year Plan and beyond, a major effort in exploration and development of a coal infrastructure, increased use of coal for power generation, replacement of increasing quantities of oil and gas through increased coal use in the industry, especially in the cement industry, and the use of coal briquettes to meet part of the domestic fuel demand, rationalizing of competing fuels prices to encourage coal production and utilization, encouragement of the mining industry through improved licensing and financing facilities, and establishing a National Coal Authority to activate and coordinate the major aspects of coal development.

The Government, recognizing the energy potential of coal and in the light of the Consultants' recommendations, fixed the coal production targets at 5.40 million tonnes for the 6th plan period.

The fulfillment of the production target depends entirely on the extent of the market available and on the scope for utilization of coal. The main consumer of the indigenous coal at present is the brick-kiln industry, which consumes not less than 95% of the total coal production of the country. There is a definite limit to which the brick-kiln industry can consume coal production. Because of some slack in construction activity, the demand for bricks has declined during the past two years. At the same time, increased production of coal from Lakhra and other areas in Sind has resulted in a glut situation, depressing the prices of coal all over the country. The coal industry, despite all talk about its development and expansion, has been facing a severe crisis in the country for the past two years. The public and private sectors have been forced to reduce the prices drastically. Despite that, the stocks are accumulating and it is being found increasingly difficult to dispose of the stocks. The mining industry in the country is incurring heavy losses at the moment on account of a steep fall in the price of coal. The entire reliance for utilization of coal in one industry is not a happy situation and cannot provide any incentive to the public or private sector for development of coal. No investment in the coal industry will be worthwhile under the present cirucmstances. If the coal industry has to be developed in order the meet the energy requirements of the country, it is necessary that its utilization is diversified and the market expanded.

The total reported production of the country is about two million tonnes of

coal, while it is believed that a few 100,000 tonnes production goes unreported. It is beyond the capacity of the brick-kiln industry to consume the entire coal production. For this reason, the coal mining industry in the country is organized neither for large scale economic production nor for meeting the growing demand of a variety of consumers. With a view to developing the coal mining industry, it is imperative to remove the market constraint that is seriously inhibiting the growth of the coal mining industry.

It is generally believed that the indigenous coal has the ability to substitute for imported oil and gas with favorable impact on the national economy. Despite its large reserve potential and relatively low mining costs, the coal continues to remain a neglected fuel; although before the discovery of natural gas the indigenous coal was a predominant energy resource and was used in power generation, industries, railways and as a household fuel. The largest potential demand for coal is in power generation, followed by the cement industry. Coal-oil mixtures can be used where complete conversion to coal firing is not technically feasible. A concentrated demand for coal or coal-oil mixtures can be developed in existing power plants and the industrial sector by substitution of gas or oil for process heat. The urban and rural household demand for energy is bound to increase due to the increase in population. A part of the demand for domestic heating is met by kerosene oil, and out of its total consumption of over 600,000 tonnes, nearly 60% is met through imports. The coal briquettes can be used as a domestic fuel in substitution of kerosene oil, firewood or charcoal. Last but not least, of all possible new coal conversion routes, coal gasification is well established commercially. The gasification of Makerwal coal for production of chemical fertilizer shows the prospects of coal gasification in Pakistan. The production of low/medium BTU gas from indigenous coal is considered technically feasible and can be used in power generation, while the medium BTU gas known as "Town Gas" can be fed to the natural gas distribution network, thus supplementing the dwindling supplies of natural gas. The future growth of coal in Pakistan will, therefore, be more productive provided necessary R&D facilities and expertise is provided in the country to develop suitable beneficiation and coal conversion processes.

Coal cannot regain its original position as a source of energy nor can it be introduced to new market uses without the support of the Government. The coal all along has been treated as a mineral and it has never received the attention or support of the Government which it deserves as a potential source of commercial energy. In view of the growing energy needs, the indigenous coal should enjoy a prominent position as an energy resource. The Government's support to the coal sector should be based on the role it can play in the overall energy perspective of the country. Some of the measures that can be considered in this context are:

- For effective energy system planning, it is necessary to bring together all energy supply sectors in a composite and interactive manner so that if and when one or more sectors fail to achieve the targets, adjustment could be made from the viewpoint of the entire energy system. As such the planning for coal production cannot be done in isolation and should form a part of the overall energy development plan in order to effectively coordinate all the aspects of planning, exploration, exploitation, utilization, pricing, financing, etc. at the Federal level.

- Lack of authentic and reliable data on coal quality and reserves being an important constraint on the development and expansion of the coal mining industry, the coal exploration program has to be intensified to meet the coal production target. Exploration and evaluation involving sizeable risk capital is time consuming and

capital intensive. For that purpose, suitable incentives need to be given by the Government to public and private sectors.

- The trend towards increasingly large output from a fewer number of well mechanized production units should be encouraged. The operation of larger units for deeper working, calls for a high degree of expertise and large capital investment in mechanization. Adequate funds on concessionary terms for the development of larger production units need to be made available in order to accelerate the pace of coal exploration and development.

- The present restricted market of coal does not provide any incentive to the mining industry to develop the coal mines. The use of coal in power plants and cement industries should be encouraged as a matter of policy and through enactment.

- PCSIR should involve itself more actively in research on uses of local coal. The research and development capabilities should be upgraded to develop modern coal firing technologies which are suited for low grade indigenous coals.

- The coal is found in remote parts of the country devoid of social amenities and infrastructure facilities. The absence of railroads, telecommunication, water and electricity is seriously hampering the growth of a local coal mining industry. Adequate infrastructure facilities need to be provided in the mining areas to support the future coal development program.

- The mining sector should be encouraged to invest in the development of new coal mines on scientific lines for sustained and economic production liberal credit facilities in local and foreign currency should be extended to this sector.

- The possibility of attracting expatriate firms for investment in the coal sector and participation on an equity basis may be given serious consideration. The foreign investors will not only bring with them the much needed foreign exchange, but also the modern technology.

- Liberal imports of mining machinery and equipment should be allowed and mining companies be exempted from payment of import duty and sales tax at least for five years.

- The mining laws should be rationalized and made more development-oriented to protect the long term investment of the Government and that of the investors.

The expansion of the coal sector and the use of coal as a source of energy cannot be ensured without the support of the Government and suitable re-orientation and adjustment in the policies with regard to the development and utilization of energy resources. With the backing of the Government, the indigenous coal resources should play a significant role in narrowing down the widening gap between energy supply and demand in the country. Apart from the impacts of coal utilization on the economy, the increased use of coal will provide an impetus to the development and expansion of the coal mining industry, which offers in particular large socio-economic benefits in the under developed regions of the country.

PAKISTAN NATIONAL ENERGY POLICY

Mr. Sadaqat Hasan Mir
Managing Director
Enerplan

Pakistan, with its population of 94.7 million, is predominantly an agricultural country with about 72% of its population living in rural areas. Being a developing country with a sustained GDP growth at 6.5% for the last decade, its present per capita income is estimated at $324 while per capita consumption of commercial energy has been very low. Based on global survey 1979, the per capita consumption of commercial energy in Pakistan (166 k.g. of oil equivalent) corresponds to 1/2 of the average consumption in developing countries of Asia and Pacific countries, 1/9th of the world average and 1/48 of the United States.

Pakistan's total primary energy consumption in 1984-85 was estimated at 24.5 million tons of oil equivalent (TOE) of which 16.5 million TOE or 67% was commercial energy with traditional fuels (firewood, dung and straw) making up the remainder. In the commercial energy supplies, natural gas constitutes 34% of the total and petroleum 39%; only 25% of petroleum is produced locally. The role of coal in this energy mix is currently very modest, providing only 8% of the commercial energy. The role of coal has been rather suppressed because of relatively low priced natural gas, both for industrial and domestic purposes. It is now being realized that this gas is a limited resource and that is has been over consumed and needs to be conserved.

Pakistan currently produces about 2 million tons of coal per year. Pakistan's coal resources occur in three major areas. It's major coal fields lie in North Eastern Baluchistan (Sore Range-Degari, Khost-Sharigh, Mach and Dukku); Northern Punjab (Makarwal and Salt Range); and in Southern Sind in Lakhra and Sonda-Thatta areas. The proven, indicated and inferred reserves of coal in all of these fields has been estimated of the order of 1 billion tons. But geologically it is considered to be much more, and could go up to 2 billion tons. What is needed is detailed and systemized exploration in the geologically promising areas.

Most of the Pakistani coals are lignite to sub-bituminous with limited coking potential. They have high ash content and contain medium to low sulphur. They belong to the Eocene and Palascene ages. Their BTU value ranges from 6,000 to 12,000.

The characteristics of coals of different regions are briefly described below:

Baluchistan Coal

Baluchistan coals are generally higher quality than Punjab or Sind coals. Analysis of run-of-mine coal at Sharigh indicates 1 to 2% mosture, 36 to 42% volatiles, 26 to 44% carbon, 9 to 35% ash, 5 to 7% sulphur and 9,557 to 10,297 BTU/lb. Thus, Sharigh coals have coking properties, and if washed fractions were mixed with other mid volatile, low sulphur, low ash coals, it seems likely that they could be used by the Pakistan iron and steel industry, which is consuming about 4.25 million tons of imported coal. The coal is then subject to spontaneous combustion, but not to the degree of Lakhra coal. The best quality coal in this region is from the Sor Range, where analysis indicated 1 to 3 percent sulphur. There are low sulphur seams in the Deghari range, but not consistently.

Punjab Coal

There is considerable variance of ash and sulphur content in Punjab coal, where claorific values range from 6,000 BTU/lb to 9-10,000 BTU/lb in the Central Salt Range and Makerwal. Central Punjab has not been opened to coal exploration, although oil companies reported shows of high quality Permian coal at 3,000 feet some years ago.

Sind Coal

Coal from Lakhra has the following characteristics: 23 to 27% moisture, 26 to 32% volatiles, 23 to 31% fixed carbon, 14 to 24% ash, 4 to 6% sulphur and 5,800 to 7,734 BTU/lb. Its strong tendency to spontaneous combustion makes storage and transport difficult and its main markets would continue to be located not too distant from the coal fields. Resources at Lakhra are at least 300 million tons. Its best utilization is evidently for thermal power generation right in the mine areas.

The reserves at Sonda are thought to be quite large, of the order of 500 million tons.

Energy Imbalance and Need for a New Energy Policy

Pakistan's balance of payment position greatly worsened as a result of soaring prices of oil from early 1970's. Pakistan was categorized as one of the most seriously affected (SMA) countries. In order to keep pace with the expanding economy, the development and expansion of industrial system boosting agricultural sector and providing necessary comforts in residential sector, Pakistan had to struggle hard to provide adequate energy resources in time. The condition became serious when in 1981-82 the import bill of oil and petroleum products reached a staggering figure of $1.7 billion which has now come down to $1.44 billion, forming about 57.6% of total foreign exchange earnings from exports. In order to meet this serious situation, the Government of Pakistan enunciated its energy policy for the 6th Five Year Plan 1983-88 in July 1983.

The 6th Five Year Plan particularly focuses to reduce the elasticity between the rate of growth of energy and that of GDP to 1.15. For making necessary adjustments to high energy prices on the international level, the basic objectives of the 6th Plan are to:

Ensure adjustment for realizing growth targets of the 6th Plan in an energy efficient manner, giving proper emphasis on energy conservation;

Arrange interfuel adjustments with the objective of minimizing import dependence. This is particularly reflected to substitute gas and oil use with indigenous coal;

Prepare ground for self-reliance in energy by developing known indigenous resources with particular emphasis on the development of coal;

Intensify research for undiscovered resources, develop nuclear and renewable energy resources, and to acquire substitution;

Ensure coverage of the entire rural population residing in compact villages by rural electrification;

Evolve mechanism for greater participation of private sector in meeting the energy requirements;

Ensure proper institutionalization of long term energy planning, monitoring and evaluation; and

Rationalize energy prices both in respect of consumers and producers.

The Coal Sector

There had been a sharp decline of share of coal from 59.1% in 1947 to 8% in 1984-85 in total commercial energy consumption. This aspect has been given serious consideration during the preparation of the 6th Plan. Despite about one billion tons of proven, indicated and inferred deposits of coal of the reported production through-

out the last decades remained static, around 1.5 to 1.9 million tons which, if unreported and imported coal is also included, may reach about 3.5 million tons. Therefore, it is seen that there was a massive diversion to substitute coal with gas and oil which was among other factors, also due to the price differential.

The increasing demand of energy and its supply position indicated strongly the necessity of activating the indigenous coal sector so as to play an important role in energy supplies, particularly in the field of power generation, industrial sector, besides domestic and commercial uses to substitute gas, kerosene oil and fuel oil.

Particularly for the development of coal as a policy issue, the 6th Plan has laid emphasis on the following:

- Larger use of coal in domestic and small industry sector to replace the present gas and fuel oil being used in the industries sector, particularly for cement production;
- To develop short term and long term plants for power generation, particularly based on the development of the Lakhra and Duki coal fields and their use in power generation;
- Production of smokeless coal briquettes, mainly for domestic and small industrial uses;
- To accelerate the work on general assessment of coal resources and to plan out a long exploitation;
- To study the feasibility of gasification of coal;
- Consideration to be given for the establishment of a National Coal Authority which will be a body having a focal point for management and coordination of policies relating to exploration, prospecting and development of coal resources and its use for generation of electricity and to substitute other energy resources.

Potentials for Coal Sector Development

As indicated earlier, the potential for using coal to increase Pakistan's energy supply and dependence on indigenous resources is very significant. Development of the abundant resources will take Pakistan a long way on the road to meeting its energy shortfalls. It will conserve precious oil and gas resources for higher value uses.

The Government of Pakistan is taking policy actions to increase the demand for indigenous coal. It plans to construct first two large 300-350 MW coal fired power generating units based on Lakhra coal deposits, to be followed by other units in the future. Moreover, the Government has discouraged the use of natural gas for the cement industry and has significantly restricted the further use of natural gas for power generation. The GOP and private sector are now actively looking into coal as a source for both power and the cement industry. It is also encouraging the substitution of coal briquettes for scarce firewood and costly kerosene for domestic and commercial use. Two independent feasibility studies are being undertaken at the instance of PMDC and PUNJMIN by Soframin of France and a consulting Australian firm respectively, while USAID is conducting a marketing study of coal briquettes as domestic fuel substitute.

The private sector already plays a predominant role in coal development in Pakistan and is expected to continue to do so in the future. About 80% of Pakistan's coal is mined by private firms and an equal share is consumed in small independently-owned brick kilns. Transportation is largely through private truckers and transport companies. There is thus a clear scope for private sector expansion in areas such as power generation and coal conversion. The Government of Pakistan foresees that effective expansion of domestic coal production can occur through investments and management by private sector, both

domestic and international. There is considerable scope for private investment in large scale coal mining ventures in which advanced technology, machinery and managerial skill will be needed. Use of coal as domestic fuel substitute in the form of smokeless and sweet briquettes has great promotional opportunity. Substitution of coal in the cement and sugar industries, and other industrial boilers have considerable potential. Above all, great scope lies in the use of coal in power generation, both by large and small power generating units.

As has been earlier stated, the Government of Pakistan foresees that effective expansion of coal production and its utilization can occur through the efforts and active cooperation of the private sector. To provide an opportunity for deliberating upon this potential and its realization, the Government of Pakistan, with active assistance of USAID, decided to hold the First Pakistan National Coal Conference at Karachi, inaugurated today by bringing together representatives of multinational organizations, international financing institutions with local entrepreneurs and financiers and Senior Government officials to suggest ways and means of encouraging investment, both foreign and local, in the development and utilization of the coal resources of Pakistan.

FACTORS EFFECTING FUTURE DEMAND AND SUPPLY OF COAL IN PAKISTAN*

Mohammad Nawaz Khan
Secretary, Mineral Coordination Board
Ministry of Petroleum and Natural Resources

ABSTRACT

Conditions of perfect market do not exist to allow a fair competition to coal against other energy sources in Pakistan. On the institutional side also indigenous coal is disadvantageously positioned compared with oil, gas and hydel power.

Estimation of future demand of coal requires perception of future changes on national level in the energy demand management policies, political and fiscal factors effecting the imported energy sources and interests of international lending institutions. Indigenous coal presently being the least preferred energy source in the country, requires extensive governmental support in its introduction in cement, power generation and other energy intense industries.

In case policy decisions are taken in favor of local coal, a demand as high as 22 million tonne (10 MTOE) or about 18% share in energy supply is expected by the year 2000. This shall be hard to meet unless extensive reorganization and large scale investments are made in coal sector.

INTRODUCTION

Economies of developing countries are plagued with multifarious constraints of indigenous origin such as high population growth, weak technology base, slow capital formation and many others which the people and their governments can and should resolve through sustained and sharply focused efforts, change in social outlook and belt tightening. There are, however, other problem areas of developing nations which are there and persist because of hegemony of industrialized countries, exerted through lending agencies, fixation of trade quotas, tariff imposition, restraints on technology transfer and such other restrictions. Energy is an area where the programmes of the developing nations get influenced substantially by the political and economic expediencies of industrialized countries. In such circumstances projections of energy demand and of contribution of coal in the energy supplies are fraught with many uncertainties which get further compounded in Pakistan as the local coals never got adequate opportunity to establish itself as industrial fuels. The economic burden of oil price hike of 1973 and 1979 was overcome to some extent through increased consumption of natural gas as industrial fuel, proportionate increase in domestic oil prices, but these short term solutions are yet to be supplanted with long term measures for self reliance in the field of energy.

ENERGY RESOURCES

Pakistan's principal commercially

*The views expressed are those of the author and do not necessarily represent the views of the Government.

exploitable energy resources consist of hydro-power and natural gas, followed by oil and coal. In addition, Pakistan has a substantial non-conventional energy resource base, consisting mainly of fuel wood, agricultural and animal wastes. To date most of the country's energy resources are underutilized and hence the prospects for increasing their supply are considered good.

Out of estimated 30,000 MW hydro-power potential, only 9.7% (2897 MW) has been developed so far. Natural gas, accounting for 34% (1984/85) of commercial energy supply has sufficient reserves for about 44 years at the present rate of consumption (991 MMCFD) and the prospects for increasing reserves appear good. Proven oil reserves are modest at about 140 million U.S. barrels although intensive efforts and investments are being made in the public and private sectors to find new oil fields. These exploration efforts have resulted in some new oil field discoveries and the domestic production of crude oil has increased to an average of 26,100 barrels per day in 1984/85 compared to 9,770 barrels per day in 1979/80. Known coal reserves of all categories amount to 1,180 million tonnes, of which proven reserves are 102 million tonnes. There is a large potential to increase the coal resource position as more exploratory data is available. With the present coal production of hardly 3 million tonnes per year, the reserve/production ratio in respect of coal is much higher compared to oil and gas. The coal being geologically of recent age is generally high in both ash and sulphur with poor coking properties.

ECONOMIC REVIEW AND OUTLOOK

Despite the rising burden of oil imports; Pakistan experienced rapid and sustained growth between 1972/73-1982/83 while other indicators of economic performance showed steady improvements. During this period real GNP per capita averaged growth of 3.6% per annum. Average real GDP growth during 1972/73 to 1976/77 was 4.4% per annum and onward it has sustained above 6%. This growth rate was interrupted in 1983/84 and declined to 4.5% mainly due to major shortfall in cotton crop and resultant adverse effect on cotton based industries. During 1984/85 GDP grew by 8.4% but growth could not be translated into higher exports despite 12.3% depreciation of Rupee against strong US dollar nor it resulted into any substantial increase in public revenues.

An analysis of the growth rates of different components of GDP indicates that higher growth rates in the manufacturing sector are responsible for maintaining a higher GDP growth despite the fact that this sector in absolute terms has a smaller base than that of agriculture. The only jump in agriculture sector came during 1965/66 - 1969/70 (3rd Plan) when it registered a growth rate of 6.29% compared to 8.10% for manufacturing during the same period. During 1977/78 - 1981/82 (5th Plan) agriculture growth rate was 3.97% compared to 10.53% for manufacturing. In 1984/85, mining and quarrying sector (inclusive of oil and gas) have registered high growth rates of 14.8% but its contributory effect in overall GDP growth is insignificant due to very small base. This clearly indicates that to maintain acceptable GDP growth rate, increasing reliance shall have to be placed on

the growth of manufacturing sector.

ENERGY DEMAND AND SUPPLY REVIEW

IEDC of Switzerland prepared a long term energy plan for Pakistan under different economic scenarios. One of these, termed as Nominal Development Scenario is based on approximately the same ratio between contributions to growth rates of agriculture and of manufacturing sectors as of Sixth Plan while maintaining overall GDP growth at above 6%. Under such a scenario which also assumes adoption of conservation measures, IEDC has estimated primary energy demand (commercial fuels only) of 33.28 MTOE in 1992/93 rising to 43.09 MTOE and 55.42 MTOE in 1997/98 and 2002/03 respectively.

IEDC's projections for Nominal Development Scenario (NDS) are based on extension of physical targets of the 6th plan and indicate an elasticity of about unity and during the 7th plan of 0.92. This coefficient during the 5th plan period was 1.75. On the basis of provisional data of GDP and of energy supplies for the first 3 years of 6th plan, this coefficient appears to have improved to about unity which apparently is incorrect as no large scale efforts or legislative measures for energy conservation were applied during that period. It has therefore to be kept in mind that the demand projections for NDS require extensive conservation measures.

Actual domestic supplies of primary commercial energy in MTOE during 1984/85 and IEDC's projections for 1987/88 (last year of 6th plan) are as in the facing column:

Domestic	Actual 1984/85	IEDC Projection 1987/88
Oil	0.63	1.36
Gas(Incl. feed stk)	7.18	10.37
Coal	1.00	2.41
Hydel(Incl. losses)	2.91	3.65
Nuclear	0.08	0.14

IEDC estimates that domestic energy supplies shall be able to meet 72% of the demand of NDS in 1987/88 which may be increased to about self sufficiency by 1997/98 depending among others on the level of investments and the success ratio in exploration of fossil fuels. Level of investments to achieve various levels of domestic energy production have been estimated. To achieve near to self sufficiency by 1997/98 for NDS demand, the following levels of investments are indicated:

Fuel	Production Level 1992/93	1997/98	Investment Level in VII	VIII
	(MTOE)		Plans (10^9Rs)	
Oil	2.9	4.9	18.7	26.0
Gas	13.6	18.2	11.1	12.5
Coal	5.3	8.1	8.9	8.6

The above level of investments, although of indicative nature, clearly bring out that the investment/growth rate coefficient is lowest (1.3) in case of coal,compared to 4.07 for gas and 3.3 for oil, despite the fact that coal has a very small starting base.

SHARE OF COAL IN ENERGY DEMAND

In October 1973 when OPEC pushed up oil prices to an un-precendented level, coal although relegated to a

secondary position was the only choice to meet the challenge. Coal however did not have to establish anew like nuclear energy, it had a prestigious industrial revolution to its credit. Most of the developed countries having abundant coal resources had significant coal mining activity and coal based industry which was geared up to alleviate the strain caused by hike in oil prices. Coal figured prominently in the post -1973 plans of all energy importing countries such as "Project Independence" of the USA and Britain's "Plan for Coal". This surge in coal activity also served as a catalytic effect for switch over to coal of many industries in developed countries having demand of low grade energy.

In Pakistan the issue of oil price hike however had a subdued effect on industry as well as the planners. This was primarily due to sense of complacency falsely derived from gas reserves of Sui and Dhodak and perhaps this oil price hike was considered as a temporary phase. Another factor adding to the situation of delayed awareness and reaction was the absence of any major coal based industry in Pakistan. The period spanning from 1952, the year of Sui field discovery, to late seventies witnessed an aggressive policy of gas marketing. This resulted in change over to gas whatever little coal-based industry was existing in Pakistan, leaving brick kilns as the only major users of coal. Appraisal of gas reserves and consideration that use of natural gas as a fuel was a poor value-addition has lately effected the gas marketing policy. So naturally come back of coal in Pakistan was delayed and required a gestation period for planning coal based industries, development of coal mines for large supplies, creation of a fiscal regime to build an efficient coal market and above all to clear prejudices against coal.

The Sixth Plan taking full cognizance of the role that coal has to play in meeting the national energy requirements, enjoins a prominent position to coal as an energy resource rather than treated as a mineral, as in earlier Plans. During Sixth Plan period coal is expected to replace prevalant use of high grade fuels for low grade energy production, save afforestation by supplying coal briquettes to rural areas and secure a good foothold in electricity generation. These are routine conventional uses of coal and would not require any specialized technology.

Despite the roll back on oil prices witnessed recently, domestic coal has a very strong case to get maximum possible share in energy supplies on the grounds of lower investment/growth rate coefficient and of much larger employment potential it provides in comparison with oil or gas. These advantages can not be overlooked in the context of Pakistan economy and population explosion and would overweigh the resistance of the industrial consumers, camoflauged under expression of environmental and quality constraints.

Power Generation

Major potential demand for indigenous coal is in power generation. IEDC's projections for electric power require installed rated capacities of 13,600, 20,100 and 28,600 MW by the end of 7th, 8th and 9th Plan periods respectively. Such large power generation capacities cannot be met by hydel alone which apart from longer construction periods and high capital

cost, has wide fluctuations in availability. IEDC in the conceptual generation plan has proposed commissioning of 6 units of total 3,550 MW between 1988 and 1999 based on indigenous coal.

Power generation by coal is contributing in a big way in many countries having centrally planned or free or mixed economics. In some countries (Greece, Turkey and Yugoslavia) even inferior quality lignites are being used for power generation. Statistics (1980) of power generation from coal of some of the countries are given here under:

Country	Total Installed Capacity (Coal Based Capacity) MW	Total Power Generated (GWH) (Power Generated from Coal (%)
China	65,869 (34,602)	300,400 (64)
Greece	6,250 (2,800)	23,100 (48)
India	33,007 (16,620)	110,900 (50)
Morocco	1,396 (618)	5,250 (19)
Turkey	5,119 (1,500)	24,900 (24)
Yugoslavia	14,043 (4,500)	59,100 (44)

Under West Germany law, all new boiler installations and boiler replacements and expansions when they are used for steam raising or electricity generation, must be designed for coal-firing. In addition, EEC coal (preferably West German coal) must be used for firing for 15 years, and a minimum coal consumption must be guaranteed. In the USA, Utilities probably will never again build oil fired boilers for raising steam. As a matter of price, availability, and public policy, utilities have seen the writing on the wall. These signals were given added substance in 1978 with passsage of the Power Plant and Industrial Fuel Use Act, which essentially prohibits oil use in new generating units.

Comparative cost illustration of power generation with different fuels (Annexure-I) as presented by the Electric Power Development Company of Japan to the Symposium on coal for Electricity Generation (1982) amply brings out that for a 300 MW base load generation, bus-bar cost/KWH is much lower with coal as fuel than with oil, gas or gas turbines. This fact is further substantiated by a study done by Fichtner Consulting Engineers Stuttgart, W. Germany for KESC's power plant extension of 300 MW. Comparison of power generating costs with oil fired and coal fired plants estimated in this Study is at Annexure-II.

The generation costs with indigenous coal even after providing for environmental control costs due to its high sulphur and ash contents shall still be less than the oil based generation. Indicative environmental control costs given in Annexure-III clearly bring out this point. In case of WAPDA however, due to subsidized fuel prices, the options exercised in selecting fuels for power generation are distorted and are working against selection of high thermal efficiency power generation route, improvement in O & M to conserve heat losses and above all against use of indigenous coal.

Subsequent to 1973 hike in oil prices, a number of countries carried out conversion of oil fired power station boilders to coal or dual fuel. The experience of Kiwana power station on Western Coast of Australia in statistical form is given on the next page.

* Units converted = 2 x 200 MW and 2 x 120 MW.
* Original design = heavy fuel oil produced from Middle East Crude.
* Conversion on = Dual firing (fuel oil having 2 % sulphur or coal of Max. 0.5% sulphur or coal + furnace oil for peaking).
* Derated Capacity when firing with coal only. = 60% for 2 x 200 MW 90% for 2 x 120 MW
* Annual avalability with coal firing. = 95 %
* Cost of Conversion for 2 x 200 MW (A $ 1975) = A $ 27.2 million
* Time taken for conversion = 2 years (1976/78)
* Cost of conversion for 2 x 120 MW (A $ 1980) = A $ 37.3 million
* Time taken for conversion = 2 years (1980/82)
* Capital cost recovery due to savings in fuel cost. = In 9 months operation of one unit (or 4½ months of 2 units).

Despite the fact that coal based power generation is economical under free market conditions compared with oil or gas, it requires policy decisions in its favour and support of the Government under such other conditions where fuel prices are not linked to its heat value and to the investments required for utilization and there is virtually monopoly over power generation and distribution. The potential of providing employment to a large number of persons in coal mining (1 Tonne per year provides job to 2-3 persons) should be an overriding consideration for decision in favour of power generation on local coal. Such conscious decisions need to be taken urgently as coal based power stations require a much longer lead time for commissioning.

Cement

Another area where indigenous coal can compete with other fossil fuels is cement manufacturing industry. Various projections based on correlation with GDP growth rate, place the cement demand at about 9 million tonnes in 1989/90 and 21 million tonnes in 1999/2000. Present (1984/85) cement production of 4.7 million tonnes is based on fuel oil which is distributed on subsidized price.

As compared with steam generation, cement industry can use higher ash and sulphur coals without requiring investments in flue gas disulphurisation and ash disposal as most of the sulphur and ash gets fixed in the clinker itself. Investments in particulate control would pay inself any way due to recovery of clinker also. The limitations of original design in coal conversion of a boiler also do not apply to the coal conversion of a kiln.

Presently most of the cement production in the country is by wet or semi-wet process which would offer no insurmountable difficulties in coal conversion. Till early 60's a number of cement kilns were being fired on local coal. A number of experienced firms are also available in the USA and Europe who have gained extensive experience in such conversions subsequent to oil price jump of 1973. The economics of coal

conversion are also very favourable in view of substantial savings in fuel cost. In the case of dry process kilns however, conversion on high sulphur coal is possible if a variable bye pass is provided in the design. Variations in the blends of high sulphur coal with low sulphur fuels and in the percentages of flue bye-pass should enable a trouble free operation of pre-heaters.

Households

Another area of potential demand for local coal, although unconventional, is as a domestic fuel in rural areas which presently use Kerosine oil or fire wood. During 1984/85, 748,426 metric tonnes of Kerosine oil were consumed for domestic use. Since it is a deficit product, 489,000 tonnes had to be imported during this year to meet the aforesaid consumption. In view of social consideration, the price of Kerosine oil is heavily subsidized. Processing of local coal into smokeless briquettes is feasible and can economically replace Kerosine oil. Government subsidy during initial years would help in accelerating acceptability of briquettes in households. 100% replacement of Kerosine in domestic use would require around 1.8 million tonne of coal briquettes (0.8 MTOE) by 1987/88 and 2.1 million tonnes (0.9 MTOE) by 1992/93.

Process Steam/Heat

Another potential area for coal utilization is in replacement of other fuels being used in various dispersed industries mostly for raising steam. This potential use can however be realized only if it is possible to prepare coal-liquid mixtures with local coals and boiler configurations allow firing of such mixtures.

Summary Potential Demand

Demand of local coal for various sectors can be summarised as under:

Sector Conversion and new	Demand (MTOE) 1987/88	1992/93	1997/98
Power	0.28 (200 MW)	2.10 (1500 MW)	4.90 (3500 MW)
Cement	0.45 (3 MTPY)	0.80 (5 MTPY)	2.00 (15 MTPY)
Bricks	1.3	1.5	1.8
Briquettes	0.3	0.8	0.9
CLM	0.1	0.2	0.4
Total:	2.43	5.4	10.0

EXPANSION IN COAL PRODUCTION CAPACITY

A lot having been said on the potential uses of local coal in power, cement and process heat, the expansion potential of the mining industry for a relatively sophisticated demand (compared to brick kilns) also need to be scrutinized.

Until early 80's, coal mines in Baluchistan and Punjab were supplying to a monopolised market of brick kilns to whom other alternate fuels were denied. This position although enjoyed by the mine operators as there was no regulation on coal prices as on oil and gas but it gave a great set back to the mining industry. The concepts of higher productivity, economy of scale, acquisition of technology were of little relevance to most of the mine operators in such a situation. This monoply situation was reversed to some extent in late 70's when Lakhra coal field low-cost production started competing in brick kilns market with the coal from other provinces. 5-6 years of competition with this low priced

coal were overcome mainly by slashing profit margins and a stage has now arrived that unless concepts of modern management and efficient mining practices are applied, most of the Punjab and Baluchistan mines shall be uneconomic to operate with the existing arrangements. This would give an idea of the present insecure institutional and technological base of the existing mining industry.

Reliance on the existing mining base for enhanced and economical coal production in order to meet the potential demand is not possible unless extensive restructuring is undertaken. Such a restructuring of the coal mines requires detailed guidelines to be given by the government alongwith its regulatory implementation.

In the context of Pakistan economy, coal has to play a major role in meeting energy demands and it shall be unwise to consign its planning and development to the market forces alone. Notwithstanding that coal is a provincial subject, the Federal Government need to play a direct role in the improvement of institutional and technological base of the coal mining industry. In view of the national considerations such an intervention by the Federal Government appears necessary and would hopefully be welcomed.

The position of coal reserves, although satisfactory in a general way, requires to be improved through extensive exploration and determination of coal characteristics with the end-use in view. This requires financial inputs by the government which may be recovered through levy of development surcharge as on other fossil fuels.

Sustained enhancement in coal production capacities require large investments for which all possible resources need to be mobilized. Apart from governmental credits, conducive conditions have to be created to induce investments through loans or equity by foreign mining companies and machinery suppliers.

CONCLUSION

Despite the recent roll back on oil prices, there is every justification to utilise large resources of indigenous coal in power generation, cement and process heat. Reservations of the consumers to the use of low quality indigenous coal should be reversed through exposure to technologies with which such coals are being economically utilised elsewhere. Regulatory measures may also be adopted as done in many other countries to ensure utilization of local coal. Coal mining industry in Pakistan requires an extensive restructuring before any reliance could be placed on it for sustained large supplies at competitive prices. Federal Government in view of national importance of coal in the future energy supplies need to play a leading role in this matter.

Abbreviations used:

MTOE : Million tonnes oil Equivalent.

MMCFD: Million cubic feet per day.

MTPY : Million tonnes per year

MW : Mega Watt

WAPDA: Water & Power Development Authority.

KESC : Karachi Electric Supply Company.

COAL RESOURCES OF PAKISTAN

BY

WAHEEDUDDIN AHMED
DIRECTOR GENERAL
GEOLOGICAL SURVEY OF PAKISTAN

COAL - AN OVERVIEW

The pattern of energy production and consumption in Pakistan has changed markedly in the past witnessing several distinct episodes each characterised by one fuel type dominating most others in the total energy budget. At the time of independence in August, 1947, coal with an average annual consumption of 300,000 tonnes (including about 50 percent imported) used to meet about 60 percent of the commercial energy demand. It powered railway engines, fueled cement factories, heated brick kilns and met some of the domestic requirements too. The discovery of natural gas at Sui in 1951 p[illegible]d Pakistan with [illegible] cleaner and more convenient fu[illegible]ch with its artificially low price rapidly rep[illegible]ed coal from almost all of its conventional uses except the brick kilns. The development of hydroelectricity resulted in a further decline of the use of coal. So a stage arrived when coal was regarded simply as a fuel for brick industry. And today with a reported annual production of about 1.8 million tonnes, coal barely meets 5 percent of the domestic demand for commercial energy. This level of production is hardly commensurate with the available reserves and the potential uses it can be put for.

The utilization of coal in Pakistan has lagged behind primarily because of the lack of a clear cut energy policy for introducing its use in different spheres of economic activity such as in power generation, as fuel in cement and sugar industries, in making briquettes, blende with imported coal for steel making and steel re-rolling etc.

Another impediment in coal utilization has been the absence of reliable data about the indigenous coal resources. This happened largely because of the fact that, barring a few isolated examples of field investigations, the coal exploration programme on a national level could not be given the importance and priority it deserved. The net result has been a rather confused state of estimates and projections about the coal reserves and their quality and mineability. It was only during the last 2 years that the GSP has attempted to assemble, collate and synthesize the existing data on coal in the country, supplement it with additional field checks wherever necessary and draw up a balanced exploration strategy for different coalfields according to a set programme.

The coal deposits of Pakistan differ from most of the major coalfields of the world in having been formed in an environment dominated by lacustrine, estuarine to marine conditions. They are also relatively younger in age and have generally suffered severe tectonic deformation. These are relatively poorer in grade because of the short span of putrefaction and particular environments these were deposited in. Consequently they fall into the poor grade - low rank category. Naturally, therefore, the quality factor has imposed certain limitations on its industrial use. It is thus evident that considerable geological exploration and R & D efforts in coal utilization are necessary before an expanded but economically competitive market for domestic coal can be ensured.

As a corollary to these obvious factors, the GSP has lately set up special exploration cells in each province and has embarked upon a systematic exploration programme. This programme, being partly executed with US assistance, include training of geoscientific personnel in coal geology and exploration, establishment of specialised sedimentation, coal petrographic, and analytical laboratories, enhancement of drilling capability and addition of geophysical logging units. Based on geological criteria the priority assigned to coalfield exploration is as under:-

Priority-I

-- Lakhra coalfield, Sind.
-- Sonda-Thatta coalfield, Sind.
-- Sor Range-Degari coalfield, Baluchistan.

Priority-II

-- Khost-Sharig Harnai coalfield, Baluchistan.
-- Salt Range coalfied, Punjab.
-- Permian coal, Punjab.

Priority-III

-- Makerwal-Gullakhel-Kurd coalfield, Punjab & NWFP.
-- Cherat coal occurrence, NWFP.
-- Pir Ismail Ziarat coalfield, Baluchistan.
-- Mach-Abe Gum coalfield, Baluchistan.
-- Meting-Jhimpir coalfield, Sind.
-- Bahlol-Chamalong-Bela Dhaka coalfield, Baluchistan.
-- Others.

A summary of the data on major coalfields of Pakistan is presented in Table-I & II.

GENERAL GEOLOGY

All the known coalfields of Pakistan are confined to the Indus Basin which is a remnant of the progressive regression of the Tethys sea. The shoreline of this sea probably once passed through the area now characterized by some of the discrete orographic features and syntaxial bends such as the Salt Range, the Sibi-Quetta syntaxis, the Kirthar Range, etc. The development of these features has been influenced greatly by the pre-orogenic Sargodha, Jacobabad and Hyderabad highs. As a result the stratigraphic sequence now exposed in these areas, though predominantly marine, also included lacustrine-estuarine, deltaic and lagoonal deposits containing plant fossils and carbonaceous beds at several horizons.

The coalfields of economic importance are situated in the Indus Basin of Pakistan in three distinct areas, termed here as coal provinces. These are Hyderabad (Sind), Quetta-Kalat (Baluchistan) and Salt Range-Makerwal (Punjab). All the other occurrences of coal, so far investigated are of minor importance. Fig.1 shows the outcrop areas of coal bearing formations.

Coal from all the major coalfields in Pakistan occurs in the Early Tertiary rocks.

Most of the coalfields in the country have been affected by orogenic movements of different intensities during different times, resulting in warping and dislocation of coal seams.

Coal seams are generally lenticular and range in the thickness from fraction of a metre to a few metres.

The coal of Pakistan is lignitic and sub-bituminous. It is friable; has a relatively high content of ash and sulphur, (Liable to spontaneous combustion) and has an average heating value in the range of 6,000-10,000 B.T.U. per pound. It is characterized by marked physical and chemical variations, both within individual beds and from one coalfield to another.

The Quetta-Kalat coal province comprises the coalfields of Sor Range-Daghari, Khost Sharig-Harnai, Kach-Pir Ismail Ziarat, Duki-Chamalang, Mach-Bibi Nani and possibly in Johan area. The coal beds are localized in the Middle Ghazij Formation of Middle Eocene age in this province. Fig.2 shows the probable original extent of coal bearing beds in the Ghazij shale.

The Salt Range-Makerwal coal province comprises the coalfields of eastern, central and western Salt Range between Khusab-Dandot and Khewra. Makerwal coalfield is in Trans Indus Range, Mianwali. The coal beds are associated with Patala Formation and Hangu Formation of Early and Late Paleocene age.

The Sind coal province comprises the coalfields of Lakhra, Thatta-Sonda and Meting-Jhimpir. In Sonda-Thatta coal is associated with Rani Kot realm rocks of Late Paleocene age. In Meting-Jhimpir area coal is found in Laki realm of Early Eocene age while in Lakhra Rani Kot coal is found.

Of the coalfields listed above, GSP has partially explored and evaluated the Sor Range-Daghari and Duki in Baluchistan; eastern Salt Range in Punjab and Lakhra, Sonda-Thatta in Sind.

The exploration data on the partially evaluated coalfields is given as under:-

1. Lakhra coalfield (Sind)

Extent	200 sq.kms.
Cumulative metreage drilled	5453 metres
Number of bore-holes	38

Reserves (in million tonnes)	Proved	Probable	Possible
	60	40	200
			Total = 300

Isopach and geologic map (1:50,000) issued.

Fig.3 shows the geology and drill hole locations in the Lakhra coalfield.

2. Sonda-Thatta coalfield (Sind)

Ex ent	600 sq.kms.
Cu ulative metreage	5056 metres.
Number of bore holes	24

Reserves (in million tonnes)	Proved	Probable	Possible
	15	47	78
			Total =140

Sonda Seam

Fig.4 shows the geology and location of Sonda-Jherruk coalfield.

Fig.5 illustrates the columnar and cross-section along drill hole No.18,19 & 20.

3. Duki coalfield (Baluchistan)

Extent	300 sq.kms.
Cumulative metreage	3316 metres.
Number of bore holes	10

Reserves (in millions tonnes at 0.6 m. cut off)	Proved	Probable	Possible
	3	5	5
			Total =13*

Geologic and structure contour maps and draft report issued.

The geology and coal outcrops are described in Fig.6.

4. Sor Range-Daghari coalfield (Baluchistan)

Extent	50 sq.kms.
Cumulative metreage	3000 metres
Number of bore holes	17

Reserves (in million tonnes)	Proved	Probable	Possible
	6	12	16
			Total =34

Geology of the coalfield and coal outcrop is shown in Fig.7.

5. Salt Range coalfield (Punjab)

Extent	260 sq.kms.
Cumulative drilling	5228 metres.
Number of bore holes	33.

Reserves (in million tonnes)	Proved	Probable	Possible
	7	10	58
			Total =75

Geologic report issued.

EXPLORATION STRATEGY

Coal exploration is an interlinked process of multiferious technical and economic activities with the basic objective either to locate a new field or to find out whether or not to exploit an identified coal deposit. What must be shown through exploration is that with a chosen level of confidence corresponding to an acceptable level of risk, the deposit contains sufficient coal reserves of a quality needed for one or more particular uses. The quantity of coal should be enough to sustain a certain rate of production for a definite period of time and the production is commensurate with the economics of sale.

Prepared in the backdrop of the coal resources scenerio presented in the earlier chapters, the strategy evolved by the GSP for the systematic exploration and assessments of the country's coal resources has the following goal-oriented and phased out ingredients:-

1. to prepare comprehensive data files on the known coalfields and occurrences according to a specially devised computer programmable proforma;
2. to fill in the existing gaps in the coal data base through additional field checks, analyses, and other specific sutdies to be carried out by special task force;

* Reserves of 5 Seams of 0.6m cut off thickness.
Reserves of 12 seams of less than 0.4 m thickness 35 m. tons.

3. to arrange and provide preliminary coal petrographic and sedimentologic data as a supplement to the store of information on coal analyses and tests as a means of attempting to establish inter-seam correlation and more meaningfully determining the quality, rank and grade of indigenous coal;
4. to standaridise methods for the collection and storage of surface, mine and core samples; techniques of proximate, ultimate and trace element analyses; coal petrographic, reflectance and sedimentological studies and physical tests, and to establish necessary research laboratories for this purpose;
5. to complement the field and labortary data with suitable research in the relevant aspects of sedimentation and tectonics, paleontology, palynology and stratigraphy and other specialised geoscientific studies as may be considered necessary;
6. to assemble and synthesize such applied geoscientific data as may be necessary in investigating water problems of coal mine areas, and
7. to set up an efficient information service in the GSP for advising the Government, industry, mine owners and users in all aspects of coal geology.

Classification of Reserves

In defining coal reserves and resources, the Geological Survey of Pakistan is evolving its own model in keeping with the geological realities of the Pakistan's coalfields. The high variation in thickness of a coalseam splitting and pinching & swelling behaviour of the coal beds, high variation in composition and lithology of the coal measures, and the structural and physiographic complexities of the coal fields make reserve estimation quite a complex geological problem.

The past experience in coal reserves classification in Pakistan has shown that the normal categorisation of reserves into proved, probable and possible types does not always fully portray the actual position regarding available reserves to varying workable depths in a coalfield. Therefore, a novel approach is being adopted by the GSP to further qualify the conventionally classified reserves into Feasible-high; Feasible-medium and Feasible-low categories. The new approach, based on the geological prognosis of the field, will indicate the availability of a definite quantity of coal reserves in a coalfield within well defined parametres including but not limited to such factors as average thickness and extent of coal seam(s), depth from the ground and dip-depth of the coal seam(s), volume of overburden, depth of water table, and the number of bore holes and the cost of drilling needed to properly prove and demarcate the coal reserves block. In this way the quanitty of coal per unit area and depth will be precisely known enabling sound mine development planning.

The new classification will be particularly useful in determiring priorities of exploration for different coalfields, and in further selecting the relatively more favourable blocks within the same field for intensive exploration and development studies. Consequently, it will now become easier to identify 'blocks' of coal reserves in all the coal producing areas of the country which can be selectively and economically developed on high priority basis for the setting up of power generation plants of different capacities. Similarly fields and areas can also be demarcated for other coal uses in future such as in cement and sugar factories, fertilizer plants, steel re-rolling units, chemical industry, and bricks & briquettes making.

Based on the above approach the future coal exploration strategy of the GSP will essentially have two important components. Firstly, a general assessment of all the coal basins of the country will be made through new mapping and the updating of previous mapping. The mapping target is expected to cover an area of about 26,000 sq. kms. in different parts of the country. Secondly, a systematic programme of drilling will also be undertaken to verify the results postulated on the basis of mapping and broadly delineate the limits of different coalfields.

NATIONAL COAL EXPLORATION PLAN

The broad outlines and the overall objectives as discussed earlier are being transformed into a well defined National Coal Exploration Programme which will be implemented through development funding by the Government of Pakistan and the technical assistance to be provided by USAID and other agencies. For this purpose separate PC-I Schemes will be pre-

pared for different coalfields. This programme will aim at evaluating Pakistan's known coal resources after standardising methods and procedures for reserve estimation and categorisation and to prescribe techniques and requirements for sampling, analysis, assays and other laboratory tests. Additionally the programme will also take care of the proposed mapping requirement of 26,000 sq.kms. and exploration drilling under PC-I Schemes.

An important element of the National Coal Exploration Programme will be to examine all those minor showings and occurrences of coal which have been reported from different parts of the country but have not been discussed in the present paper. These will be studied so as to draw conclusive results about the economic exploitability or otherwise of the coal reserves contained in these occurrences. Similarly the known coalfields will also be studied as to bring up their field and laboratory data to a comparable level with each other enabling to draw uniformly valid conclusions about their reserves and quality.

The programme of exploration as being proposed herein is based on a new modelling approach in which the key factor is the economic exploitability of a measured quantity of coal under specific conditions of influence with regard to dip depth or the depth from the surface. Accordingly, the coalfields have been divided into segments of Feasibility-high, Feasibility-medium and Feasibility-low having depth/dip depths of 0-450, 450-950 and 950-1,400 meters from the interception point or outcrop. With drilling at appropriate spacing and further ground control reserves in each segment can be converted into proved, probable and possible reserves as the geological certainty and feasibility of economic recovery progressively increase. This has necessitated suitable modifications in the USGS-USBM model of reserve-resource classification often referred to as the McKelevey's Box.

These changes alongwith data on Pakistanis coal reserve is presented in Table-III.

Concurrent with the regional coal assessment, the GSP will also be doing exploratory drilling in the already studied areas for identifying such mining blocks in Sind and Baluchistan which may be considered for supplying coal to the proposed power plants. It has been estimated on the basis of the heating values of the indigenous coals that about 1.5 to 2.0 million tonnes of coal per annum will be required for a 300 MW power plant in Sind and about 250,000 tonnes a year will suffice to run a 50 MW plant in Baluchistan. To ensure coal supplies to such power plants, about 80 million tonnes of coal reserves need to be blocked out in Sind and approximately 10 million tonnes in Baluchistan. Similarly an attempt will also be made to delineate such coal blocks of reserves in the Punjab and NWFP also but there the blocks will probably contain lesser reserves than in Sind and Baluchistan.

The GSP's coal exploration programme will be implemented in steps and phases and is designed to ensure availability of coal reserves from Feasible-high and medium segments on a 30-year basis for 7 power plants each of 50-MW capacity in Baluchistan, 5 units each of 50 MW capacity in the Punjab and 8 power plants each of 300 MW capacity in Sind. In this connection projections have been made for tieing up 25 and 54 million tonnes reserve potential through 25,500 and 87,660 metres drilling in Feasible-high and medium segments in Baluchistan; 25 and 35 million tonnes reserve potential through 22,500 and 32,500 meters drilling in the Feasible-high and medium segments in the Punjab; and 600 and 146 million reserve potential through 128,000 and 56,500 metres drilling in these two segments in Sind. Table-IV gives the cost analysis and requirements for proving coal in Baluchistan, Sind & Punjab.

Details of drilling requirements in different coalfields and their segments under the National Coal Exploration Programme are given in Table-III.

The economic, technological and environmental aspects of coal utilization are not discussed here as they are not within the purview of the GSP's sphere of activities. Therefore, the geological favourability of coal utilization as discussed in this report should be treated as a function of geological reserves and not as a part of any techno-economic feasibility. This important aspect need to be evaluated separately by other specialists and researchers.

FIG. 1 MAP SHOWING LOCATION OF MAJOR COALFIELDS OF PAKISTAN

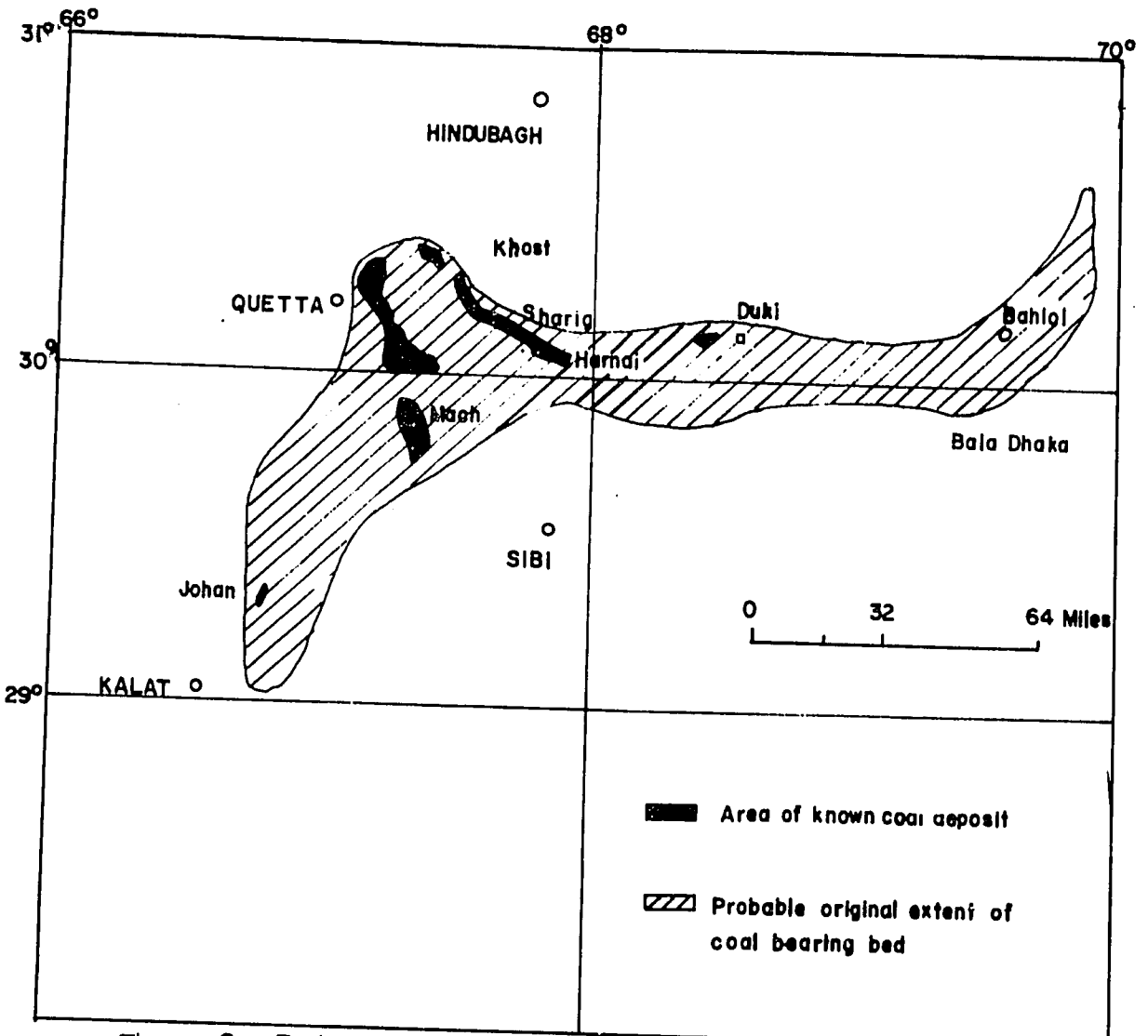
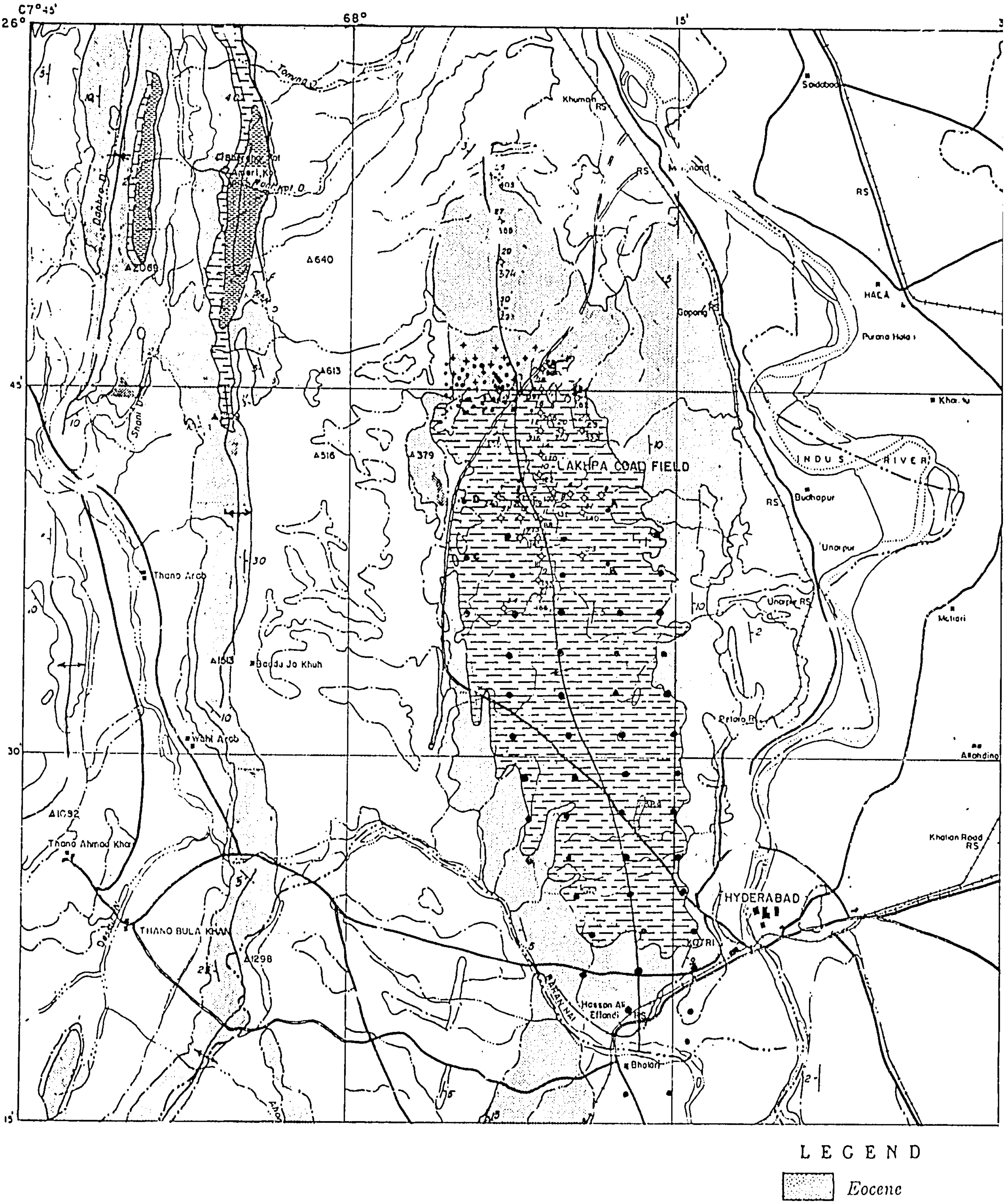


Figure 2:—Probable original extent of coal—bearing beds in the Ghazij shale, Central Pakistan



Metres 5000 0 5000 15000 Metres

LEGEND

Eocene

Paleocene

• 50 Bore Holes Proposed

FIGURE 3.—GEOLOGY & DRILL HOLE LOCATION MAP OF LAKHRA COAL FIELD

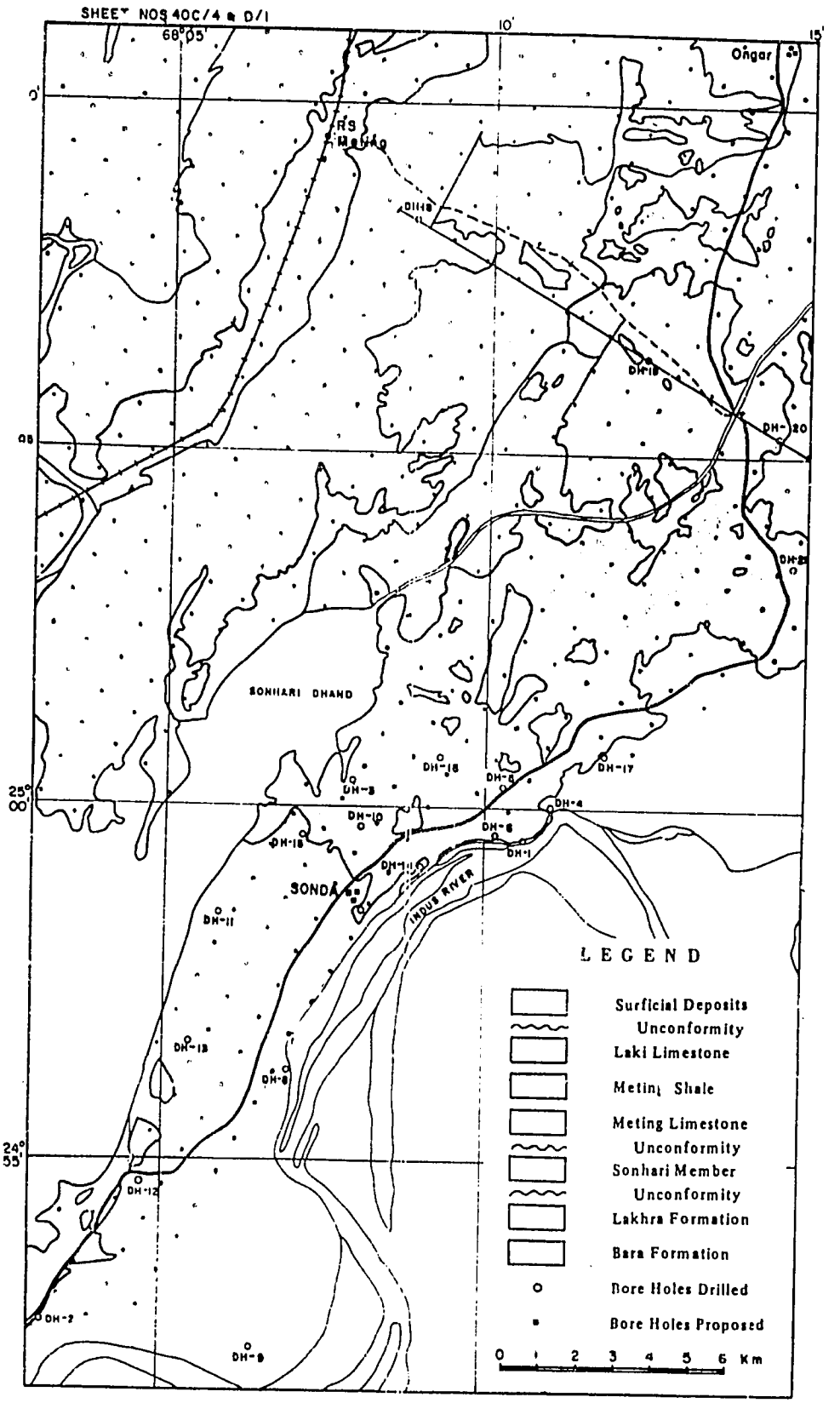


Fig.4–GEOLOGY & DRILL HOLES LOCATION MAP OF SONDA – JHERRUCK COAL FIELD

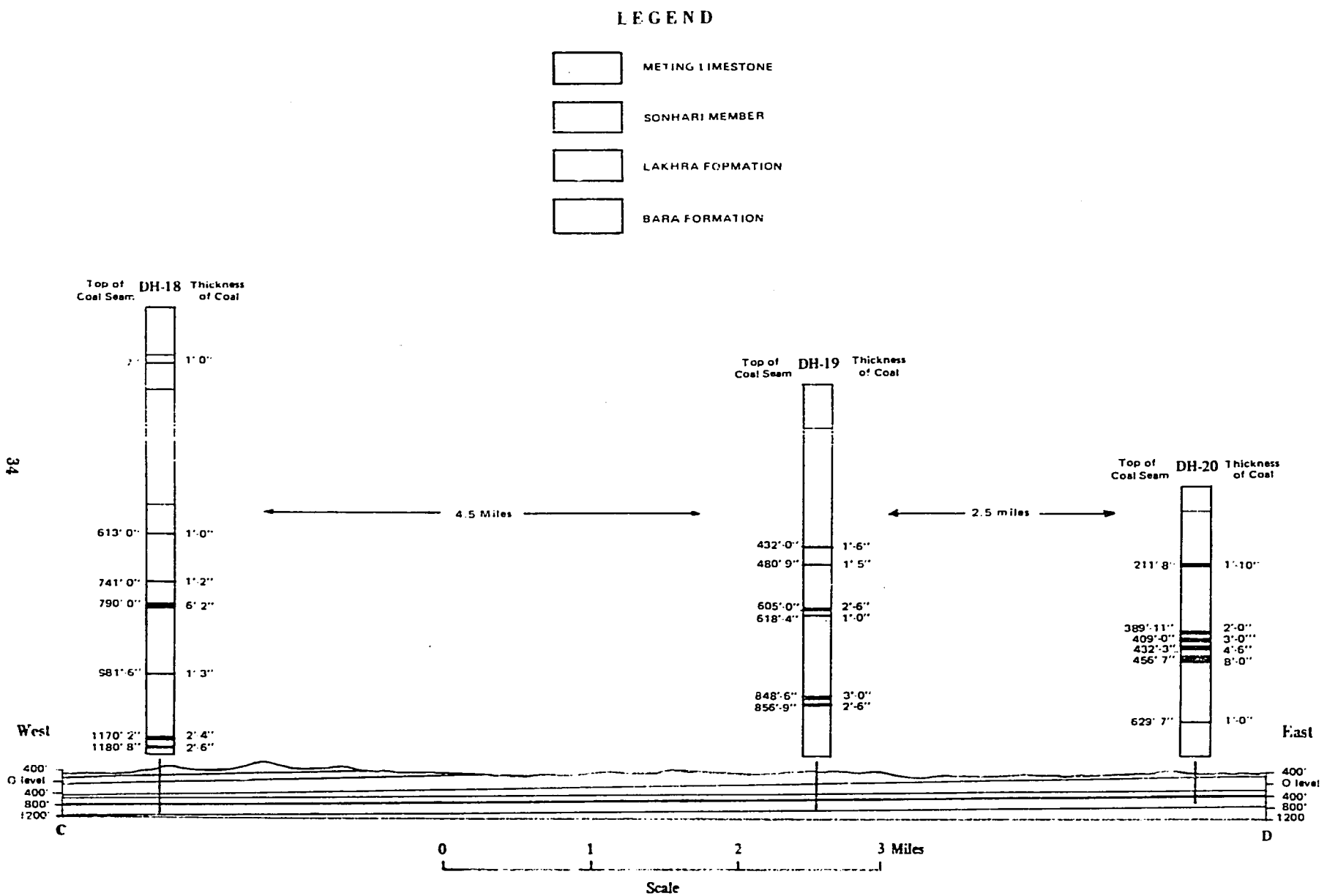


FIGURE 5.—COLUMNAR & CROSS SECTION ALONG DRILL HOLES No. 18, 19 & 20 (Meting Jherruk area)

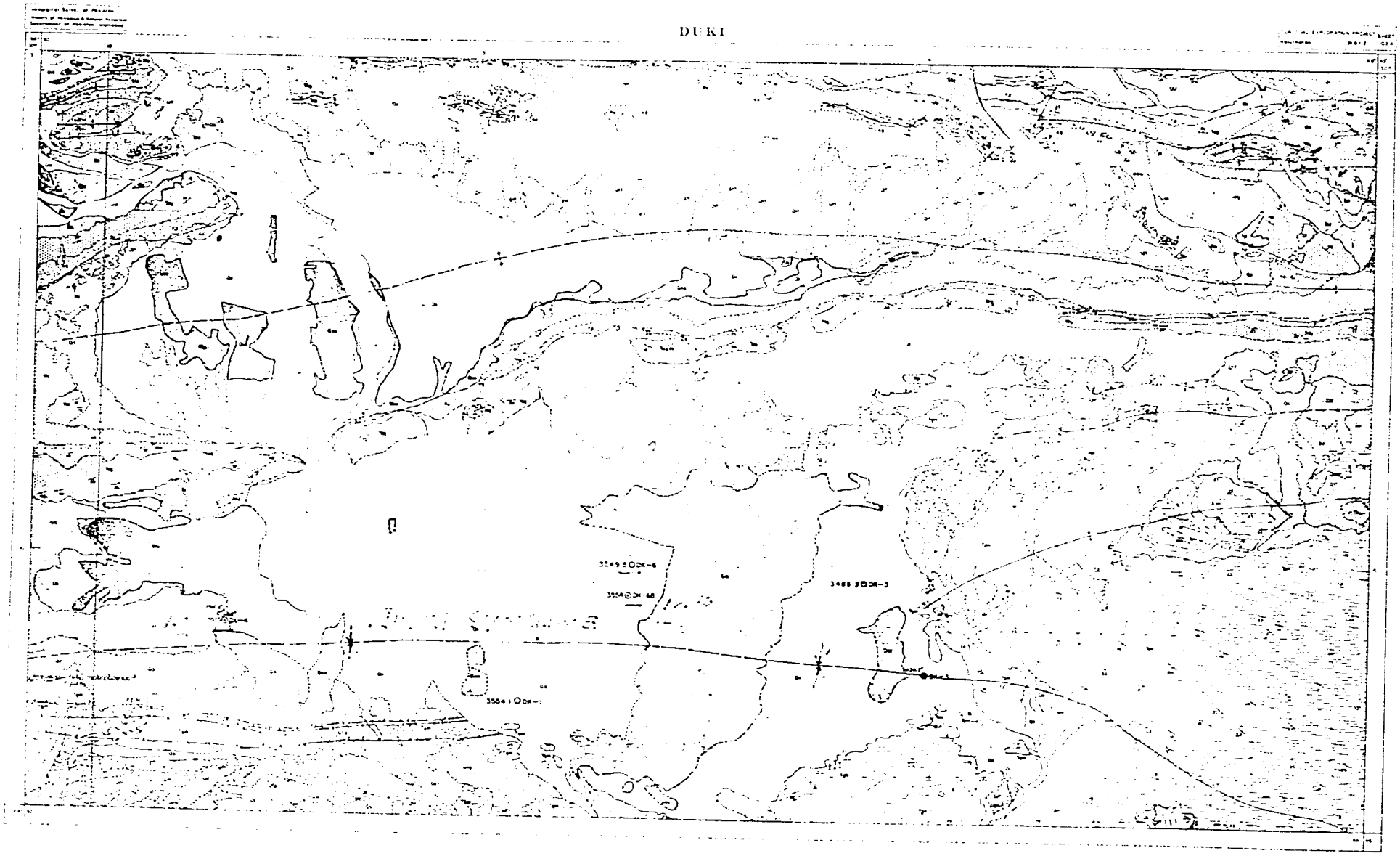


FIGURE 6.--GEOLOGY & COAL OUTCROPS IN THE DUKI SYNCLINE.

Figure 7.— Generalized Geological Map of the Sor Range - Daghari Coalfield and Adjacent Areas, Pakistan

Table I-DATA ON MAJOR COALFIELDS OF PAKISTAN

GEOLOGICAL CLASSIFICATION				COAL FIELD						Depth of the Workable Coal Seams in meters.	RESERVES (in million metric tonnes)			
Basin	Realm	Coal-Bearing Formation	Age	Name	Province	Area in sq. km.	Variation Thickness of the Workable coal seams (in meters)				Proved	Probable	Possible	Total
							Maximum	Minimum	Average					
Indus Basin	Ghazij Realm	Ghazij Formation	Middle Eocene	MACH	Baluchistan	45	1.75	0.3	1.0	70	3	6	6	15
				Sor-Range-Sinjidi-Degari		50	3.25	0.3	1.75	800	6	10	14	30
				Pir Ismail Ziarat-Abe Gum		80	2.5	0.3	0.75	500	2	4	5	11
				Khost-Sharig-Harnai		200	2.0	0.3	0.75	700	8	16	16	40
				Duki		150	1.0	0.3	0.5	1000	13	10	20	43
				Dahlol-Chamalong-Bela Dhaka		120	1.0	0.3	0.5	250	1	4	-	5
	Laki Realm	Laki Formation	Early Eocene	Meting-Jhimpir	Sind	90	1.0	0.3	0.5	500	3	5	17	25
	Ranikot Ream	Bara Formation	Middle to Late Paleocene	Lakhra		200	2.5	0.5	1.5	25 - 175	60	44	134	238
				Sonda - Thatta		620	1.0	0.3	0.5	80 - 120	6	19	32	57
		Patala Formation	Late Paleocene	Salt Range	Punjab	160	1.75	0.3	0.75	500 - 700	5	20	40	65
	Makerwal Realm	Hangu Formation	Early Paleocene	Makerwal-Gultakhel		65	3.5	0.5	1.5	700	1	4	9	14
				Surghar Range Sho - Kurd	NWFP	45	2.5	0.3	1.0	150	1	1	3	5
											109	143	286	548
											110	140	300	550

NATIONAL COAL EXPLORATION PLAN

Table III/1 COAL RESERVES IN HIGH, MEDIUM & LOW FEASIBLE AREAS

Name of Coal Fields	Coal Field Area Sq. Km.	Average thickness of seam in metres	Depth of workable seam	Reserves in million tonnes Feasible High (0-450 m) *	Reserves in million tonnes Feasible Medium (450 to 950 m) *	Reserves in Million tonnes Feasible Low (950 to 1200 m) *	No. of Bore holes and total meterage	Cost in Million Rupees	Cost of proving one ton of coal in rupees
1	2	3	4	5	6	7	8	9	10
B LUCHISTAN									
1. Sor Range-Daghari	50	1.25 m	1000 m	8 mT (plus 8 MT extracted) in 8 sq.km.	12.55 MT(plus 5 MT extracted) in 8.4 sq.km.	14.4 MT in 7.0 sq. km.	10 BH, 2800 m in Col.5	Rs. 7.0 M @Rs.2500/m	Rs. 1.14
							24BH,17000m in Col.6	Rs.51.0M @Rs.3000/m	Rs. 4.08
							20BH,24000m in Col.7	Rs.108.0M @Rs.4500/m	Rs.14.4
2. Khost-Sharig-Harnai	100	0.75 m	+ 700 m	5.63 MT(plus 2MT extracted) in 6 sq.km.	10.3 MT in 7 sq. km.	6MT (plus 3 MT extracted) in 6 sq. km.	25BH,6250m in Col.5	Rs.15.63M @Rs.2500/m	Rs. 2.77
							23BH,21800m in Col.6	Rs.65.4M @Rs.3000/m	Rs.6.35
							20BH,31000m in Col.7	Rs.139.5M @Rs.4500/m	Rs.23.25
3. Harnai Syncline(North)	47	0.75 m	+ 700 m	4.65MT(plus 4.65MT extracted) in 6 sq. km.	9.0 MT in 6 sq. km.	8.5MT in 6 sq.km.	23BH,4830m in Col.5	Rs.12.07M @Rs.2500/m	Rs.2.60
							20BH,14000m in Col.6	Rs.42.0M @Rs.3000/m	Rs.4.67
							19BH,2945m in Col.7	Rs.132.52M @Rs.4500/m.	Rs.15.60
4. Khost-Sharig(South flank)	16	0.75 m	+ 700 m	1.65MT(Plus 2.6MT extracted) in 5 sq.km.	4.7MT in 5 sq.km.	4.7MT in 5 sq.km.	15BH,3150m in Col.5	Rs.7.87M @Rs.2500/m	Rs.4.77
							15BH. 10500m in Col.6	Rs.31.5M @Rs.3000/m	Rs.6.70
							20BH.24400m in Col.7	Rs.109.8M @Rs.4500/m	Rs.23.50
5. Sharig (Lakhi flank)	37	0.75 m	+ 700 m		8.75MT in 9.7 sq.km.		31BH,6500m in Col.6	Rs.26.25M @Rs.3000/m	Rs.3.00

* Dip depth

Table III

-2-

1	2	3	4	5	6	7	8	9	10
6. Abe-Gum(Pir Ismail Ziarat)	18	0.75m	+ 500 m	2.8MT(Plus 2.8MT extracted) in 4.4 sq.km.	6.3MT in 5 sq.km.		14BH,4340m in Col.5	Rs.10.85M @Rs.2500/m	Rs.3.9
							14BH,13300m in Col.6	Rs.39.9M @Rs.3000/m	Rs.6.3
7. Mach	60	0.75m	+700m	1.9MT(plus 1.9MT extracted) in 3.3 sq.km.	2.4 MT in 2 sq. km.		12BH,4200m in Col. 5	Rs.10.5M @Rs.2500/m	Rs.5.5
							6BH,4560m in Col.6	Rs.13.68M @Rs.3000/m	Rs.5.7
8. Abe-Gum (South)	20	0.75m				5.8 MT in 4.5 sq.km.	15BH,8100m in Col.7	Rs.36.45M @Rs.4500/m	Rs.6.3
Total cost of exploration in Baluchistan				Rs.63.93 to prove 24.63 million tonnes = Rs.2.59	Rs.263.06 million to prove 54 million tonnes = Rs.4.87	Rs.526.27 million to prove 39.4 million tonnes = Rs.13.35 (uneconomical)			
SIND				FEASIBLE HIGH* (107-213 m)	FEASIBLE MEDIUM* (213 -305 m)	FEASIBLE LOW* (305 - 400 m)			
1. Sonda-Jherruck	900	0.72m		241MT in 280 sq.km. (Proved 14 m.T)	146MT in 170 sq.km. (Proved 1 m Tonnes)		356BH, 58000m in Col5	Rs.87.0M @Rs.1500/m.	Rs. 0.36
							217BH,56500m in Col.6	Rs.85.0M @Rs.1500/m	Rs.0.58
2. Lakhra	650	1.0m		47MT proved in 40 sq.km. (Additional 377 MT reserves) in 314 sq. km			50BH,8000m in Col.5	Rs.12.0M @Rs.1500/m	Rs.0.25
							400BH for conversion to proved reserves to 425MT,64000m in Col.5	Rs.96.00M @Rs.1500/m	Rs. 0.25
Total Cost of exploration in Sind				Rs.99.0m to prove 288MT = Rs.0.34 or Rs.195m to prove 660 or 600 million tonnes = Rs.0.32	Rs.85million to prove 146 million tonnes = Rs.0.58				
PUNJAB									
1.Central Salt Range plus Eastern Salt Range	400	0.6	600 m	25. m.T	35 m.T	-	50 BH x 450 m = 22500 m. in col. 5	Rs.45.00 millions @ Rs. 2000/ m	Rs. 1.80
							65 BH x 500 m = 32500 m in col. 6	Rs. 81.25 millions @ Rs. 2500/ m	Rs. 2.32
2. Permian Coal Jhang Plains a) Seismic Survey								Rs. 15 million	
b) 10 Boreholes of 1000 m depth.							10 BH x 1000 m = 10,000m in col.6	Rs. 30 millions @ Rs. 3000/ m.	

Vertical Depth from surface for almost horizontal seam

NATIONAL COAL EXPLORATION PLAN

Table IV COST ANALYSIS AND REQUIREMENTS FOR PROVING COAL IN BALUCHISTAN, SIND & PUNJAB

		BALUCHISTAN	SIND	PUNJAB
FEASIBLE HIGH AREA	1. Reserves (Million Tonnes)	24.63 million Tonnes	600 million Tonnes	25 million Tonnes.
	2. Value of Coal	Rs. 14,778 million @ Rs. 600/- Ton	180,000 million @ Rs. 300/- Ton	Rs. 8750 million @ Rs. 350/ Ton
	3. No. of Bore Holes	99 B. H.	800 B. H.	50 B. H.
	4. Total Meterage	25570 metres @ Rs. 2500/ m	128,000 Metres @ Rs. 1500/ m	22500 metres @ Rs. 2500/ m
	5. Total cost	Rs. 63.92 million	Rs. 192 million	Rs. 45 million
	6. Cost/ Ton	Rs. 2.59	Rs. 0.32	Rs. 1.80
FEASIBLE MEDIUM AREA	1. Reserves (Million Tonnes)	54 Million Tonnes	146 million Tonnes	35 million Tonnes
	2, Value of coal	Rs. 32,400 million @ Rs. 600 / ton	Rs. 43,800 million @ Rs. 300/ ton	Rs. 12,250 million @ Rs. 350/ ton
	3. No. of Bore Holes	133 B. H.	217 B.H.	65 B. H.
	4. Total Meterage	87660 metres @ Rs. 3000/m	56,500 metres @ Rs. 1500/ m	32500 metres @ Rs. 2500/m
	5. Total Cost	Rs. 263 million	Rs. 85 million	Rs. 81.25 million
	6. Cost/Ton	Rs. 4.87	Rs. 0.58	Rs. 2.32

THE WORLD STEAM COAL TRADE AND ITS IMPLICATIONS FOR PAKISTAN

by

Kenneth A. Schweers

Senior Vice President

ICF Incorporated

Washington, D.C.

It is clear that coal and coal imports will be an important part of a diversified energy supply strategy for Pakistan in the future. Applications will be primarily in the generation of electricity, which is in critical short supply, but also in industrial applications, either in the brick and cement industries, or as a fuel in large boilers as Pakistan's industrial base expands.

The purpose of this paper is to review briefly the major forces influencing the future markets for world steam coal trade. I first provide an historical overview of the world coal trade. Next this trade is discussed (1) from the perspective of the major consuming countries, and (2) from the view of the major coal exporting countries. Given this background, I then review the implications for potential steam coal imports into Pakistan and the likely delivered prices for these imports. The intent of this discussion is to provide a basis for individuals to assess the reasonableness of future imported steam coal prices and how this source of supply compares with domestic supplies in Pakistan. Importantly, these prices are a key element for comparing the relative economics of the Lakhra power plant compared to a power plant near Karachi designed to burn imported bituminous coal.

INTRODUCTION

In order to better understand the potential role of major world coal exporting countries in meeting likely future import requirements for steam coal in Pakistan, it is useful to review the history and the overall supply and demand for world coal. In providing such a review, it is useful to divide the world coal markets into two separate groups of consumers and suppliers -- those dealing with coals and those using coal for steam purposes. Each has its own histozy and factors influencing the levels of demand and the major participants in each market. For purposes of the following review, it is also useful to divide the discussion into two periods of time, the pre-1970's and the post 1970's. The major events serving as the points of distinction between these two periods being the pre-enminence of OPEC during the 1970's and the significant increases in the world price for imported crude oil in 1973-74 and again in 1979-1980. These events greatly, and perhaps irrevocably, changed the relative role of coal in both the metallurgical and steam coal markets, especially in the world coal trade. It is this latter market that is of particular interest to Pakistan and their interest in possibly importing steam coal for electric power generation.

HISTORICAL OVERVIEW

Prior to the early 1970's, the overseas world trade in coal was dominated by metallurgical coal. While "local" export markets for steam coal developed in Europe and in North America, these were primarily an extension of domestic markets which happened to cross geo-political

boundaries. Poland's exports to other European countries and the U.S. exports to Canada are primary examples of this situation. During this period the U.S. and later Western Canada and Australia developed substantial markets in the export of various grades of metallurgical coals, principally to the steel industries in Europe, Japan, and more recently Korea and Taiwan.

In the post-1980 period, the world trade in metallurgical coals declined and then entered a period of sluggish to stagnant growth. Several factors contributed to these trends which are likely to continue for some time into the future. The series of oil price-shocks which quadrupled the price of imported crude oil brought severe world-wide economic recession and a restructuring of the industrial activities in the major coal consuming countries of the world. Technological changes, rationalization of existing steel-making capacity, substitution of new, energy-efficient products for steel, and the re-industrialization of the major steel producing countries (e.g., the U.S., Europe, and Japan) all will serve to reduce substantially the world-wide demand for steel and metallurgical coal.

However, the world trade in steam coal has experienced a very different set of circumstances. Following the doubling of world oil prices in 1973-74 and again in 1979-80, the relative economics for burning coal for steam purposes in lieu of oil and natural gas changed dramatically. Beginning in 1974 and continuing to the present, substantial efforts have been made by major energy-consuming countries to replace oil and gas with coal. This was particularly true in the cement and lime industry, the steel industry (supplemental firing in blast furnaces), and for utility powerplants that at one time had been designed to burn coal. These economic and relatively easy conversions greatly increased the demand for steam coal during the latter part of the 1970's and into the 1980's. Further, the first oil shock (accentuated by the second) changed the underlying economics for large, new fossil fuel fired boilers in favor of coal.

The result has been a significant increase in absolute and percentage terms in the amount of steam coal traded in the international, overseas markets. In particular, the emergence of South Africa as a major exporting country was directly tied to the increasing attractiveness of coal as a substitute for oil and gas for steam purposes. Moreover, the continuing development of Australia and Western Canada has been maintained primarily as a result of the increased interest in steam coal exports from these countries, which heretofore had exported almost exclusively metallurgical coals. New entrants into the world coal trade such as Colombia have been drawn into the trade because of the expectations of an ever-expanding demand for steam coal.

Therefore, the markets, trading relationships, and contracting mechanisms for participating in the world steam coal trade are relatively new and at present strongly influenced by those that existed in the metallurgical trade. These, however, are changing and forming around the special needs and requirements of the large utility consumers in the steam coal market. It is expected that this market will place a high premium on reliability and security of supply and

will tend to negotiate long-term, cost-based contracts which will protect both the supplier and the consumer from unexpected swings in the market price and in the demand for its product.

In addition, it is important to recognize that the current conditions in the international coal markets do not represent the expected long-term relationship of supply and demand. In response to the anticipated increases in both steam and metallurgical coal requirements, numerous efforts were undertaken to expand the available mining capacity serving the export markets. Expansions in South Africa, Western Canada, and Australia are the most notable followed by the significant emergence of Colombia as a major coal exporting country. Contributing to the current oversupply situation was the unexpected rapid return of Poland to the export markets at levels equal to or greater than those prior to the labor unrest in Poland of 1980 and 1981. As a result, the current world coal markets have experienced intense competition and price pressures due to the large amount of supply available compared to the depressed levels of demand now evident in Europe and the Pacific Rim. While this situation is expected to continue through the latter part of the 1980's and into the first part of the 1990's, it cannot and will not continue for long. The implications of this assured improvement in the future coal supply and demand balance on future steam coal exports and pricing is discussed later in this paper.

DEMAND FOR STEAM COAL IMPORTS

As recent history attests, forecasting future demand for coal imports, whether for metallurgical or steam coal purposes, is a difficult and uncertain process. This is because those factors likely to have a positive influence on the demand for steam coal, such as world crude oil prices, also tend to have a counterbalancing effect on economic activity reducing the overall demand for energy. Also, as the World's major energy-consuming countries have adjusted to recent trends in energy prices (both increasing and more recently declining world oil and gas prices), it has been difficult for analysts to separate short-term perturbations and trends from longer-term readjustments in the world energy markets. More often than not the result has been a significant overestimation of the likely demand for imported steam coals. An illustration of this can be seen in Table 1 in which two separate forecasts by the Energy Information Agency (EIA) of the U.S. Department of Energy are compared. The mid-demand estimate for 1995 world coal imports in 1982 is 140 million tonnes higher than the more recent estimate made in 1985.

Table 1

Comparison of EIA Steam Coal Import Demand Forecasts: December 1982 versus May 1985 (millions of metric tons)

Region	1990 L	1990 M	1990 H	1995 L	1995 M	1995 H
Western Europe						
12/82	123	150	170	180	200	240
5/85	80	95	105	90	115	137
TOTAL						
12/82	235	272	300	350	380	430
5/85	165	188	210	190	240	275
DIFFERENCE BETWEEN FORECASTS	70	84	90	160	140	155

In spite of these difficulties and uncertainties, it is useful to forecast future world coal demands and import requirements. In so doing, one gains (1) a better appreciation of

those factors influencing future demands and their relative importance, and (2) a better perspective regarding future movements in coal prices. This is discussed in greater detail later in this paper.

Table 2 below provides a concensus of the latest forecasts of the potential import coal demands for both steam and metallurgical coal by major consuming regions. The estimates for metallurgical coal are provided for perspective to show the limited growth through the forecast period compared to the forecasts for steam coal import requirements. Each of the major consuming regions are reviewed briefly below.

Table 2

Import Demand for Coal
(millions of metric tons)

Region	Historical 1973	1980	1983	1984	1985	1990	1995
Steam Coal							
Pacific Rim	2.0	12.9	29.3	34.6	42-45	54-65	75-95
Western Europe	17.8	67.5	62.2	72.1	77-82	95-110	115-140
Others [1]	[2] 7.9	32.8	39.2	42.2	43-48	48-55	50-60
Total	27.7	113.2	130.7	148.9	162-175	200-225	245-290

[1] Others includes Eastern Canada, South America, and Eastern Europe.

[2] Only includes Canada.

Region							
Metallurgical Coal							
Pacific Rim	56.0	67.8	70.0	80.2	7-81	81-90	90-100
Western Europe	23.5	47.9	37.3	44.5	40-45	45-48	48-52
Others [1]	7.02	22.1	28.0	31.1	30-33	33-35	35-40
Total	86.5	137.8	135.3	155.8	144-159	159-173	173-192

[1] Others includes Eastern Canada, South America, and Eastern Europe.

[2] Only includes Canada.

Steam coal import demand rose at an average annual rate of over 20% between 1973 and 1980. Higher oil prices after 1973 encouraged both utility and industrial users to substitute coal for expensive oil imports in large boilers and process applications when conversions are relatively easy such as in the cement and brick kilns and blast furnace operations. After the second oil price increase in 1979-1980, world import demand increased a further 15% over the three-year period ending in 1983. This increase occurred despite the recession in Western Europe which caused an 8% decline in European steam coal import demand during these years. With the recovery in the world economy, steam coal import demand has increased steadily, rising 14% in 1984 and an expected 13% in 1985.

Over the next ten years, import demand is expected to rise significantly, growing at an annual average rate of about 5% between 1985 and 1995. Increased steam coal use by the electric utility and industrial sectors in Western Europe and in the Pacific Rim countries are expected to account for most of the rise in total import demand for steam coal. At the same time, indigenous coal production in many of the major importing nations is likely to decline, although slowly. Hence, most of the incremental steam coal demand in these countries will be met by imports.

Western Europe

In Western Europe, steam coal imports are expected to increase at an annual rate of about 5.0 percent between 1985 and 1995. This increase reflects some slight displacement of expensive subsidized domestic coal production with imports and new demand spurred by growth in economic activity. Italy is likely to have the largest increase in imported steam coal, with levels rising from the 10.8 million tonnes imported in 1984 to about 25 million tonnes in 1995. Denmark, another country with limited energy reserves and a national policy

designed to reduce its reliance on oil, should also boost steam coal import demand. By 1995 coal imports are expected to climb to around 15 million tonnes from their current level of about 11 million. France, meeting most of its future electricity needs with nuclear power, is likely to reduce coal imports, despite falling domestic production. This reduction could reduce France's steam coal imports by about 50% (5 million tonnes) by 1995.

The United Kingdom and West Germany are not expected to be major contributors to the increased demand for coal imports as they have large domestic coal industry interests to protect. The U.K. has fluctuated between being a net importer and export of coal depending upon the condition of its domestic coal industry and economic activity. West Germany has continued to import coals but has limited the degree to which coal imports can capture existing markets from domestic producers.

Pacific Rim Countries

Although overall import levels are lower than those in Western Europe, the growth rates of Pacific Rim steam coal demand will be higher. Steam coal imports are expected to rise from 29.3 million m.t. in 1983 to 75-95 million m.t. by 1995. Japan, the leading coal importer in Asia, is forecast to increase steam coal imports from 17 million m.t. in 1984 to 25 million m.t. by 1990. South Korea, which must import all of its steam coal needs, is expected to increase imports from about 6 million m.t. in 1984 to about 10 million m.t. by 1990. Similarly, Taiwan's steam coal imports are also expected to rise substantially, increasing from over 5 million m.t. in 1983 to near 10 million m.t. by 1990. Other important actors in the Pacific Rim include Hong Kong with major coal-fired power plant additions to satisfy a steady growth in electricity demand, the Philippines, and to a limited extent India.

Other Countries

As developing countries in South America, Asia, and Africa begin to expand their economic activities, moving increasingly into manufacturing and in some cases traditional smoke-stack industries, steam coal imports will prove to be an economically attractive source of energy. Mediterranean countries such as Israel, Turkey and possibly Egypt are also expanding their use of coal imports for electric power generation and in industrial applications.

WORLD SUPPLY OF STEAM COAL

The major steam coal suppliers to the international markets are shown in Table 3 on the following page with estimates of their recent levels of exports. These countries are shown in their likely relative importance to Pakistan. Perhaps more important to the current state of the world coal trade markets than current export levels, is the productive capacity each country has available to satisfy increased demands for exports. As noted earlier, in response to the unanticipated increases in steam coal demand during the late 1970's and early 1980's, many countries embarked upon major expansion programs in new mines and the supporting infrastructure. Australia and Western Canada were the most active among the established coal supply countries, while Colombia was the most significant newcomer.

Table 3

Exports from Major Coal Exporting Countries in 1984
(in millions of tonnes)

Countries	Steam	Metallurgical	Total
Australia	29	47	76
South Africa	32	5	37
Colombia	1	0	1
Western Canada	3	22	25
U.S.	22	52	74
China	4	3	7
Poland	33	10	43
Others[1]	25	17	42
Total	149	156	305

[1] Others primarily include the United Kingdom, West Germany, and the U.S.S.R.

It is estimated that among all the suppliers listed in Table 3 somewhere between 50 to 100 million tonnes of excess productive capacity currently is available, exceeding the current levels of import demand discussed previously. This excess capacity can be utilized to satisfy any increased demand for coal imports without any appreciable change in the current market price levels and is a major reason for depressed prices and intense supplier competition existing in the current world coal markets. How and when this excess capacity will decline is a major consideration in estimating near-term and spot market prices for coal exports.

The following discussion summarizes the trends affecting export capacity, export levels, and mining, transportation, and shipping costs for each of the major supply countries of interest to Pakistan.

Australia

Australia is capable of producing low-cost steam coal for world markets, particularly to for the Pacific Rim countries given its favorable location relative to these countries. However, the historical contantious bickering between the traditional coal industry, federal and state governments, Australia's fragmented labor unions, Japanese coal importers, and international energy companies attempting to appropriate any available profits from the strong competitive market position of Australia has tended to raise delivery costs and disrupt production.

Production Costs

Australia has around 110 billion tons of recoverable reserves. Australian coal is generally low in sulfur content (1% sulfur or less) and has a high Btu value comparable to bituminous coals in the Eastern part of the U.S. Lower grade sub-bituminous and lignite coals exist but are produced primarily for domestic electricity generation. Australian export mines have thick seams and excellent geologic conditions that permit relatively low-cost extraction. The mining industry is sophisticated, technologically advanced, and is continuing to improve. At the present time, about 55 percent of the reserves are surface-mined. The shift from underground to open-cut mines, which began in the late 1960s, is expected to continue into the future. It is anticipated that by 1990 approximately 75% of Australian coal will be surface-mined.

In the past, Australia steam coal has primarily come from New South Wales, where production has increased at existing mines and some soft metallurgical coals have been marketed as steam coal exports. Queensland's status as a major coal producer has been based almost completely on metallurgical coal. The current development of steam coal reserves from some of the more remote regions in Queensland should rapidly alter these patterns. Queensland's steam coal producers need extremely large tonnage contracts to offset the high initial investment costs involved in

surface mining. However, the simpler geology of Queensland's reserves results in higher average productivity -- output per man shift is 50% higher in Queensland than in New South Wales -- and lower unit production costs.

Australian labor costs are relatively high by international standards. Labor unions are fragmented and strongly competitive. Approximately 30 unions are involved with the mining, transporting, and loading of coals destined for the export market. Any one of these unions can break this export chain, and thereby delay export shipments. This tactic is especially effective in Australia where limited stockpiling facilities and high demurrage costs can substantially increase the delivered costs.

Recent disputes affecting Australia's export coal trade largely have involved personnel in industries servicing the coal industry, such as railway, utility, and maritime workers. However, there is some evidence that labor relations in Australia's coal industry have improved in the past few years. Plans to reduce the number of unions associated with coal exports have been discussed. Union leaders are also urging members to seek reconciliation before taking specific strike actions. Labor disruptions are likely to pose less of a problem problem in the near future than history would indicate. However, this outlook could alter quickly if coal prices rise and unions were to attempt to expand their share of the potential profits.

Industry Structure

Unlike South Africa where investment decisions are concentrated in the hands of the government and a few large mining companies, Australia's ownership patterns are more diffuse. A high proportion of Australian coal is produced for specific end-users. Australian mines tend to supply coal either for export or for domestic markets, but not for both.

The Government plays a large role in the Australian coal mining industry, both at the state and federal levels. The state governments exercise control over exploration, production, and distribution through the leasing of resources and the opening of new mines. The federal government has responsibility for setting national energy policy, including the power to control expo s, foreign investment, and tax rates. The primary objectives of the state and federal governments are to ensure adequate supplies of cheap, high-quality coal for domestic consumption and to promote the stable development of coal production in relation to export market capacity.

Australian mining companies, who traditionally handled metallurgical coal but are currently producing steam coal for exports, tend to secure long-term contracts before expanding capacity. The publicly-owned Electricity Commission also conducts extensive coal mining operations to supply power stations and has tried to establish joint ventures to produce steam coal for exports.

Foreign interests also control a significant portion of Australia's export production. Large international energy and mining companies have become involved in the Australian coal industry during the last decade. Treating coal as an international energy commodity, these companies tend to respond more quickly to market incentives, concentrating

largely on spot market sales. Japanese utilities and other industrial users often have equity participation in the capital-intensive surface mines in Queensland. Japanese involvement provides Australia with scarce risk capital and ensures Japanese coal users reliable access to reasonably priced coal supplies.

Transport Costs

Major coal reserves and current mining operations are located relatively close to the ports, generally within 250 miles. Over the past several years there has been a significant increase in the rail rates charged to export coals; consequently, on a cost-per-ton-mile basis the rates are much higher than those in the U.S., Canada, or South Africa. While a large part of the rail system has been developed specifically for coal, some small parts of the system are outdated and inefficient. However, because mining companies are required to finance or help finance rail improvements and expansions, needed rail expansions will most likely keep pace with coal export expansions.

Australia has seven major ports capable of handling a total of over 100 million m.t. of coal per year and accommodating vessels up to 120,000 DWT. Australian ports have little stockpiling capacity, and demurrage charges can significantly affect the cost of coal. Because Australia's coal reserves have very favorable geological characteristics and are located close to the ports, both mining and transportation costs for exported coals are relatively low. Given this situation, the Australian government has instituted policies to ensure that its coal exports garner the most favorable contract terms in both quantity and price. As such, wherever market conditions permit, Australia has sought to price its coals above its marginal mining costs and to price it as high as the market will bear. In many cases, the "excess profits" (economic rents in economist's terms) are captured by the Australian government through high rail charges, port fees, export tax levies and royalty payments, and are used for development of the infrastructure for continued growth of coal exports.

Exports

In fiscal year 1985 (7/1/84 to 6/30/85), Australia's total coal exports were 82.5 million m.t., up 24% over fiscal 1984. Steam coal exports were 29.4 million m.t. or 36% of the total. However, at these high export levels, many companies are operating at extremely narrow profit margins, and little investment in export capacity is planned in the near future.

When world steam coal markets are depressed, as is the case in the current markets, Australia's exports are demand-limited. Although Australia's real underlying marginal costs of steam coal production are below current market prices, inflated wage and transportation rates -- as well as export tax levies and royalty payments -- all raise actual production costs. Hence, current low steam coal prices do not always cover these inflated costs, often leaving the producer with minimum returns on his invested capital.

Over the next few years, Australia will be the swing supplier for international steam coal markets, and as such, spot market prices and new contracts will reflect Australia's incremental production costs. Incremental increases in world import demand will be met by increases in

Australian exports. Higher cost producers, such as the U.S. and Canada, can still retain market share as a result of previous contracts and the willingness of importers to pay a premium in order to diversify their supplies, but in the face of significant excess capacity, the pressure to diversify suppliers will be minimal.

Australian export capacity is thus likely to exceed actual export levels in the short-term. By one estimate, current Australian steam coal export capacity as determined by mining and infrastructure capability is as high as 75 million m.t., or 2.5 times greater than 1985 fiscal year export levels. However, labor disruptions and expanding metallurgical coal exports have the potential to reduce actual steam coal export capacity substantially.

As mentioned previously, metallurgical coal exports can significantly affect Australian steam coal export capacity, since reserves of both types tend to be found in the same area and use the same transport facilities. Currently, metallurgical markets are depressed and likely to remain that way. Metallurgical coal demand comes primarily from steel producers. As car makers and other industrial steel users substitute away from steel towards lighter and cheaper materials, steel demand growth will slow. New technology in steel production also uses less metallurgical coal than previously, further reducing metallurgical coal demand. Hence, the slow growth in metallurgical coal demand, on the order of 1-2% per year through 1995, could free resources to promote steam coal export growth. Metallurgical coal exports are thus expected to remain relatively constant over the forecast horizon, shrinking as a share of Australia's total coal exports.

Australia's labor/management problems can also influence export capacity, as determined by existing mine and infrastructure capabilities. Labor disruptions are particularly likely when actual export levels approach capacity, as they did in 1980-82. As actual export levels and the economic rents associated with Australian steam coal production expand, the fight over the distribution of these rents may become worse, thereby disrupting supply. If labor relations continue to go well, export capacity may be as high as 75 million metric tons.

The preceeding analysis suggests that export levels will not reach export capacity until markets improve sometime in the early 1990s. Exports and export capacity appear in Table 4. A fairly wide range is reported in the forecast tables, reflecting the uncertainties arising due to the complex ownership and decision-making structure involved with Australia's coal exports.

Table 4

Australian Coal Exports
(million of metric tons)

Capacity Forecasts

Year	Total Export Capacity	Metallurgical Coal Exports	Steam Coal[1] Export Capacity	Steam Coal Exports
1985	100-130	[illegible]	50-75	35-40
1990	100-130	[illegible]	50-75	40-50
1995	100-130	[illegible]	50-75	50-65

[1] Steam coal export capacity, given that actual metallurgical export levels are equal to those forecasted above

South Africa

South Africa tends to be the low cost producer of steam coal for the world's two largest import markets, Western Europe and the Pacific Rim. The South African government has a

large degree of control in determining export levels and in keeping its coal exports competitively priced.

Production Costs

South Africa is estimated to have between 70 to 120 billion metric tons of recoverable coal resources, most of which is steam coal. The higher estimate reflects a more recent refinement of earlier work supported by the South African government to classify and quantify the country's coal reserves. About half the coal reserves are lower grade sub-bituminous coals, which have been developed primarily for conversion to oil at the Sasol facilities.

Nearly half of the coal reserves are mineable by less-expensive surface methods. Most of the reserves to be developed by underground mining techniques are at depths of less than 700 ft. with very thick seams. The sulfur content of these reserves ranges between 1% and 1.5%.

Labor costs in South Africa are low relative to other major coal suppliers. Although wages are expected to rise significantly over the next decade -- particularly among black mineworkers -- productivity gains resulting from the increased use of mechanized loading in underground mines and the spread of open cast mining should keep unit production costs down.

Industry Structure

In 1984, South Africa exported about 32 million metric tons of steam coal, a 22% increase over 1983 levels. Given South Africa's low costs of production and the extensive role of the government in the important decision making processes, future export levels are likely to be determined by rail and port constraints, rather than the overall foreign import demand for steam coal.

The South African government controls steam coal production and exports through a number of channels. Domestic steam coal prices are controlled at relatively low levels in order to provide a cheap source of energy for the domestic generation of electricity. Transportation rates for both rail and port facilities are set by the South African government. These rates reflect actual costs and tend to be low by international standards. Further infrastructure investment is also at the government's discretion. Because of these policies, export quotas have been enforced to ensure that enough coal is available to meet domestic needs at the artifically low prices and to allocate limited port and rail capacity among coal exporting companies.

The marginal cost of South African coal production is below the international market prices in Western Europe and the Pacific Rim. Although these prices may not provide producers their full, expected rate of return on investments in current mining operations, most can provide some contribution to these fixed, sunk capital costs. Thus, South Africa will export as much coal as the existing infrastructure can handle. However, when coal markets are depressed and interest rates are high, international coal prices may not ensure an adequate return on new infrastructure investment, thereby limiting increases in steam coal exports. Hence, increases in export capacity are dependent on infrastructure development, which largely reflects the South African government's assessment of future steam coal prices.

Infrastructure Capability

South Africa currently has 3 rail-to-port facilities capable of handling a combined 42 million m.t./year of coal exports. The major port facilities are located in Richards Bay, where recent development has raised export levels from 22 million m.t. a year to over 40 million m.t. This expansion has been expensive and is reflected in the large rail and port rate increases of the past several years.

Plans to further expand exports at the Richards Bay facilities have been delayed due to depressed international coal prices and high interest rates. If coal markets begin to tighten, expectations of future price increases may encourage further expansion at Richards Bay. Current facilities could be expanded to 60-65 million m.t./yr relatively easily.

Existing rail capacity could handle 20 million metric tons more per year, with little investment beyond that required for additional rolling stock. The coal terminal at the port would need an additional loader, but not the heavy expense on civil engineering work which was necessary to expand capacity to 40 million m.t. Both of these projects could be carried out within 2-3 years of a decision by the South African government. Current market conditions suggest that such a decision is not likely to be made before the late 1980s.

To expand the Richards Bay's facility beyond 65 million m.t., to 80 million m.t., would require a much greater expenditure. The rail system would require some engineering work on the track, perhaps some upgrading of the rail line, and additional rolling stock. The terminal would need a fifth loader and quay, and there would probably be heavy civil engineering costs. In addition to these costs, the channel may need widening to relieve congestion, depending on the magnitude of other bulk cargo exports. Richards Bay's facilities are thus likely to have a capacity no greater than 65 million m.t. over the forecast period through 1995.

International markets are not likely to firm soon. Hence, it is unlikely that South Africa will decide to start expanding the facilities at Richards Bay, before the late 1980s. Thus, South Africa's export capacity is estimated to be between 60 and 65 million metric tons/year by 1995.

Additional Considerations

Labor disruptions within the coal mining industry are not likely to reduce exports significantly. The wages of black mine workers increased almost eightfold -- albeit from extremely low levels -- during the seventies and early eighties, creating a privileged group with more to lose from labor disruptions. Strikes in the mining industry are usually ended quickly and can result in large-scale firings.

Large stockpiles of coal further increase the reliability of South African producers. Proposed import sanctions on South African coal by Denmark, France, and Sweden are not likely to have much of an effect. As a low cost producer, South Africa can undercut Australian prices to the Pacific Rim countries although its preferred market is Western Europe where it has a transportation advantage over most other world coal suppliers. However, increasing violence and political instability in the society as a whole could potentially have a large impact on the industry.

Forecast of South Africa's Coal Exports

Consistent with the above discussion that South Africa will export coals up to the limits permitted by its rail and port facilities, exports from South Africa are likely to increase 50% by 1995 as shown in Table 5.

Table 5

South African Coal Exports (millions of metric tons)

Year	Steam Coal	Met Coal	Total
1985	37-38	4-5	41-43
1990	45-50	4-5	49-55
1995	55-60	5-6	60-66

Colombia

By 1990, Colombia will be a significant player in international steam coal markets. Colombia is a low-cost producer and exports are likely to expand as rapidly as export capability can be built and purchasers found.

Production Costs

Colombia's potential reserves are estimated to be 22 billion metric tons, most of which is comprised of steam coal. Colombia's coal is very high quality with a high Btu content (as high as 14,400 Btu/lb.), a sulfur content of 0.4%, and ash contents of around 4-7%. It requires no preparation other than crushing and sizing. The coal lies close to the surface, in very thick seams making it easy to strip mine. The mines in the El Cerrejon district are located within 100 miles of the export port now being developed as part of the Exxon/Carbocol project. Furthermore, the country's favorable geographical position may give it some advantages in marketing its coal first to Western Europe, and then to the Pacific Rim; Colombia's coal port is only 400 miles from the Panama Canal.

Export Capacity

Currently Colombia is engaged in extensive exploration activities and is seeking partners to help finance and develop its coal reserves. Exxon has joined Carbocol, the government-owned coal company, to develop the first large, export-oriented mine -- the El Cerrejon mine, in the northern zone of the El Cerrejon reserves -- and supporting rail and port facilities. At its design capacity this project will produce over 17 million tons per year of coal by 1989, starting from about 2.8 million tons in 1985. Most of the infrastructure development is ahead of schedule, making these targets achievable provided world market conditions warrant such an expansion. Both Exxon and Carbocol need to begin to realize some return on the sizeable investments made and estimated to be on the order of between $3.0 and $3.5 billion. Exxon, in particular, is under pressure because its contract with Colombia expires in 2008, at which time all the assets revert to Carbocol. Hence, both companies are aggressively marketing this coal. A Spanish consortium is participating in the development of the central zone of El Cerrejon. Colombia, Brazil and Mexico have agreed to form a tri-national company to exploit the southern zone of the El Correjon reserves. The total output from these reserves of about 5 million metric tons per year will be purchased by Mexico and Brazil.

Given current world import demand forecasts, Columbia is likely to be able to export no more than 17 million

m.t. by 1990. However, exports could reach close to 30 million m.t. by 1995 as international steam coal markets tighten. Export forecasts for Colombia appear in Table 6.

Table 6

Colombian Steam Coal Exports
(millions of metric tons)

Year	Steam Coal Exports
1985	2-4
1990	12-17
1995	25-30

Western Canada

Canada is a relatively high-cost producer. Like the U.S., Canada can act as a swing supplier when import demand is high.

Production Costs

Recoverable reserves are estimated to be between 60 and 70 billion tons, most of which are in Western Canada and are low in sulfur content (less than 1%). About half of Canada's recoverable reserves are lower-grade sub-bituminous and lignite coals located in the plains areas of Alberta and Saskatchewan. These lower-grade coals are being developed for domestic electricity generation and potential synthetic fuels conversion.

Mining costs for the higher-rank bituminous coals in Western Canada are high compared to those in Australia and South Africa. Most of the Canadian reserves can be surface mined. However, the reserves have multiple seams and are steeply inclined, folded, and faulted, which makes mining expensive. Labor costs are high, especially in remote areas with harsh weather conditions. Labor strikes, however, tend to be infrequent and short-lived.

Transport Costs

The Canadian infrastructure is well developed. The railway system is one of the most efficient in the world and was developed in large measure for the export trade. Large unit trains of 100 cars or more are used. However, in many instances Canadian coal exports must be transported over 700 miles through some of the most mountainous terrain in the world. Also, the ability of existing Canadian rail lines to serve the competing interests of both the future grain and coal markets is questionable. To increase exports significantly, Canada will have to finance new facilities. Canada is considering the alternative of slurry pipelines and may develop a coal-water slurry for some of its Japanese exports. Such developments, however, are not likely to materialize before the mid-1990's.

Canada's ports are deep and uncongested. Several can accommodate at least 100,000 DWT vessels. There are plans to expand Roberts Bank, the largest port in Canada, to accommodate 250,000 DWT vessels; double its storage capacity; and increase its export capacity to 25 million metric tons per year. A new port at Ridley Island is planned with an initial capacity of 13 million metric tons per year and the capability to handle 250,000 DWT vessels.

Exports

Canada's biggest constraint in expanding its coal exports will probably be its high costs. Furthermore, in the long-run, mining costs are likely to rise faster in Canada than in other producing countries given the difficult geologic conditions of many of its bituminous reserves.

Canada has undertaken several new export-oriented projects. It has received significant investments from the Japanese both in the form of equity and loan agreements. Also, it has recently signed several new long-term export contracts, including a metallurgical coal contract to supply 7.5 million metric tons per year to Japan for a 15-year period. Estimates of Canada's export capacity through 1995 appear in Table 7.

Table 7

Canadian Coal Exports
(millions of metric tons)

Year	Steam Coal Export Capacity	Metallurgical Coal Export Capacity	Steam Coal Exports
1985	5-10	20-25	3-4
1990	10-15	20-25	6-10
1995	15-20	20-25	15-20

United States

The United States has the highest annual coal production rate in the world with significant excess productive capacity estimated to be on the order of 100 million tonnes. Exports account for only a small fraction of total U.S. coal production. The U.S. is also a high-cost producer of coal for export, given the relative high transportation costs to move the coal from its operating mines to the importing country's consumers. Hence, the U.S. will tend to serve most significantly as a swing supplier in international steam coal markets, particularly when import demand is high relative to the productive capacity of the low-cost suppliers.

Production Costs

The United States has estimated total recoverable coal reserves of about 525 billion metric tons. Coal quality, seam thickness, and mining methods vary greatly throughout the U.S.

Coal in the western part of the country comes from a variety of coal basins, although for these discussions it is useful to categorize these basins into two major areas - the sub-bituminous coal regions of the Powder River Basin and the bituminous coals found in the Rocky Mountains. The coals in the Powder River Basin are mined by large surface operations and are found in very thick, shallow seams. Btu content ranges from about 6,000 to 9,500 Btu/lb with sulfur content ranging from 0.4 to 1.5%. In the Rocky Mountain area both surface and underground mining methods are employed. The heat content of the coals ranges from 10,500 to 13,000 Btu/lb, with a sulfur content of 1% or less.

Coal produced in the Midwestern part of the U.S. is quite different from the Western coals. The coal is both strip- and deep-mined and usually has a sulfur content of 3 percent or more. It is interesting to note that this is the only place in the world where coals of this consistently high sulfur content are produced in such quantities, approximately 135 million metric tons per year. Like the Western reserves, the coal seams are quite thick. Btu content is only moderately high for bituminous coal, around 11,000 Btu/lb.

Coal deposits in Appalachia are also different and contain both high sulfur coals (in Northern Appalachia) and low sulfur coals (in Central/Southern Appalachia). The coals are predominantly bituminous with Btu contents in the range of 12,000 Btu/lb. and above. Both surface and deep-mining techniques are

employed, although most deep-mining operations require coal preparation facilities to market an acceptable product. The seams are thinner than those in the Midwest, and mountainous conditions lead to smaller, more numerous mining operations.

Alaska has extensive coal deposits, but due to its remoteness from major domestic consumers and limited surface transportation facilities, Alaskan coal has not been subjected to a rigorous analysis. However, after the 1973/74 oil embargo Alaskan reserves were given much more serious consideration, especially by potential importing countries in the Pacific Rim. At present, some coal shipments have been made to Korea and a contract for shipments of about 0.8 million metric tons per year reportedly has been signed. There are currently other prospects under investigation to export Alaskan coal to other Pacific Rim countries. Most of the currently developed Alaskan reserves are sub-bituminous or lignite, and are very low in sulfur.

Labor costs in the U.S. are quite high relative to those in other countries. Strikes are fairly predictable. They are more common in the Eastern U.S. than they are in the West, where union representation and activism are not as great.

Transportation Costs

Transportation costs from the mine to the port are high and reduce U.S. competitiveness considerably. Since steam coal exports have emerged as a potential market, railroads in the U.S. have taken steps to increase their efficiency and lower costs. By world standards they are still relatively high, on the order of $15 per metric ton in the East and $20-25 per metric ton in the West.

Port facilities in the U.S. have been expanded dramatically since the congestion of 1980 and 1981. New, improved facilities with ground storage have been added at East coast ports, most notably in Baltimore, Newport News, Philadelphia, and Charleston. Expansion plans at the Gulf Coast ports of Mobile and New Orleans have been completed. On the other hand, the expansion plans for the West coast ports of Long Beach/Los Angeles and Portland in the Pacific Northwest have been delayed due to the poor current market conditions. However, these plans could be completed fairly expeditiously should market conditions improve.

Port dredging to accommodate 80,000 to 120,000 DWT vessels has also been delayed. Should the export markets improve significantly there is no guarantee that operations would be completed since dredging is still a controversial political issue.

Export Capacity

The U.S. currently has a substantial amount of excess export capacity available. In 1985, the U.S. coal industry is likely to have on the order of 100 million m.t. of excess productive capacity, due to relatively weak domestic demand. If international prices rise, additional domestic coal production and transport capability could be diverted towards the export markets. In 1985, total exports are expected to be 82-90 million m.t. -- well below the peak export levels of 110-115 million m.t. recorded in 1981. Substantial infrastructure investment has subsequently reduced the transportation constraints which limited exports in 1981. Hence, total export capacity should be easily over 130 million m.t. Future export

capacity depends on domestic supply and demand for coal, further port expansion programs, and the magnitude of other exports which compete for the same transport facilities. Given the metallurgical forecasts reported in Table 8, steam coal capacity is likely to be over 70 million m.t. through 1995.

Actual Exports

The United States is a high-cost producer of steam coal. Since the domestic consumption requirements are far greater than exports, and rail and port facilities have not been developed primarily for coal exports, the U.S. will tend to act as a swing supplier of steam coal. High international prices justify directing existing resources to coal exports, while low prices do not. Additional U.S. exports, then, will roughly be the difference between international import demand and the total supply available from lower cost producers. Export levels and capacity forecasts appear in Table 8.

Table 8

U.S. Coal Exports
(millions of metric tons)

Capacity Year	Total Coal Export Capacity	Met Coal Exports	Steam Coal[1] Export Capacity	Steam Coal Exports
1985	130	55-60	70	25-30
1990	130	50-60	70	20-25
1995	130	50-60	70	25-45

[1] Steam coal export capacity, given that actual metallurgical export levels are equal to those forecasted above

China

Despite the enormous size of the domestic mining industry, Chinese steam coal exports are expected to be constrained by rising domestic demand and inadequate infrastructure facilities.

Production Costs

China has an estimated 100-200 billion tons of recoverable reserves. At the present time, most of the reserves in China are deep mined. Many of the seams are deep and thick. The coal generally has a low sulfur content and a high ash content. The majority of the coal is bituminous; the rest is anthracite. Mining is inefficient compared to other suppliers. Wages are high for China (though very low relative to other suppliers) and equipment is quite outdated.

Export Capacity

To become a major exporter, China needs to modernize its coal industry. The Chinese government has given coal industry development a top priority, seeking foreign participation in the expansion of its coal industry. The involvement of international companies in these projects is growing rapidly. At the present time, Poland is participating in the design of a large coal preparation plant and is providing mining machinery as well as safety equipment for a number of projects. Japan is lending China $1 billion for projects related to the shipment of coal for exports. It is using export credit loans from Italy, France, Japan and Great Britain to finance mine expansion and infrastructural developments. Occidental Petroleum of the U.S. is involved with the development of two mines in the Shanxi province, which will produce 16 million tons of coal per year, with about half slated for export. Shell Coal International and China have agreed to sign a contract for feasibility studies of China's Jining No. 2 mine in Shandang Province. Thyssen of W. Germany has joined in the development of a shaft coal mine in northern China. Other joint ventures are continually being sought. The effect of such ventures

on the Chinese coal industry is highly uncertain.

The biggest constraint on China's exports is its limited and outdated infrastructure. Although the rail system is being improved, it will be many years before it adequately serves the most desirable deposits. The number of ports that have coal export facilities is very small, only 6 out of an approximate total of 200.

In 1982, China produced about 700 metric million tons of coal, of which only 9 million metric tons were exported. Due to the enormous size of China's coal industry and its proximity to the Pacific Rim Countries, this country is most assuredly a potential force in the Asia and Pacific Rim market. Of all the supplying countries, China faces the most uncertain future.

Chinese officials have stated they hope to reach an annual export level of 15 million metric tons by 1995 and 20 million metric tons by 2000. However, many analysts feel that this will not be possible given the timing and scope of current development and production plans. China is already having problems fulfilling an existing contract with the Japanese. Increased domestic demand, inadequate infrastructure facilities, and lack of coordination will continue to constrain China's exports. To the extent this occurs, many analysts believe an export level of 7 million metric tons by 1990 is more likely. Forecasts of export capacities appear in Table 9.

Table 9

Chinese Coal Exports
(millions of metric tons)

Year	Steam	Met.
1985	4	3
1990	6-8	4-6
1995	6-8	4-6

Poland

Poland has a controlled economy and has no market price which can be used to cost its coal exports. Given the location and characteristics of its reserves, it is likely that the true marginal costs for its coal production are quite high. Hence, as existing reserves become depleted, Poland will struggle to maintain current export levels, given the financial constraints which limit mine and infrastructure investment. On the other hand, because of Poland's need for hard foreign currency, it will likely continue to price its coal exports to produce the exchange requirements it needs.

Production Costs

Although Polish coal reserves are plentiful, mining is expensive due to poor seam conditions, reflecting the degree to which the in-situ reserves have been extensively exploited. The coal is low-sulfur (less than 1%) but varies in Btu content.

The Polish coal industry is run by the state and is highly mechanized, an inheritance from World War II which forced Poland to rebuild its industrial base with less labor-intensive methods. The Polish government places great importance on the coal mining industry and sees it as a basis for economic recovery.

Export Capacity

In 1985, Poland is expected to export 28-30 million m.t. of steam coal, down from 35 million m.t. in 1984, due to increased domestic consumption during an unusually harsh winter. Despite the fact that new mines are under construction, exports are not likely to increase since the new operations will merely replace output from older mines which are nearing exhaustion. Poland has

already increased lignite production from 46 million m.t. in 1983 to an expected 55 million m.t. this year. This and future expansions in lignite production will enable Poland to continue to commit its bituminous reserves to the export market.

The majority of the Polish coal exported to Eastern bloc countries is transported by rail, while the coal going to Western Europe is transported by ship or barge. Because the distances are not great, transportation costs are not high relative to other suppliers. Poland's inland transportation system needs to be improved so that exports can move more smoothly and efficiently to ports for shipment. There are plans to build new railroads which will connect the major new mine developments to Baltic ports and improve the interconnections with Poland's large rail system.

Poland has 5 major ports. The largest one, Gdansk, can accommodate vessels up to 100,000 DWT and has an annual throughput of 10.5 metric million tons. Currently, there are no plans for expansion at this or the other major coal ports.

Since the labor strikes of 1981, some buyers have become skeptical about Poland's ability to consistently live up to its contractual commitments. They also question Poland's reliability, since there is the perception that preference is given to Soviet Bloc countries. However, at the present time Poland is aggressively marketing its coal for export and offering competitive prices in order to regain its share of the European markets which was lost in 1980 and 1981. These actions have been successful in short-term sales where pricing tends to be the decisive factor, but longer term contract sales, where reliability becomes more important, have remained more elusive.

Poland has stated that its goal is to maintain its level of steam coal exports at around 40 million m.t./year throughout the decade. Poland's uncertain financial conditions, however, raise doubts about Poland's ability to meet this export objective. Considerable mining and rail investment will be needed to achieve that goal as the reserves supporting existing operations are exhausted. These new mine developments will be appreciably more expensive than existing mine operations because of the significant depletion of Poland's reserves. Poland is thus likely to export only 30-32 million m.t. of steam coal by 1995, as shown in Table 10.

Table 10

Polish Coal Exports
(millions of metric tons)

Year	Steam	Met	Total
1985	28-30	7-8	35-38
1990	30-32	9-11	39-43
1995	30-32	9-11	39-43

WORLD STEAM COAL PRICING

As noted briefly in the introduction, there are a number of elements which determine the pricing of steam coal, whether from domestic production or from coal imports. Just as coal is not a homogeneous product neither is the price for coal one unambiguous figure. The price will vary depending upon the type of coal being purchased, when it is purchased, how it is purchased, and the terms and conditions of the contract specifying the purchase. For this discussion, it

is useful to view coal pricing as falling into three different types of contracts:

- o Spot market purchases where there is a single amount purchased within a short period of time.
- o Short-term contract purchase in which a specific amount is purchased to be delivered over a period of one to three years.

  Long-term contract purchase in which a specified annual amount of coal with specific quality characteristics is purchased to be delivered over a period of five years or longer (generally on the order of 10 to 20 years).

The type of contract purchase that is most relevant to coal imports into Pakistan for purposes of electricity generation is the long-term contract purchase. Reliability of supply, consistent quality, reasonable control on expected delivered coal costs, and established supply relationships are important considerations when purchasing coal for power generation. These considerations are best addressed under a long-term contract purchase which also, over the long run, will yield the lowest possible average delivered price for imported stream coal. For example, utilities in the U.S. will typically buy about 80% of their coal requirements on long-term contract with the remainder split between short-term contract and spot market purchases. Those factors causing U.S. utilities to pursue this type of contracting strategy are even more dominant in the international coal trade (long transportation linkages, distant supplies, limited ability to quickly change suppliers and the type of coal being purchased, etc.).

Therefore, the delivered coal price most relevant to providing an imported coal option to Pakistan is that for a long-term contract purchase. This would be for deliveries of about 1.5 to 2.0 million tonnes of low-sulfur, bituminous steam coal supporting the baseload operations for each 400 Mw power plant located near Karachi, Pakistan. Given the time to plan, design, permit, and construct such a facility, the most likely startup data would be around 1993 to 1995. Therefore, it is the likely price of imported coal at this point in time that is relevant, not the price that exists in today's market.

In general, under this type of contract the delivered price for coal will reflect the underlying full costs for mining, transporting, and shipping the coal to Pakistan. These costs would include a fair return on all of the invested capital in the imported coal supply network. Typically, a base price with escalation clauses for capturing the changing costs for mining, transporting, and shipping the coal is specified in the long-term contract agreement.

Review of Historic Imported Coal Prices

In developing an estimate for the future price of imported coal it is natural that any forecast that is developed will be compared with current and recent historic steam coal prices. While these prices do provide some perspective, they do not provide a good measure of the relative "soundness" of future price forecasts for long-term coal contract purchases. The reasons for this are discussed below.

Table 11 below presents steam coal prices for the period 1977 to 1984 for Australia, South Africa, and the U.S. In general, these prices represent spot market and short-term contract prices rather than long-term contract prices. Between 1979 and 1982, the average F.O.B. price of South African steam coal rose 60%, that of American East Coast steam coal rose over 80%, while Australian steam coal prices rose by about 40%.

Table 11

Average F.O.B. Steam Coal Prices
(US $/Ton)

Year	New Castle Australia	East Coast United States	South Africa
1977	24-29	25	21
1978	25-31	26	22
1979	26-32	28	22
1980	28-30	40	28
1981	34-39	49	34
1982	37-43	51	35
1983	35-41	43	31
1984	33-40	44	28

Source: International Coal

These price increases were the result of an unusual combination of events. During this period, world oil prices doubled from about $15 to $30 per barrel. Consequently, steam coal became a more economical fuel for many facilities. Conversions to coal from oil and gas occurred in many utility boilers and cement kilns where these conversions were economical and could be accomplished easily. This resulted in an unanticipated increase in the demand for imported steam coal. At the same time that demand increased, conditions changed in a number of the major exporting countries which restricted coal supply. For example, there were severe labor problems in the coal mining and transportation sectors of the Polish and Australian economies, production capacity and port limitations in Australia and other major supplying countries, and port constraints and controls on the amount of exports from South Africa. Therefore, much of the surge in import demand had to be satisfied by U.S. producers and with the surge in demand exceeding the available traditional lower cost supply alternatives were unavailable, spot market and short-term contract prices began to rise. The U.S. share of world steam coal trade rose from 14.0% in 1979 to 37.0% in 1981 (See Table 12). Since international prices rose, higher cost domestic mining and rail capacity in the U.S. was brought on-line to produce steam coal for export.

Table 12

U.S. Share of World Steam Coal Exports
(millions of metric tons)

Year	U.S. Exports	Total Trade	Market Share (%)
1977	11.3	80	14.1
1978	9.5	88	10.8
1979	13.9	99	14.0
1980	25.9	107	24.2
1981	42.9	116	37.0
1982	37.9	122	31.1
1983	25.2	117	21.5
1984	22.3	124	17.4

Source: [illegible] Coal Production, November 4, 1985

However, things again changed dramatically in 1982 and 1983. Major economies of the world suffered recessions which reduced the overall demand for steam coal. Also, the labor problems in Australia and Poland were resolved and these countries returned to their original export levels. In fact, Poland increased its coal exports to non-Communist countries from 9 million metric tons in 1981 to 12 million metric tons in 1982 and to 22 million metric tons in 1983. Note that over this same period, 1981 to 1983, Poland's exports to Communist-Bloc Countries increased from 8 million metric tons to 17 million metric tons. Australia, limited to 51 million metric tons of exports in 1981, exported 55 million metric tons in 1982 and 66 million metric tons in 1983.

Steam coal prices temporarily firmed in late 1984, as the British coal strike continued and the world economy began to recover. However, once the miners' strike ended, the fundamental underlying demand/supply structure was reasserted and world steam coal prices began to fall (See Table 13).

Table 13

Steam Coal Spot Market Price for 1984/85[1]
(F.O.B. U.S. $/Ton)

Date	Australia	Gulf Coast United States	Richards Bay South Africa
5/2/84	30-33	35-37	29-30
11/7/84	32-43	43-44	35-37
5/8/85	35-36	36	35-36
11/8/85	32-34	33-34	31-33

[1] Source: Coal Week International

Current prices reflect the fact that the world steam coal supply currently exceeds world import demand as demonstrated earlier in this appendix. Current prices do not allow the marginal producer -- such as Australia in this case -- to recover full costs of production. A recent survey (CWI, 5/15/85) of Australian producers found that 30 out of 39 responding companies were recording little or no profits. This is due in part to high taxes and tariffs imposed by the Australian government to capture economic rents. Nevertheless, Australia is limited in its ability to garner higher prices when supply greatly exceeds demand and there is intense competition among the major world suppliers for the limited demand.

Again it should be recognized that these coal prices do not reflect those appropriate for long-term coal contracts. While some term contract prices are reported by various organizations, these prices are closer to reflecting short-term contracts of 2-5 years rather than long-term contracts of 10 or more years. Moreover, as noted previously, the world steam coal trade is still emerging and the established pricing and contracting practices have yet to be fully established. Given the current oversupply and depressed spot market prices, few long-term contracts are being negotiated and those that are have not been made public.

Moreover, the current condition of depressed steam coal prices as a result of world supply exceeding demand by a substantial amount will not continue forever. Based on current projections of world coal import demand and the expansion plans of the major world coal exporting countries, world steam coal markets are likely to move into a balance (supply equilibrating with demand) sometime during the early 1990's. At this point international steam coal prices will firm and the spot, short-term, and long-term coal contract prices will reflect those necessary to recover the full mining and transportation costs, including a fair return on any invested capital.

Therefore, it is the long-run full costs of mining and transportation that are most relevant for estimating the future long-term contract prices for imported coal into Pakistan. As discussed in the next section, the major uncertainty in estimating this price is whether future international steam coal prices are likely to be established by the new mining and transportation developments in the U.S. or those in the lower cost exporting countries of Australia and South Africa.

Long-Term Imported Coal Costs to Pakistan

The major coal exporting countries of primary interest to Pakistan as potential suppliers of imported coal are the U.S. (both East and West Coast ports), Australia, and South Africa. Others such as Colombia, China, and Western Canada and possibly Indonesia (in the future) also have supply potential. However, it will be the cost structure of these three major suppliers that will most likely determine the market clearing prices for imported coal to Pakistan. In the early 1990 period and beyond, it is the estimated long-run marginal costs for new mining developments and the full transportation and shipping costs of delivering coal to Pakistan from these countries that offer the best estimates of long-term contract costs of imported coal.

Table 14 (at the end of the document) provides an assessment of the long-run cost for each exporting country of delivering steam coal to Pakistan. The total costs reflected in this table are the sum of the long-run marginal mine-mouth production, domestic transportation, and ocean freight costs from newly developed mines and ports. These costs represent the costs associated with opening the last new mine to satisfy the last increment of demand and include a fair return on all invested capital required to bring this supply on line and to transport it to Pakistan.

It is important to realize that these are estimated costs, not price forecasts. The critical distinction is that these costs do not include possible economic rents, or profits beyond a fair return on the capital invested in production or transportation ventures. Such economic rents may be captured by the government, as is the case in Australia and South Africa (in the form of export levies or unusually high transportation tariffs), or by the producers as a result of various market strategies, or conceivably by labor unions.

Therefore, the actual steam coal market price which prevails after the early 1990's may be based on Australian or American marginal production costs, depending on import demand and the market strategies of the low cost suppliers. If in the longer run, the low cost suppliers attempt to limit their exports and thereby allow the U.S. to capture a reasonable share of the world market, then world prices will be higher, reflecting the marginal costs of U.S. production. If South Africa and Australia decide to maximize their market shares throughout the 1990s, or if Colombia expands its steam coal export capability particularly rapidly, then world prices are likely to be lower, as based on Australian or perhaps Colombian production costs. Although it is difficult to forecast the market strategies of the low-cost producers after 1995, there may be strong incentives for them to limit their exports and permit the U.S. to influence the market clearing price.

Given South Africa's concern about its limited domestic supplies of energy, it seems reasonable that the government would be particularly interested in limiting coal exports. Its market share would be sacrificed for a higher selling price, but coal resources would be conserved. The higher export profits could be used to subsidize indigenous coal production for domestic use. As a result, there

may be little incentive for the government or the producers to increase exports to a level where South African coals set the market-clearing price in world markets.

It is uncertain whether Australia could implement a market strategy that allows the U.S. to set the market-clearing price, particularly in Pacific Rim markets. Australia may or may not be able to control its level of exports or reduce competition among its own suppliers. The arguments that support the view that Australia could coordinate such a market strategy are provided below:

- The Australian government must review and approve all export contracts. The purpose of this review process is to ensure that Australian producers receive a fair market price. The process does offer some potential control over price and volumes; more importantly, it has made available better information about existing and potential export contract prices.
- Exchange of information among Australian producers is further facilitated by the numerous joint investments, the weak antitrust laws, and the limited number of producers (relative to the U.S. industry).
- Federal and State governments can control the rate of new mine development through the leasing and permitting of new mines. They may choose to restrain the growth of the coal mining industry due to concerns that rapid development will strain the availability of labor, water, and capital.

Long-term contract prices are thus likely to fluctuate somewhere between the long-run marginal costs of Australian and U.S. production. Given the cost estimates in Table 14, a metric ton of steam coal delivered to the plant gate in Pakistan is likely to cost between $50 and $80. The lower estimate reflects the minimum fully allocated long-term marginal cost of production and transportation from South Africa. Because of the limited capacity for exports from South Arfica and the domestic labor situation that raises questions about long-term supply reliability, this delivered cost is likley to represent a lower bound estimate for spot market purchases. Moreover, South Africa is likely to direct its exports to Western Europe where it has a competitive advantage and where it can realize the maximum returns to its producers. Therefore, coal from South Africa is not likely to represent the long run expected market clearing price for imported steam coals to Pakistan.

A "best guess" forecast for the price Pakistan will have to pay for imported steam coal is a price that reflects the delivered cost of coal from Australia. From Table 14, in 1985 U.S. $/tonne, this price would be on the order of $58 to $64. This implicitly assumes that Australia is unable to coordinate a market strategy that allows the U.S. to set the world market-clearing price. Hence, prices would reflect direct competition among suppliers and new mine development costs within Australia. The upper bound is higher price estimate of $80/tonne is based on the costs of U.S. or Canadian long-run marginal production and transportation costs. This price would result if import

demand grew particularly rapidly and low-cost producers were able to restrict export growth over the long term, thereby allowing the marginal producers in the U.S. to set the world market clearing price.

SUMMARY

The costs for importing steam coal into Pakistan are such that they will compete with alternative forms of energy, especially for application in large industrial or utility generation facilities. On a price-per-million Btu basis such coals are cheaper than imported oil (about $2.50/million Btu for imported coal versus $4.00/million Btu for oil at $25/bbl of crude). For Lakhra coals, current market prices are around $1.80/million Btu but for the large mine developments required to support a sizable (400-700 MW) coal-fired powerplant, these costs could be on the order of $3.40/million Btu. So imported coal can compete with the Lakhra coals as well.

When evaluating imported coal options compared to those using domestic coal supplies, economic costs on a bus bar basis for electricity generation is one measure for consideration. Others include desires for reliability and security of supply, exposure to foreign exchange requirements and fluctuations, diversity of sources of electricity supply, and the benefits that accrue from domestic developments, employment, and the transfer of technology. All of these are being considered in the economic evaluation of the Lakhra powerplant project which is still underway. Preliminary findings indicate that both imported coal and the Lakhra powerplant are likely to serve as generating options consistent with a secure, diversified, and economic utility expansion plan for Pakistan. Both will provide Pakistan the ability to grow and prosper as it continues along the road toward a better world of tomorrow.

UTILIZATION OF COAL WITH LOW-HEATING VALUE

Zeng Qinghe
Vice-General Executive
Jiangxi Provincial People's Government
Technical Development & Research Centre
Nanchang
Jiangxi Province, China.

In our Jiangxi Province of China, the geological structure of coalfield is very complicated and its coal resources is not very rich. The proved reserve of coal has reached an amount of 1.36×10^9 tons, in which coal with low-heating value takes up 0.42×10^9 tons. Besides, the reserve of bone coal is estimately above 6×10^9 tons.

As the consumption of coal is growing, our Jiangxi Province, like all over the world, are facing the problems of that the rank of coal is becoming poorer while ash and sulphur contents are increasing continuously. The accumulation of coal gangue for years is amounting to 35×10^6 tons and 2.5×10^6 tons of fresh coal gangue is being discharged per year. In recent years, the annual production of raw coal is 18×16^6 tons, ash content and heating value of one third of which is over 40% and below 3700 Kcal/Kg respectively.

In the recent decade, our Jiangxi Province has been concentrating on the research on utilization of low-rank coal and has already gained experience.

It is not economical to exploit coal with higher ash content and low-heating value by National power. Therefore, The People's Government of Jiangxi Province issues a policy to inspire the organizations and enterprises in county and countryside to exploit the small coal mines which will not be brought into national united distributing plan. Those shallow coal mineral deposits which are poor in reserve and unfavourable for mining with regular mechanization are assigned into collectively owned management or privately owned management.

It is one of focal points in our province to open up paths for compenhensive utilization of coal to gain a better econmic benefit. Through our practices, these paths may be induced into two aspects:

1. To adopt the technique of fluidized-bed combustion.

The fluidized-bed combustion is featured by its strengthened combustion and intensified heat transfer at low temperature. The coal of low-heating value can be ignited rapidly and burns stably in fluidized-bed.

In Jiangxi Province, there are more than 6,000 sets of power station boilers and industry boilers, 98% of which are burned with coal (about 4×10^6 tons annually). Many of these boilers have been old and consume much coal. In order to save the energy resources, these boilers should be subjected to technical reformation.

Since 1976, we have successfully reformed a batch of boilers into fluidized-bed combustion type, and brought up many specilists and skilled people who can master the technology on ignition of coal and the method to prevent the immersion tube from rubbing in fluidized-bed and enhance the burning efficiency.

The boilers with reformed fluidized-bed, used in Chemical Fertilizer Factory of Chongren county, Pingxiang Municipal Winery, Nanchang Municipal Resin Factory, Nanchang Municipal Chemical Fibre Factory and etc. in Jiangxi Province have shown their superiority and won acclaim by their endusers

On the basis of the conclusion of technical reformation for industrial boilers, Jiangxi Boiler Works----a leading factory among boiler industry in our province, reseraches and develops two series of product, i.e.,fluidized-bed combustion boiler and reciprocated grate boiler.

From 1976 to 1985, this factory have produced 155 sets of 6--35 tons/hr. fluidized -bed combustion boiler with which the coal gangue, lignite, sub-bituminous coal can be used so that we have provided an excellent service for the industries of coal, textile, rubber, paper-making, drug-making, wine-making, chemical engineering and small type chemical fertilizer.

A fluidized-bed combustion boiler of 20 t/h, produced by Jiangxi Boiler Works, was put into operation in Jilin Provincial Chemical Fibre Factory in 1981 with lignite of 2,400 Kcal/Kg in heat value as fuel. This boiler can work for more than 5,800 hours in average per year and the immersion tubes have been operating normally up to now.

The Ministry of Coal in our country pays great attention to the application of fluidized-bed combustion for electric power. Under her organization and through the coordination of Jiangxi Provincial Economical Committee and Jiangxi Provincial Departmentof Coal, Jiangxi Boiler Works has successfully developed fluidized-bed combustion boiler up to 35 tons/hr., two of which were put into use in GaoKeng Power Plant under Pingxiang Coal Mine Bureau in April and October of 1982 respectively. The capacity of its matched generator set is 12,000Kw. By the end of 1984, the single generator had run up to 27,616 hours and generated $1.6x10^8$ KWH of electric energy. Its fuel is coal gangue with 1,560 Kcal/Kg in heat value. The boiler efficiency is 71.39%. In the year of 1984, this power plant made a profit of 1,300,000 RMB (Yuan). The third generating set is ready to put into installation in that plant. The Fengchen Coal Mine Bureau and The Anyuan Coal Mine Administration in our province will build up coal pit-out power station to adopt fluidized-bed combustion boiler with local coal gangue as fuel subsequently.

The operating condition of the two generating sets in Gaokeng Gangue Power Plant mentioned above indicates:

a. The benefit of electric generation is good. The plant made a profit of 6,400 RMB(Yuan) during the trial-running in 1982 only. In 1984, the two generators was running regularly so that the production cost was lowered and in turn the power plant profitted 1,280,000 RMB(Yuan). After the third generating set at the second engineering stage having been completed, the three generators will run simultaneously. Each generator can run for 5,500 hours per year so that the total yearly production of electric energy will reach an amount of $99x10^6$ KWH. Therefore, this power station will supply 8,452,000 KWH in electric energy to the public deducting their own consumption and wire loss.

b. The effectiveness to save energy resources is high. From the beginning of operation to the year 1984, Gaokeng Gangue Power Plant generated electricity up to $1.6x10^8$ KWH, burning 460,000 tons of fluidized-bed combustion coal with 1,560 Kcal/Kg in heat value, 70% of which were washed coal gangue amounting to about 320,000 tons whoseheat value may be converted into 88,400 tons of standard coal. Once after the operation of the three generating sets are realized, the electricity supply can be counted to 84,520,000 KWH, thus saving standard coal up to 51,000 tons for our country, which can be converted into 71,400 tons of raw coal. If we want set up a thermal power plant with the same capacity as that of Gaokeng power plant, we must supply it with 71,400 tons of raw coal from coal mine. However, it needs 10,700,000 RMB(Yuan) to found a pair of mine pits with 71,400 tons annual output of raw coal. From this it shows that building up pit-out power plant in mining area by making good use of coal gangue on the spot is the most effective path to utilize and save energy resources adequately and much high grade coal can be contributed to urban industrial construction.

The Gaokeng pit-out power plant has the following obvious social efficiency:

a. Since Gaokeng Coal Mine Administration is self-sufficient, the circuit loss from the large electric network to that mining area can be reduced. They gained an extra amount of 5,916,400 KWH of electric energy in 1984.

b. Because the coal is utilized on the mining spot, it saved 1,428 wagons and relieved the pressure on railway transportation for coal.

c. It may burn 260,000 tons of coal washery waste annually in Gaokeng power plant, whose heat value is equal to that of 58,000 tons of standard coal, and additionally, its cinder and ash are properly utilized. The result gives a better effect to environmental

protection.

Besides the fluidized-bed combustion boiler, Jiangxi Boiler Works has also developed the boiler with reciprocating-grate. From 1976 to the present, 267 sets of 2-10 t/h reciprocating-grate boiler have been produced. They supplied Shijiachang Wool Mill in Hebei Province in 1981 with a set of reciprocating-grate boiler type SZW6-13 with water cooling system. That boiler possesses a good adaption to different varieties of coal. Five varieties of coal may be burnt well within it. The efficiency is 71% when the boiler is operated with bituminous coal class I, producing 3363 Kcal/Kg in low heat value on as-fired basis. The efficiency is 757%when the boiler is burnt with bituminous coal class II, producing 4245 Kcal/Kg in low heat value on as-fired basis. The efficiency is 79.3% when the boiler is burnt with bituminous coal class III, producing 5130 Kcal/Kg in low heat value on as-fired basis. The efficiency is 73.2% when the boiler is burnt with dry-burning coal, producing 5960 Kcal/Kg in low heat value on as-fired basis. The efficiency is 74.2% when the furnace is burnt with lignite, producing 2835% Kcal/Kg in low heat value on as-fired basis.

2. Comprehensive utilization of producing building materials:

a. To produce internal-fired coal gangue brick.

Some coal washery waste, which cannot be used as fuels for boiler due to its low combustion value even below 800 Kcal/Kg, is pulverized by pulverizer, stirred with water, moulded into form and sintered in kiln to make internal-firing coal gangue brick whose quality is much higher than that of common clay brick. For example, $1x10^7$ pieces of brick need 30,000 tons of coal gangue, thus saving 1500 tons of standard coal. The first coal gangue brick factory in our province was set up in the early 1970's. It has made more than $130x10^6$ pieces of coal gangue brick out of 400,000 tons of coal washery waste during the recent ten years, thus saved 20,000 tons of standard coal. Until 1985,we have produced $90x10^6$ pieces of coal gangue brick annually by making use of over 300,000 tons of coal gangue, i.e. we have saved 15,000 tons of standard coal which may be used to produce building materials in our province.

b. To produce cement.

The scientific reseach institution and production unit under the departments of coal industry and building material industry in our province have undertaken a long-term work on production of cement by utilization of coal gangue, and opened up three paths:

(1). Coal gangue is used as raw material to produce cement and additive as well.

The Cement Plant under Yinggangling Coal Mine Administration and the Cement Plant under Leping Mining Bureau have both successfully made raw meal nodule out of coal washery waste at its own mining area, which was sintered into portland cement clinker in mechanical vertical kiln and common kiln. Then clinker was blended with proper fired spontaneous ignition coal washery waste into mixture which finally was pulverized into cement. Its grade may remain higher than No.325. Such practice proves that it is possible in technology to replace clay with coal washery waste. The result in energy saving is impressive when we use coal gangue as partial fuel to produce the building materials, and it is good to the quality of cement when use fired coal washery waste as active additive.

(2). To make good use of the cinder of fluidized-bed combustion .

The cold cinder and overflow cinder accounting for 55% of total exhausted coal cinder,with 1% low carbon content and good activity, are excellent additive for cement production. The blending percentage may be 15-20%.

Cold cinder and overflow cinder are also used as lightweight aggregate to produce building block and as filler for mining pit.

The dropping ash taking up 21% of total cinder with 5% carbon content approximately may be used as raw material for internal for internal firing brick and also used as mortar for general building as inside wall and joint.

The calorific value of flue dust is about 700 Kcal/Kg high and may be used as raw

material for internal firing brick or as fuel for production of brick and tile.

(3). To produce cement without clinker by utilization of fired coal washery waste or cinder in fluidized-bed combustion boiler.

Gaokeng Building Material Factory in Pingxiang Region has built up a production line to produce coal gangue cement without clinker, whose production capacity is 6,000 tons per year. This No.325 cement without clinker is made out of composition of fired spontaneous ignition coal washery waste water-quenched slag, gypsum lime.

The Scientific Research Institute of Building in Jiangxi Province took Brick and Tile Factory of Fengcheng County as a base to produce cement without clinker. Its major raw material is fired coal washery waste at Fengcheng Mine. Its percentage of components are: fired coal washery waste is 73.5%; quick lime is 20% and gypsum is 6.5%. Its compression strength has reached the standard specified for No.294 and No.308.

In turn we provide a small hollow building block of coal washery waste cement without clinker by using this coal gangue cement as building material, as well as river pebble and river sand as coarse and fine aggregate which are composed in proportion, mixed after adding water, formed under vibration and cured with steam. To produce this building block, we may achieved many advantages, such as powerful capacity to digest the gangue, low consumption in fuel, simplicity in production technology and convenience in execution, low cost, 98-129 Kg/cm^2 in strength etc.. This block can meet the requirement for a civil building of six storeys and is a new material for wall body. On the basis of production cement without clinker, Gaokeng Building Material Factory and Scientific Research Institute of Building in Jiangxi Province is searching for a best way to produce cement without clinker mainly with cinder out of fluidized-bed combustion boiler in Gaokeng Power Plant and search . In the meanwhile, they have developed medium and small type hollow block of concrete without clinker. The cement without clinker is used as cementing material, the coarse fluidized cinder is used as coarse aggregate instead of original pebble, and fine cinder is used as fine aggregate other than original river sand. To produce it, the cinder is digested more rapidly and the cost is reduced at a large extent. So this is an effective way to utilise comprehensively the cinder out of fluidized-bed combustion boiler in coal Gangue Power Plant.

(4) To utilize coal washery waste for producing other building materials.

The cinder out of fluidized-bed combustion boiler is also a raw material to manufacture lightweight aerated concrete.

The aerated concrete is made from taking cinder out of fluidized-bed combustion as major raw material, adding a certain quantity of lime as binding agent, using a small amount of aluminium powder as gas forming agent,and passing through raw mix proportioning, mixing, placing, pressing with steam and curing. The quality of aerated concrete made mainly of cinder out of fluidized furnace is better than that made of river sand, fly ash, and cement with iron ore slag additive. To produce this To produce this concrete, it may save 10-20% of cement and lower the cost by 20%.

A light weight aggregate made of fired spontaneous ignition coal washery waste is a light aggregate used for concrete. It is featured to be light in weight, excellent in performance of heat preservation, fire-proof and anti-vibration. It is about 30% lighter than that of common concrete.

Nowadays, we are engaged in research on making good use of coal with low-heating value. There are two points as follows:

a. Utilization of high sulphur coal.

It is mainly to achieve a better sulphur--burning technology in combustion process to increase the utilization of limestone. Fengcheng Coal Mine Bureau is executing the test work for this subject.

b. To strengthen the research on the technology in coal washing and selecting.

To supply the customers with coal in different grades according to their requirem is advantageous to save transportation fee.

We have endured a history of one hundred years to engage in coal mining in our Jiangxi Province. We have accumulated a certain experiences in exploration, design, pit-erection, wash and selection, utilization and environmental protection. In the recent years, we have created a certain results in the equipments for mining machinery.

We are ready to offer coorperation with our friendly countries.

PAST AND FUTURE ENERGY SHARE OF COAL IN THE ENERGY ECONOMICS OF INDONESIA

M.T. Zen
Deputy Minister of Research & Technology
Chairman of the National Agency for the Assessment
and Application of Technology
Republic of Indonesia

INTRODUCTION

Coal has become very important in the Indonesian development scheme, and has become a matter of heated discussions lately. The central issue is namely whether coal can replace oil in the Indonesian energy economics, considering the deposits are located in areas where energy is not needed as much and in view of the availability of othe resources.

The objective is this paper is twofold:

- To expose the current coal program of Indonesia, the aim of which is to replace as much as possible the role of oil;
- To discuss whether such a program, with assumptions made in 1982, can still hold with the lowering international oil prices.

Data and information used in writing this paper are derived from publications and unpublished reports from the Ministry of Mines and Energy of Indonesia, papers and documents presented at conferences organized by the Indonesian National Agency for the Assessment and Application of Technology (BPPT), unpublished reports of BPPT, World Bank Development Report 1984, Statistics of Indonesia, Indonesia's Mining Year Book, and Indonesia's National Energy Policy.

INDONESIA'S ECONOMIC DEVELOPMENT

The Country

Indonesia is an island republic which consists of + 13,676 islands. The total land mass is 1.9 sq. km. The EEZ included, the area under the jurisdiction of Indonesia is ± 7 million sq. km.

The Indonesian population numbers 160 million, of which more than 60% are concentrated in Java. Although the family planning program is intensive and quite successful, the population growth rate is still high. It was 2.3% in 1982; since then it has fallen to nearly 2%. With this growth rate it is expected that the population of Indonesia will swell to more than 200 million in the year 2000.

Since the first Development Plan was launched in 1968, the economic growth has increased steadily until 1982, with an average rate of more than 7% per year. Indonesia has been severely hit by the worldwide recession, and in 1984 its economic growth rate barely reached 4.2%. In 1985 it was between 4.5 and 5.0%, and for 1986 it is still expected to vary between 4.5 and 5.0%. The development budget for the Fourth Development Plan is around US $145 billion, of which 50% will have to come from the oil and gas sector.

The current problems for Indonesia are a slower economic growth rate, rapid population growth and labor force, and the

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problem of employment. The inflation for 1985 was 4.3% and the dept service ratio (1982) was 21.1% of GNP. The GNP/capita is US $600.

The Energy Scene and the National Energy Policy

Between 1960-1979 the growth rate of energy consumption in Indonesia was 7.4% p.a.; between 1970-1974 the growth rate was 9.94% p.a.; during the Second Development Plan (1974-1979) the growth rate was 13.8% p.a. It was projected that the energy consumption during the Third Development Plan would be 11.5%. By then the total commercial energy consumption would be 52,780 million TCE (Tons of Coal Equivalent) (See Table I.) That is the general picture of the energy consumption. If the consumption is scrutinized by sector, the following figures are obtained for the consumption of 1979-1980:

131.009 million BOE (81.86%) from oil
28.994 million BOE (18.12%) from non-oil

Of the non-oil sector, 15.31% or 24.495% BOE was derived from natural gas and 0.40% or 0.647 million BOE was derived from coal, and 2.41% or 3.852 BOE was derived from hydropower.

These figures show that the energy economics of Indonesia are very much dominated by oil.

The Energy Policy of Indonesia, officially issued in April 1982, has six general objectives. These are:

- To secure the domestic energy supply;
- To save oil as much as possible for export (foreign exchange earnings);
- To save oil and gas as feedstock for petrochemical industries and for transport fuel;
- To develop other sources of energy;
- To conserve the environment;
- To promote national resilience.

The immediate target(s) for the Third Development Plan was to decrease the use of oil by diversification: oil from 81.8% to 77.48% (1978/1979 - 1983/1984); to increase the role of the non-oil sector from 18.12% to 22.52%.

Due to the Energy Policy and its consistent implementation, other sources of energy have come into the picture in Indonesian energy economics. The role of natural gas increased from 15.31% to 16.47%; coal from 0.40% to 1.58%; hydropower from 2.41% to 4.41%. Lately geothermal energy has come into the picture (35MW), and very soon biomass energy (woodwaste; wood from energy plantations, and peat).

TABLE I

Increase of Various Sources of Energy in Mill Barrels Oil Equivalent (BOE).

Kind of Energy	End of 2nd Dev. plan 1978/79	End of 3rd Dev. plan 1983/84	Increase from 2nd to 3rd Dev.plan
. Natural gas (incl.LPP)	24,495 (15,31)	41,382 (16,47)	68,94%
. Coal	0,647 (0,40)	3,977 (1,58)	514,68%
. Hydro	3,852 (2,41)	11,067 (4,41)	187,30%
. Geothermal	- (0,00)	0,146 (0,06)	(Dev. Actual)
. Oil	131,009 (81,88)	194,615 (77,48)	48,55%
Total commercial Energi	160,003 (100%)	251,187 (100%)	56,99%

SOURCE : INDONESIAN ENERGY POLICY, 1982.

Since the Third Development Plan, Indonesia has speeded up its coal program for electric generation and as an export commodity.

The following assumptions have been adopted for the period 1980/1981 - 1990/1991:

- A GDP growth rate of 6-7% p.a.
- A population growth of 2.15-2.30% p.a.
- Income and Energy Demand Elasticity of 1.55.

For the period of 1990/1991 - 2000/2001, the figures were assumed as follows:

- A GDP growth rate of 5.5-6.5% p.a.
- A population growth rate of 1.8-2.0% p.a.
- Income and Energy Demand Elasticity of 1.3.

Based on those assumptions the following energy demand has been predicted:

415 million BOE in 1990/1991 (low projection)
482.25 million BOE in 1990/1991 (high projection)
782.85 million BOE in 2000/2001 (low projection)
1032.51 million BOE in 2000/2001 (high projection)

For 1984 the total commercial energy consumption was 295.5 million BOE and 60% of this (182.4 million BOE) came from oil and gas. The energy consumption growth rate during the Third Development Plan was 7.3% and during the Fourth Development Plan it was projected at 3.7%.

A market increase in the non-oil sector was recorded during 1984: coal, an increase or 28x; hydropower, an increase of 3x; geothermal energy, an increase of 6x; and natural gas, an increase of 1.5%.

By 1984 Indonesia emerged as the largest LNG producer in the world. Towards the end of the current Development Plan Indonesia hopes to be able to increase its oil production to 1.75 million bbl/day and the production of natural gas to 5.4 billion SCFD.

THE ROLE OF COAL IN THE ENERGY ECONOMICS OF INDONESIA

History

The history of coal mining in Indonesia dates back to 1849 when the first coal mine was officially opened in Pengaron (East Kalimantan) by the East Borneo Company. The first attempt to exploit the coal deposit of Sungai Durian in West Sumatra in 1880 failed completely. The second attempt was more successful when the Ombilin Mine was officially opened in 1892. In South Sumatra, the Bukit Asam Mine was in operation 1918. The production was modest but kept increasing until the Second World War. Since then the role of coal was overshadowed by the oil industry.

Though attempts were made to revive the coal industry after the war, real changes began to appear in 1973. From then on the Government of Indonesia (GOI) has strongly emphasized the use of coal.

Resources Base

Coal is found in many places all over Indonesia, but most of the occurrences are not of economic importance. Larger deposits are found in West Sumatra, South Sumatra, East and South Kalimantan. Smaller occurrences are in Java, Sulawesi and Irian Jaya. The resource base is quite big, though most of the Indonesian coal is young and classified as lignite. Estimates vary between 18-25 billion tons. The caloric value of the Indonesian coal ranges between 4000-7000 Kcal/kg, but for most the figure is close to 5000 Kcal/kg. But problems to bring coal into the mainstream of Indonesia's economy loom large.

First of all, because most of the significant and economic deposits are located outside Java, whereas the strong demand for electricity at present is in

Java. Therefore, the largest problem that confronts the coal program is not at the mine site, but is the problem of transportation, and also the problem of pollution that accompanies large scale coal burning for power generation. Seen as a whole, the problem lies in the system engineering management and in the economics in relation to the falling international oil price.

Current Program

The coal deposits at present being mined are those located in Sumatra and in Kalimantan. The mine in West Sumatra, Ombilin, is run by the State Coal Enterprise PN. Tambang Batubara, and the one in southern Sumatra by the Bukit Asam Coal Company, a corporate body instituted since 1981 under Presidential Decree No. 42 of the year 1980. In addition, there are private companies which are developing the eastern Kalimantan coal. They are, respectively, CV. Fadjar Bumi and CV. Enterprise (since 1980) and Kitadin Corporation PT. and Tanito Harum PT. (since 1983).

In order to augment Indonesia's coal production within the next decade the Indonesian government has offered the opportunity to develop Kalimantan coal to foreign investors. Thus, in 1981 three companies concluded a production-sharing ocntract with the government, respectively, Arutmin Indonesia PT. for the exploration of 1.26 million hectares (59.84% retained by the end of 1983); Utah Indonesia PT., 797.3 thousand hectares (59.47% retained); Agip Spa-Consol PT., 1.017 million hectares (19.17%).

The following year, 1982, three more companies followed suit: Kaltim Prima Coal PT., with an original working area of 790,900 hectares (holdings still unchanged by the end of 1982); Kedeco Jaya Agung PT., 254,804 hectares (59.93% retained); and Andaro Indonesia PT. 148.148 hectares (unchanged). In 1983 one company joined in the pursuit, namely Berau Coal PT. with an original working area of 487,217 hectares.

The Ombilin mine produced 325,662 metric tons of coal in 1983, up 7.6% from the production figure of the previous year of 302,572 metric tons. Domestic consumption was as follows: 1,714.115 metric tons by the West Sumatra State Railways; 146,316.049 metric tons by the Padang cement factory; 5,405.16 metric tons by a number of private firms; and 20,639.6 metric tons for company use. The coal was exported to the following countries: North Korea, 26,231.481 metric tons; Malaysia, 101,548.076 metric tons; Japan, 5,472.702 metric tons, and Viet Nam, 10,002.915 metric tons.

Bukit Asam mine produced 159,968 metric tons of coal (29,732 tons of antracitic coal and 130,236 metric tons of steam coal), down 10.34% from the figure of the previous year of 178,447 metric tons, 140,517 metric tons of which were shipped to Malaysia.

The following are the production figures for the year 1984 of the four private companies which are currently operating in eastern Kalimantan: CV. Fadjar Bumi, 64,188.980 metric tons; Kitadin Corp. PT, 38,152 metric tons; Tanito Harum PT, 10,600 metric tons. Of the total amount of coal of 162,609.780 metric tons produced by the four companies in 1983, 149,839.83 metric tons were shipped to Japan, South Korea, and the Philippines.

Utilization of Coal

One of the objectives of the Energy Policy is diversification of energy sources, and one of the targets of this program is to have oil fired power plants using coal. Cement and sugar plants, paper and pulp mills are also included within this program. Realization of this program is slow due to the reluctance of the users, and the reluctance is due to the uncertainty of supply related to the transportation problem and environmental constraints.

The National Economic Company of Indonesia or PLN has an extensive electric expansion program until the year 2000. Besides PLN, which is state owned, there are still companies or parties which are permitted by the Government to generate electricity. These are:

- The captive plant installations that generate electricity primarily for industrial purposes and own use.
- The small municipal and cooperative franchises which generate electricity for industry and rural electrification.

In Indonesia electric consumption for 1983/1984 was still very low. It was about 135 KWH, of which 63 KWH came from PLN and the balance came from captive power. It is expected that in the coming decades electric power demand will increase rapidly due to the increase of the general welfare and the industrialization program.

However, most of the power plants are oil fired. But from 1984/1985 onward the share of coal will be considerable (Table 2).

The largest coal power plant is the Suralaya Power Plant on the North Coast of West Java. A unit of 400 MW started operation in 1984/1985; another unit of 400 MW will be operational in 1985/1986; and another two units of 400 MW each will be operational in 1986/1987. Besides, two Bukit Asam power plants of 65 MW each are expected to be in operation in 1986/1987, whereas the two Ombilin plants of 50 MW each are expected to be in operation in 1987/1988.

A total of 1830 MW electricity will come from coal by the end of 1988.

Considering all the problems and constraints, these achievements are considerable.

DISCUSSIONS ON THE FUTURE OUTLOOK

Real attention to coal in Indonesia was given since the energy crisis in 1973, but real efforts to increase production and domestic utilization only started in 1980. Much attention has been given to coal due to its relatively hugh resource base and also due to the international price of oil. Until now most of Indonesia's foreign exchange earnings are derived from oil and lately also from gas. The philosophy behind it is namely to use oil as much as possible for foreign exchang earnings. But in 1981 the international oil price stood at US $34 to $35 per barrel. In 1985 it was at $27 and $28.

There are some speculations that oil prices might go down still further and stabilize around US $20 per barrel. Some economists speculate that the prices might go lower than US $20 per barrel. Either one of these scenarios will hold until 1990. Then it will or might go up again.

For Indonesia this does not only mean less foreign exchange earnings but the question arises whether Indonesia's current coal program can be continued.

Indonesia, which has been severely hit by the worldwide recession, already cut its development budget for 1986/1987 by 7% compared to the previous fiscal year.

However, looking at PLN's expansion program, full scale use of coal will not occur before 1987. Oil economists are optimistic that oil prices will begin to rise again by 1990.

Therefore the coal program of Indonesia has a change to survive unless there will be a dramatic collapse of OPEC's production sharing system and a subsequent lowering of oil prices until far below $20 per barrel.

However, if lowering of oil prices does occur, then cost structure in the production and transportation of coal will change also. In addition, lowering of oil prices will initiate other developments which will lead to the increased production of cement, fertilizers, electricity, steel, and others. This, of course, might lead to the increased use of existing facilities

TABLE II

GENERATAION EXPANSION PLAN IN 1984/85 - 1988/89

			MW	Year
Hydro Power Plant :				
Saguling	4 x 175	=	700	85/86
Cirata	4 x 175	=	500	87/88
Wadaslintang	2 x 8	=	16	87/88
Sengguruh	2 x 14,5	=	29	87/88
T e s	4 x 4	=	16	88/89
Tenggari	2 x 8,5	=	17	86/87
Bakaru	2 x 62	=	124	87/88
Pade Kembayung #1	1 x 10	=	10	88/89
Sentani	2 x 6,5	=	13	88/89
			1425	
Geothermal Power Plant :				
Kamojang # 2,3	2 x 55	=	110	87/88
D i e n g # 1	1 x 55	=	55	88/89
S a l a k # 1	1 x 55	=	55	88/89
			220	
Steam Oil Power Plant :				
Gresik # 3	1 x 200	=	200	87/88
Gresik # 4	1 x 200	=	200	87/88
Belawan # 1,2	2 x 65	=	130	84/85
Combine Cycle		=	100	86/87
			630	
Steam Coal Power Plant :				
Suralaya # 1	1 x 400	=	400	84/85
# 2	1 x 400	=	400	85/86
# 3-4	2 x 400	=	800	88/89
Bukit Asam # 1,2	2 x 65	=	130	86/87
Ombilin # 1,2	2 x 50	=	100	87/88
			1830	
Mini Hydro Power Plant :	(scattered)		50	
Diesel Power Plant :	(scattered)		1100	

Source: Sarjono 1984

and, over time, the development of new operations. The net effect of all these new developments will be an increase in total energy needs. This will also benefit the coal industry.

Taken as a whole, lowering of oil prices might not erode the coal program completely, but it does affect directly Indonesia's economic growth. In view of the rapid population growth, this might be a bigger problem.

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GREEK EXPERIENCE IN THE EXPLOITATION OF LIGNITES FOR ELECTRICITY PRODUCTION

Andrea Vakalis
Director, Energy Department
LDK and Associates

Deposits of Solid Fuels in Greece

Solid fuels in Greece consist mainly of lignite and peat. The confirmed deposits of lignite in Greece today amount to 5,350 million tons.

More than 90% of the lignite is concentrated in two areas, Western Macedonia and Peloponnese, where large thermoelectric plants have been built (Figure 1). Despite the relatively heavy exploitation, 35 million tons are mined per annum at present. The confirmed lignite deposits of the country continue to rise at a brisk rate, as geological research uncovers new deposits (Figure 2). Large quantities of peat, approximately 4,500 x $10^6 m^3$, have also been discovered in Greece and examined, without being exploited at present.

Exploitation of Lignite in the Production of Electricity

During the first half of the present century, the quantities of lignite mined were consumed almost entirely in household economy and minor industry.

Mining was restricted to areas adjacent to large towns and amounted to 100,000 tons per annum. In 1950, though, the situation started to change. At that time the Public Power Corporation (PPC) was founded, and undertook the task of producing electricity on a national scale, using local energy sources where possible, i.e., water and lignite.

According to this plan, PPC started developing the underground lignite mine in Aliveri, in 1951, together with a thermoelectric power station with an initial power output of 80MW (today 380MW). Electricity production commenced in 1953.

A few years later the exploitation of the surface deposits of Ptolemais started and 420,000 tons were mined in 1959. The lignite powered the Ptolemais power station built by PPC. The initial output of the station was 70MW while the present output reaches 660MW. The power stations of Kardia with an output of 1200MW and of Agios Dimitrios with an output of 1200MW also burn lignite from Ptolemais. More recently, in 1969, the lignite mine in Megalopolis was opened to feed the adjacent power station. Initial output of this station was 250MW, the present output 550MW, while a station of 300MW capacity is under construction. Lignite production by PPC started with 180,000 tons in 1953 and reached 35.1 million tons in 1985 (Figure 3). These production figures surpassed even the most optimistic projection of 1950.

The Aliveri mine, which was underground until 1980, produces xylitic type lignite with a relatively high heat yield of 3000 Kcal/kg (12500 kj/kg). A surface mining front was opened at this mine in 1975, but will soon cease operation as it is nearing exhaustion.

At the surface mining field of Ptolemais the continuous method is used mainly, with excavator wheels and conveyor belts, dumpers, loaders and auxiliary equipment. The lignite from Ptolemais has a lower calorific value of L.H.V. 1300 Kcal/kg (5500 kj/kg). The ratio of overburden to lignite ranges from 3.5 to 10.

The same mining method at Ptolemais is used also at the mining field of Megalopolis. The Megalopolis lignite has an even lower calorific value than that of

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Ptolemais, i.e., an L.H.V. of just 900 Kcal/kg (3800 kj/kg).

The use of lignite for electricity production has accelerated after 1960. The thermoelectrical power stations presently operating in Greece are:

Lignite		Oil	
Aliveri	: 190 MW	Aliveri	: 190 MW
Ptolemais	: 660 MW	Lavrio	: 450 MW
Kardia	: 1200 MW	Keratsini	: 350 MW
Agios Dimitrios	: 1200 MW		
Megalopolis	: 550 MW		
T O T A L	3800 MW		990 MW

Three plants of 300 MW each are now under construction and the construction of another three of the same output has been planned.

The development of electricity production from lignite in relation to the total electricity production, as shown in Table I, is making lignite the main fuel for electricity production and results in the reduction of dependence on other countries for energy.

Properties of Greek Lignite

The lignites that have been, are being and are expected to be used for electricity production may be graded in three main catetories according to place of origin.

Lignites of the Ptolemais Area

The average quality lignite of the Ptolemais area, for which the boilers of the area's power stations have been designed, has the following properties:

L.H.V. = 1320 Kcal/kg
H.H.V. = 1700 Kcal/kg
Moisture content = W = 58%
Ash content = A = 12%

The elementary analysis of the lignite gives the following:

Element	Average %	Range
Moisture	57%	56 - 58%
Ash	13%	12 - 14%
C	19%	18 - 19.5%
H_2	1.45%	1.4 - 1.55%
S	0.45%	0.4 - 0.5%
N_2	0.56%	0.4 - 0.6%
O_2	8.54%	6.5 - 10.0%

Other physical and chemical properties of interest of Ptolemais lignites are:

- Volatile substances in, as mined, fuel 18% with a range of 17% to 19% and 40% in dried fuel with a range of 37.5% to 44.5%.
- Fixed carbon in as mined fuel: 9.5% with a range of 7% to 13%.
- Fixed carbon in dried fuel: 21% with a range of 16% to 24%.

TABLE I

ELECTRICITY PRODUCTION FROM LIGNITE RELATIVE TO TOTAL PRODUCTION

Year	Total Production GWH	Production from Lignite GWH	%
1970	8,670	3,224	37.02
1975	14,060	6,574	46.80
1980	20,072	9,216	45.90
1985	24,670	16,266	65.90

- Grindability index: 50 to 55 Hardgrove.

- Relevant temperatures at ash in lignite:

  Softening 1250°C
  Deformation 1270°C
  Flowing 1300°C

- The chemical composition of ash in lignite is given in the attached Table II.

Lignites of the Megalopolis Area

The average quality lignite of the Megalopolis area, for which the boilers of the area's power stations have been designed, has the following properties:

L.H.V. = 950 Kcal/kg
H.H.V. = 1400 Kcal/kg
Moisture content = M = 62%
Ash content = A = 13.8%

The elementary analysis of lignite is as follows:

Element	Average %
Moisture	62%
Ash	13.8%
C	15.3%
H_2	1.3%
S	0.8%
N_2	0.4%
O_2	6.8%

Other physical and chemical properties of interest of the Megalopolis lignites are:

- Volatile substances in as mined fuel 19%, in dry fuel 50%.
- Permanent carbon in as mined fuel: 5,4%.
- Permanent carbon in dry fuel: 14%.
- Grindability index: 53 Hardgrove.

TABLE II

S.E.S. FROM NORTH GREECE - ELEMENTARY ANALYSIS OF FLY-ASH

	PTOLEMAIDA S.E.S.		KARDIA S.E.S.	
	REPRESENTATIVE VALUES %	EXTREME VALUES %	REPRESENTATIVE VALUES %	EXTREME VALUES %
SiO_2	29 - 32	26.86 - 35.2	28 - 32	26 - 35
Al_2O_3	12 - 14	10.31 - 15	11 - 12	9.5 - 14
Fe_2O_3	4.9 - 5.3	4.3 - 7.45	5 - 5.5	4.5 - 6.5
CaO	34 - 37	30 - 39.5	37 - 42	34 - 45
MgO	3.4 - 3.6	2.67 - 5.5	2.5 - 3	2 - 3.5
SO_3	6 - 7	5.0 - 7.1	6.5 - 7	5.5 - 9
K_2O	-	-	0.5 - 0.7	0.3 - 0.8
Na_2O	-	-	0.45 - 0.6	0.3 - 0.8
$K_2O + Na_2O$	0.75 - 0.85	0.5 - 1.4	-	-
TiO_2	0.3 - 0.33	0.24 - 0.48	0.25 - 0.35	0.2 - 0.5
IGNIT.LOSS	4.20 - 6	3.20 - 8.40	4.5 - 5	3 - 6
CARBON ELEM.	-	-	0.6 - 0.8	0.4 - 1.2

- Relevant temperatures of ash in lignite:

Softening 1200°C
Deformation 1250°C
Flowing 1280°C

- The chemical composition of ash in lignite is given in the attached Table III.

Lignites of the Aliveri Area

The average lignite quality of the Aliveri area, for which the boilers of the area's power stations have been designed, has the following properties:

L.H.V. = 1650 Kcal/kg
H.H.V. = 1970 Kcal/kg
Ash content = A = 17.8%

The elementary analysis of the lignite is as follows:

Element	Average %
Moisture	32%
Ash	17.4%
C	30%
H_2	2.5%
S	0.8%
N_2	14.5%
O_2	2.5%
CO_2	

Other physical and chemical properties of interest of Aliveri lignites are:

- Volatile substances in as mined fuel 31.8% and in dry fuel 46.4%.
- Permanent carbon in as mined fuel: 16.1%.
- Permanent carbon in dry fuel: 23.7%.
- Grindability index: 36.6 to 51.8 Hardgrove.
- Relevant temperatures of ash in lignite:

Softening 1120°C
Deformation 1190°C
Flowing 1360°C

- The chemical composition of ash in lignite is given in the attached Table III.

The fouling and slagging properties of the lignite, which are not great, are described in detail in the paragraph "Exploitation Problems."

There are divergencies in the above figures; for example, the graph in Figure 4 gives the typical spread of the L.C.V. of the lignite, consumed by the Kardia power station, in a two year period.

Development of Lignite Exploitation Technology

The quality of the lignite in each of the three areas in which electricity production by burning lignite was developed led to differenting exploitation technologies.

Initially in Aliveri (plants of 40 MW) combustion of the lignite took place on moving grates, while in the larger plant of 150MW the method of burning pulverized lignite was applied.

Also, in all boilers installed in lignite areas, pulverized lignite is consumed which is ground in impact mills, from where it is fed directly to the burners without intermediate storage. The mills used in all three areas, Ptolemais, Megalopolis and Aliveri are modifications of the fan type mill, Figure 5.

The mill inlet is connected with the area in the boiler directly after the burner, from which it draws hot combustion gases (700° to 900°C). The lignite is mixed in this gas flow and enters the mill. In the mill the lignite is powdered and dried and as a result we have at the mill exit a mixture of dry lignite powder, combustion gases and vapor from the drying process. In the simpler type of installation, as in Aliveri, where the lignite has a high heating value, the mixture from the mill's exit is fed directly to the combustion chamber. But in the case of Ptolemais (1300 Kcal/kg) and Megalopolis (900 Kcal/kg) if the mixture enters the chamber as it is the temperature will drop and combustion will cease. For this reason, a separation device is installed at the exit of each mill (Figure 6) for the larger part of the cooled gases and the vapor, which is called weak mixture, from the flow that

contains the larger percentage of the dry lignite and is called strong mixture.

The strong mixture is fed to the combustion chamber while the weak mixture, in the Ptolemais case (lignite with an L.H.V. up to 1400 Kcal/kg), is drawn directly over the combustion chamber (Figure 7). At Megalopolis (lignite with an L.H.V. of 900 Kcal/kg), the weak mixture, after passing through an electrostatic filter which traps the lignite powder, is exhausted into the atmosphere. Figures 8 and 9 show an élevation of a 300 MW boiler of the Ptolemais area and of a boiler of the same power for Megalopolis lignite.

The efficiency of the boilers ranges from 82% to 86% with the lower values for Megalopolis and the higher values for Ptolemais.

Exploitation Problems

The problems arising from lignite exploitation, while they are similar for power station of the same area, vary from area to area. The main problems which arise from the fuel and not other parameters are:

Problems of the Ptolemais Area Power Stations

Since the beginning of the operation of the Ptolemais power stations, problems arose concerning the quantity and quality of lignite for the units, as well as pollution of the boilers by the ash in the lignite, while there are no erosion problems:

- Development of the lignite mines in size and capacity did not keep step with the demand by newly constructed stations. As a result, it took usually four years for the mines to catch up with the incrementations of the lignite demand.

- The quality of the lignite often does not fulfill the specification, as shown in Figure 4. Because of this qualitative divergence from specified values, the boilers are often unable to produce enough steam and as a result the corresponding power stations are forced to operate at lower than nominal output, for as long as low quality lignite is mined. It has been estimated that poor quality lignite lowers the yearly total output by approximately 5%.

- Fouling problems arose in tower type boilers of 300MW, where fly-ash collects on the horizontal superheat and reheat tubes. In double flow boilers, where only the superheater and the low temperature reheater have horizontal tube, no fouling problem arises.

- Slagging occurs, to a limited extent, in all boilers of the area. This slag appears on the steam producing tubes of the furnace and the radiation superheater. The extent of hard slag is not such as to create problems in the exploitation of the lignite.

- The problem of quantitative and qualitative deficiencies was solved by mixed burning of lignite with oil (1965-1969) or by mixed burning of lignite with coal (1983 to date). During the phase of mixed burning of lignite with oil, when approximately 30% of the energy entering the boilers came from oil, severe slagging problems occurred. With mixed burning of lignite and coal, where 20% of the energy comes from coal, there appear to be no serious problems for the boilers.

- The problem of fouling on the horizontal tubes of the superheaters and reheaters of tower boilers (300MW) has been successfully tackled by using steam operated soot blowers.

Problems of the Megalopolis Area Power Stations

The main problems occurring in the Megalopolis power stations are due to corrosion and erosion. The composition of the ash in Megalopolis lignite, with a high percentage of SiO_2 causes serious erosion problems in the lower slanting part of the

boilers and in areas where effluent gases change flow direction. The high sulphur content of the lignite also causes serious corrosion problems in the cool areas of the boilers, i.e., the exit of the air heaters and the weak mixture ducts and corresponding filters from each mill to the atmosphere. There also exists an extensive network of ducts for cool exhaust gases from the boilers to the mill electrostatic filter combinations, which network neutralizes the environment in the filter, when the corresponding mill is inoperative. These problems have been tackled, to date, by intensifying maintenance procedures and accepting a lower availability of the power station of 5,000 hours yearly, while at Ptolemais availability stands at 6,500 hours yearly. A fact is that no slagging an fouling problems occur at Megalopolis.

Problems of the Aliveri Area Power Stations

At Aliveri the sole 150MW boiler was designed as a multi-fuel boiler. The burning of oil, lignite or any mixture of the two was foreseen. During operation with two fuels, ash melting creates severe slagging problems. As a result operation with simultaneous burning of the two fuels is impossible.

Mining Problems

The method of strip mining with bucket-wheel, conveyor belts, stakers and reclaimers has proved completely satisfactory for all areas in Greece except the south field of Ptolemais, where layers of very hard rock do not allow the operation of bucket wheels. At this field the rock is loosened by use of explosives before the bucket wheel commences digging.

Residues - Environment

The main residue from lignite burning is the ash that takes two forms: Fly-ash, which is very fine and is collected by electrostatic filters before the stack, and the bottom ash which is collected in a water filled basin at the lower part of the boiler. This second type of ash is large grained and includes a high percentage of combustible material. The larger part of the ash today and the total in the past was transported and used to fill gaps left by lignite mining.

The chemical composition of fly-ash, especially in the Ptolemais area (high content of active calcium) results in properties the same as those of cement.

Today, large quantities of ash are bought by cement factories and are mixed with clinker for cement production. Tests have been made for the exploitation of the bottom ash, because of high percentage of combustible material, for the recycling of the ash to the boiler. Although test results were satisfactory, this method has not been applied, as the corresponding installations have not been constructed.

The residues of lignite combustion that are exhausted from the stack are fly-ash, CO_2, SO_x and NO_x.

Initially the retention degree of the electrostatic filters in the first Ptolemais plants (70 and 125MW) was 95%, which means 50 tons of ash emissions per day for these plants. This degree was quickly judged unsatisfactory and newer stations were supplied with filters, with a retention value of 98,5% and 99%. Filters in old plants are now being replaced with new high efficiency filters.

The emission of carbon dioxide and nitrogen oxides from lignite burning power stations does not differ greatly from that emitted by stations burning other fuels. SO_2 emissions depend on sulphur content and the chemical composition of the lignite ash. For this reason, as the ash of Ptolemais lignite contains a high percentage of CaO, a large part of the sulphur oxides (over 75%) is retained by the ash and is not emitted into the atmosphere. On the contrary at Megalopolis, the ash consists mainly of silica and sulphur oxide reten-

tion is limited so that SO_2 percentage in exhaust gases is relatively high.

Surface mining of lignite degrades the environment both during the mining phase and after exhaustion of deposits. At Ptolemais, for example, approximately 150,000,000 sq.m. are to be used up by the mines. This area, which initially was a balanced landscape with trees, farming roads, villages and small town, is in danger of becoming a deserted lunar landscape after a few decades. For this reason projects for the restoration of the environment are in operation in parallel with the mining, both in Ptolemais and Megalopolis, with planting of trees, creation of lakes and ponds and experimental cultivation.

Non-electric Uses of Lignite

A relatively small percentage of the lignite mined in the Ptolemais area is used for other purposes, such as:

- The nitride fertilizer industry, which consumer approximately 1,200,000 tons of lignite per annum. Here the lignite, after being gasified, is used for the production of ammonia. Today the extension and renovation of the fertilizer industry is in the planning phase. This will multiply the output of nitride fertilizer and the corresponding lignite consumption.
- Approximately 800,000 tons of lignite per year are dried resulting in 400,000 tons of dry lignite (moisture content around 20%). 200,000 tons of dry lignite are used by the metal processing industry as a reduction medium and the rest is pressed into bricks for sale for household use.

Research and Demonstration Development Programs

The need to improve exploitation methods and to solve problems that have plagued electricity production from lignite for decades has led to various programs. The solution of some of the problems is being attempted by research projects financed by PCC, the EEC and other institutions. The most important research and demonstration projects now running are:

Lignite Gasification - Attempts are being made for the theoretical and experimental development of new technology for the gasification of the poor quality Greek lignites which have a high moisture content, without pre-drying and with minimum processing before entering the gasification reactor. The allothermal gasification process has been selected. The gasification of lignite aims at electricity production with a higher degree of efficiency and the minimum environmental pollution.

Pre-drying of Lignite at Power Stations by Co-generation Method - Greek lignites contain around 60% moisture before combustion. This mosture gasifies and absorbs approximately 30% of the chemical energy of the fuel. If the lignite is fed dry to the boilers, and not in its natural state (with a heat yield not of 900-1300 Kcal/kg but 3000 to 3500 Kcal/kg), boiler dimensions will be drastically reduced as will be construction costs and operating problems. At the same time almost 100% of the H.H.V. of the lignite can be exploited, because drying takes place outside the boiler with low pressure steam from the station's steam turbine. This project will be developed at a small 36MW station at Ptolemais.

The layers above and intercalated with the lignite in the mines often contain a high percentage of combustible materials, which are not being exploited because they are of much poorer quality than lignite. The exploitation of these layers is still another research project, as is the exploitation of bottom ash, as already stated, and the scientific design, giving consideration to aerodynamics, of a new type of lignite burner.

TABLE III

S.E.S. FROM SOUTH GREECE - ELEMENTARY ANALYSIS OF FLY-ASH

	ALIVERI S.E.S.		MEGALOPOLI S.E.S.	
	MEAN VALUES	EXTREME VALUES	MEAN VALUES	EXTREME VALUES
SiO_2	38,02	32,5 - 40,42	49,07	47,51 - 49,90
Al_2O_3	17,25	14,75 - 19.33	21,86	18,07 - 25,58
CaO	22,83	19,72 - 25,65	16,68	14,36 - 18,59
MgO	3,29	1,74 - 3,69	3,06	2,85 - 3,22
SO_3	2,20	1,32 - 3,42	2,44	2,18 - 2,65
$K_2O + Na_2O$	0,85	0,54 - 1,15	0,97	0,18 - 0,93
TiO_2	-	0,82	0,59	0,49 0,70
IGNIT. LOSS	2,7	2,5 - 4,75	0,75	0,5 - 1

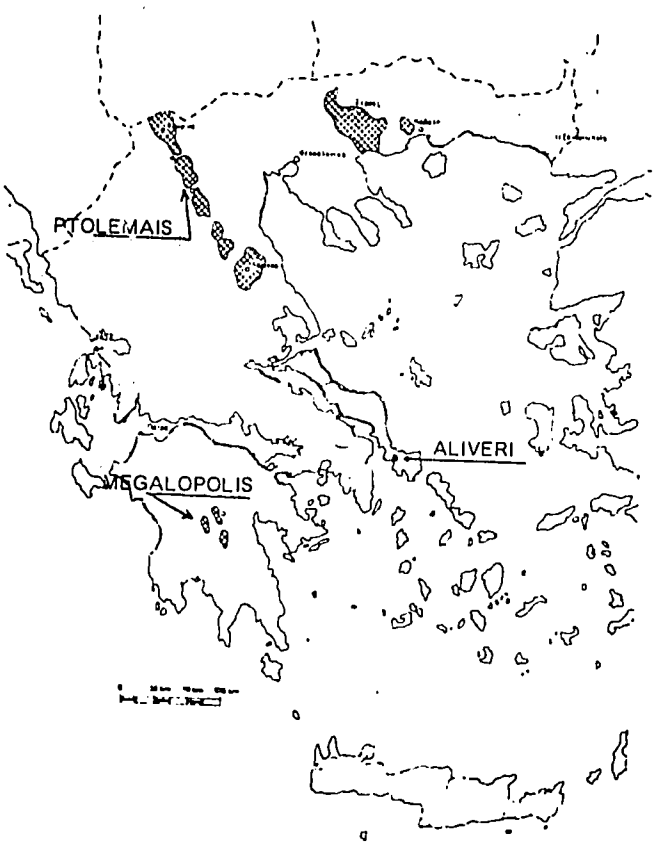


FIGURE 1

MAIN GREEK LIGNITE FIELDS USED
FOR ELECTRICITY PRODUCTION

FIGURE 2

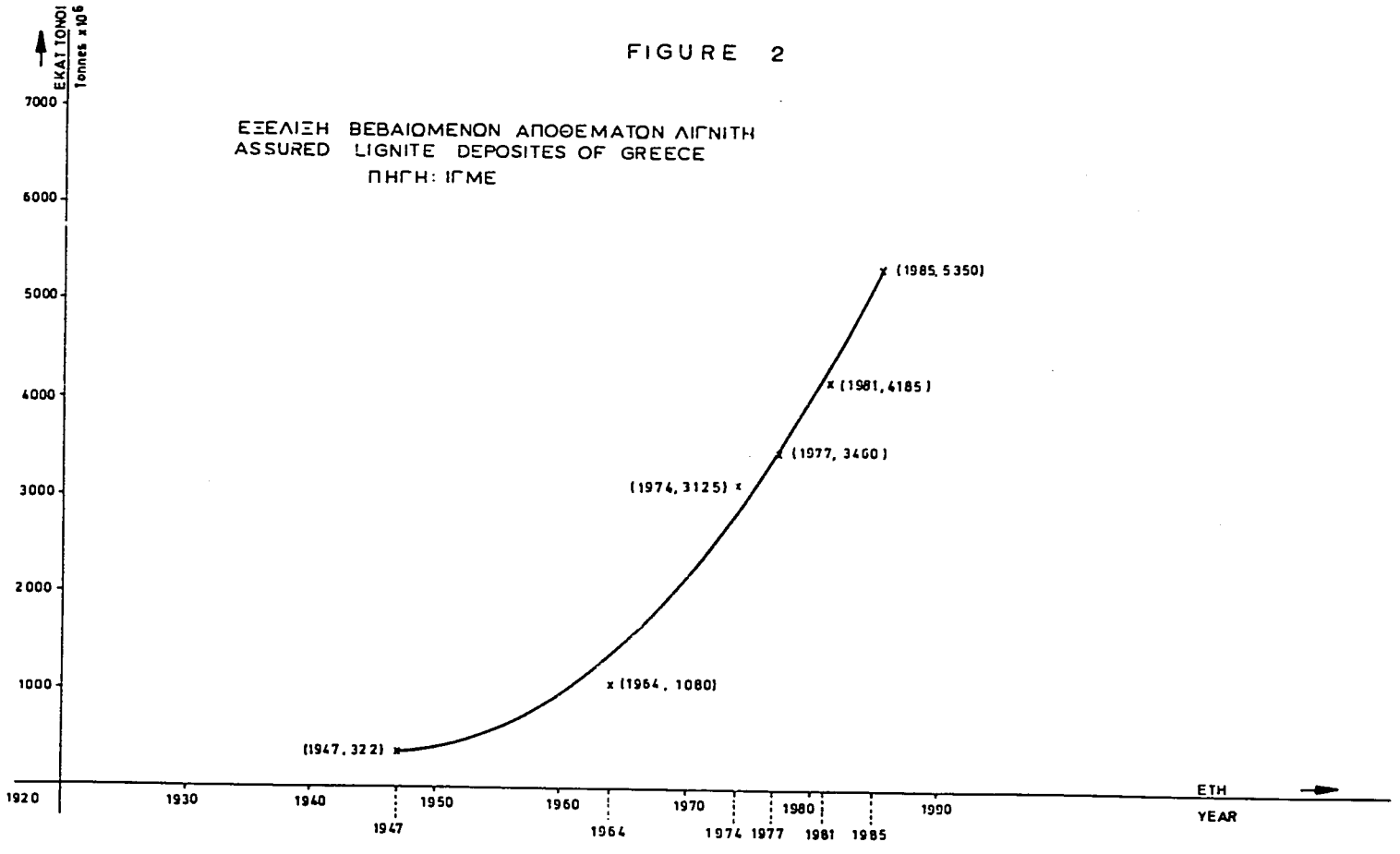

ΕΞΕΛΙΞΗ ΒΕΒΑΙΟΜΕΝΩΝ ΑΠΟΘΕΜΑΤΩΝ ΛΙΓΝΙΤΗ
ASSURED LIGNITE DEPOSITES OF GREECE
ΠΗΓΗ: ΙΓΜΕ
ΕΚΑΤ ΤΟΝΟΙ
Tonnes x10^6
7000
6000
5000
4000
3000
2000
1000
(1985, 5350)
(1981, 4185)
(1977, 3460)
(1974, 3125)
(1964, 1080)
(1947, 322)
1920
1930
1940
1950
1960
1970
1980
1990
1947
1964
1974
1977
1981
1985
ETH
YEAR

FIGURE 3

ΕΞΕΛΙΞΗ ΠΑΡΑΓΟΓΗΣ ΛΙΓΝΙΤΗ - LIGNITE ANNUAL PRODACTION IN GREECE

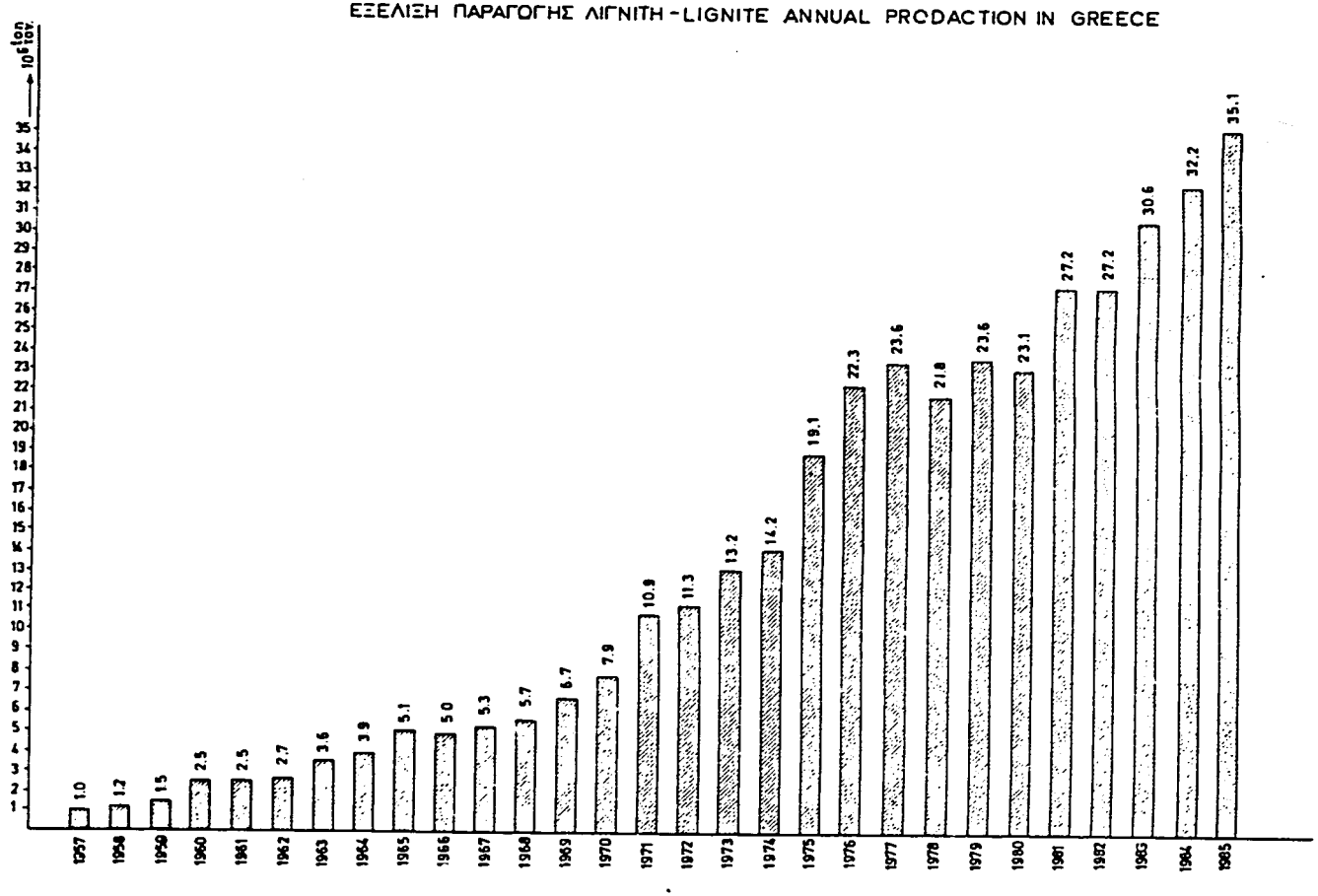
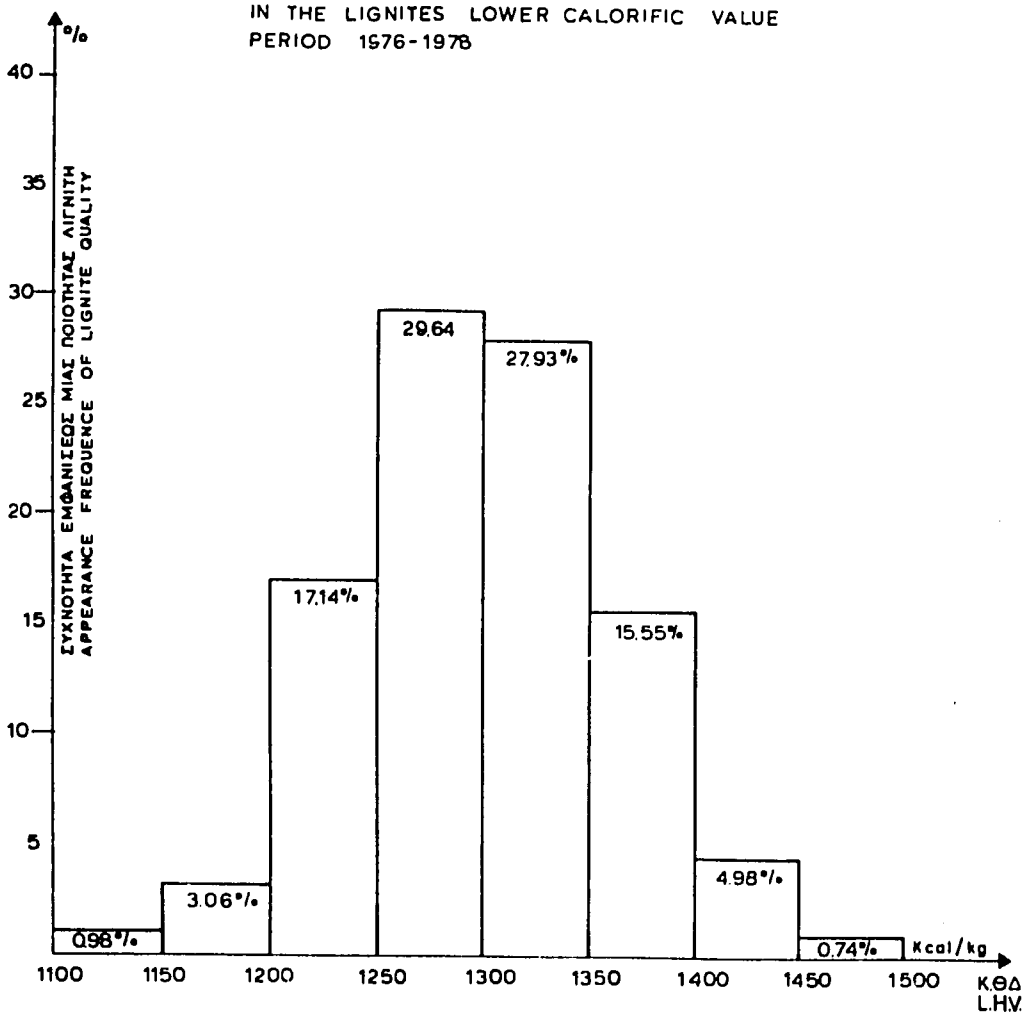


FIGURE 4

ΣΤΑΤΙΣΤΙΚΗ ΚΑΤΑΝΟΜΗ ΤΙΜΗΣ ΚΑΤΩΤΕΡΗΣ ΘΕΡΜΟΓΟΝΟΥ ΔΥΝΑΜΕΩΣ ΜΕΣΟΥ ΗΜΕΡΗΣΙΟΥ ΔΕΙΓΜΑΤΟΣ ΛΙΓΝΙΤΗ ΠΕΡΙΟΔΟΥ 1976-1978

STATISTICAL DISTRIBUTION OF DAILY FLUCTUATION IN THE LIGNITES LOWER CALORIFIC VALUE PERIOD 1976-1978



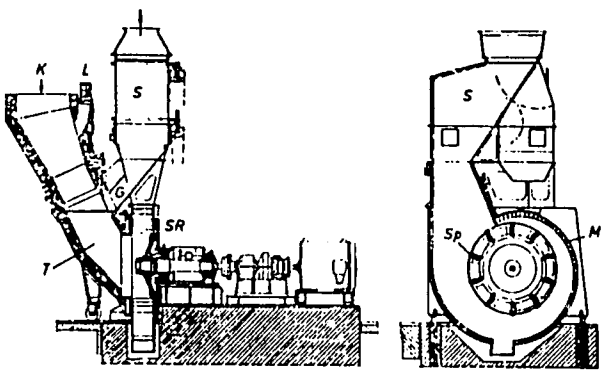


FIGURE 5

LIGNITE MILL

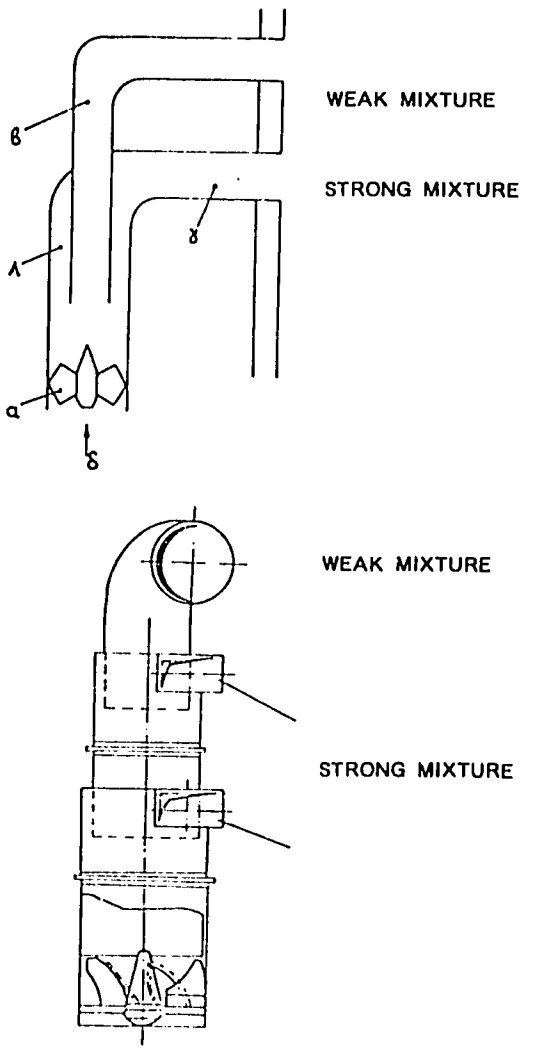


FIGURE 6

WEAK AND STRONG MIXTURE SEPARATOR DEVICE

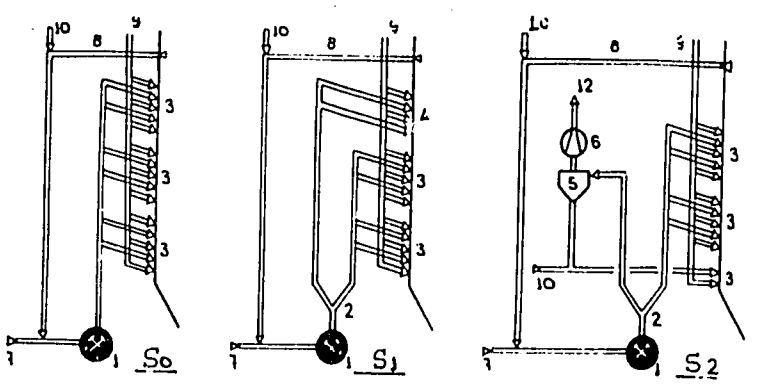


FIGURE 7

SYSTEMS APPLIED FOR THE COMBUSTION OF PULVERIZED LOW GRADE LIGNITE

S_0 : without mixture separator

S_1 : with mixture separator

S_2 : with mixture separator and lignite electrofilter

1. Mill
2. Mixture separator
3. Burner
4. Weak mixture burner
5. Lignite electrofilter
6. Fan
7. Lignite feeder
8. Hot gas suction
9. Secondary air
10. Primary air
12. Stack

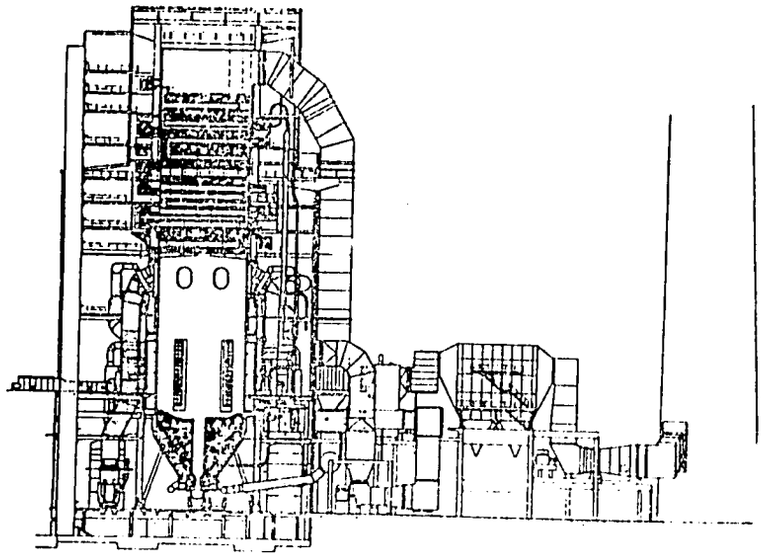


FIGURE 8

300 MW STEAM GENERATOR AT PTOLEMAIS SITE

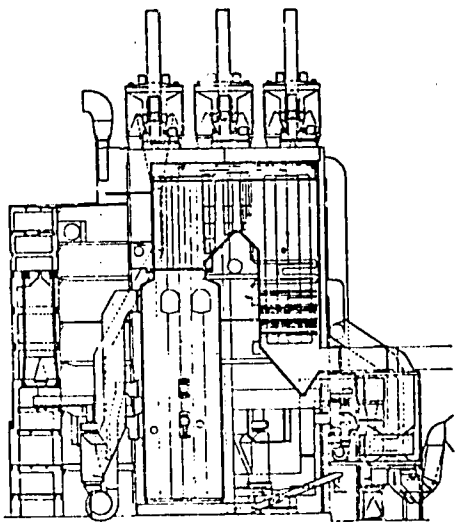


FIGURE 9

300 MW LIGNITE BOILER FROM MEGALOPOLIS SITE

THE DEVELOPMENT OF THE COAL INDUSTRY - PHILIPPINE EXPERIENCE

P.P. Gallego Jr.
Philippine Chamber of Coal Mines, Inc.
16th Floor, Strata Bldg., Emerald Avenue
Pasig, Metro Manila, Philippines

Geology and Coal Occurrence

The Philippine archipelago is the end-result of complicated tectonism with several subduction zones and associated elements having formed through the interaction of several plates. Forming the principal structure is the Philippine Fault Zone, transgressing the archipelago in a north-northwest direction. The archipelago is divided into separate pre-tertiary "basement" depositional blocks.

In contrast to extensive, continental-type, paralic deposits in many parts of the world, the coal seams in the Philippines have been deposited during the Tertiary in an active island-arc environment, within numerous discrete and relatively smaller basins. The coal basins in the archipelago could be grouped into two major classifications. The first group comprise of seams deposited in relatively stable environment which allowed for accumulation of thick seams and with simple structures. The Semirara deposit belongs to this group and the seams have been measured to range in thickness from 15-25 meters with dips from 15°-30°. The second group, which is more prevalent in the country are those seams deposited in highly mobile basins and subjected to highly complicated post-depositional structural changes, with dips commonly at 45°-60° but with overturning of the beds and splitting of the seams also frequent. Thicknesses of the coal seams belonging to this group commonly measure from few centimeters to about three (3) meters.

The oldest coal deposit found in the island of Cebu is calculated to be forty (40) million years old and the youngest, located in Mindoro, is about seven (7) million years old. Most of the deposits in Mindanao Island are approximated to have been formed twenty (20) million years ago. Large portion of the mineable coal in the Philippines are high moisture sub-bituminous coals. Bituminous coals are known to occur in the country ranging from medium to high volatile types. Anthracitic coals are also present but are associated with igneous intrusions. Extensive lignite deposits have been proven in the northern part of the country.

To date, the country's coal reserve is placed at 1.55 billion MT and about thirty (30) percent of which is found in a tiny island of Semirara. The total measured reserve is 350 million MT and 280 million MT is considered to be mineable.

Mining History

The first recorded discovery of coal in the Philippines was in Cebu Island in 1827. The first production was taken from an open-pit operation in Batan Island in 1842. Intermittent productions of nominal volumes from Cebu, Mindoro and Negros islands were recorded up to the end of the 19th century and these came mostly from shallow openings and very crude mining operations. It was only in the early 1900's when the U.S. Army carried out some formalized underground "room and pillar" mining in Batan Island that an annual output of more than 20,000 MT was recorded. Following the period of inactivity during the war years in the Philippines from 1911 to 1916 another firm mined in Batan and in 1921 established the highest production in the country coming from a single mine (500 MT per day) surpassed only when the bucket-wheel operation in Semirara Island commenced in 1982. From 1921 to 1940 the average yearly production was under 100,000 MT. Insignificant production was recorded during the war years from 1941 to 1945

Between the two World Wars coal mining in the country had a steady increase and was used extensively in railroad locomotives, cement plants, electricity generating plants, small manufacturing businesses and even for coal gas production in Manila. During the 1980's imported oil was considered very cheap and easy to handle

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and there was a swing towards its usage, at the expense of coal. Yearly production fell to around 40,000 MT by 1968.

With the advent of oil crisis starting in 1973, the government mandated the accelerated development of the coal indstry not only because the economics of using coal has again become attractive but also the government wanted to insulate itself as much as possible from external factors related to oil importation. For the first time in the entire coal production history, the country reached 1.0 million annual production in 1983. The price paid for coal has risen many hundreds of percent to more realistic level at present.

The first highly merchanized open-pit coal mining operation in the country started in 1982 when the four bucket-wheel excavators began operating in Semirara Island. Two captive coal-fired power plants, each with 7.5 MW capacity were installed in the island to supply the power requirement of the mining operation. The mine was designed based on a continuous mining system developed in Germany. The installation has about fourteen (14) kms. of conveyor system and was designed to mine coal at 1.0 million MT per annum. Presently the mine is operating at half its capacity due to design discrepancy of the power plant which contracted to use the mine output. Semirara Coal Corporation, the operator of the mine in the island started as a private firm during its exploration stages in 1977 but was eventually taken over by the government when it succumbed to financial difficulties in 1980.

Designed initially to be a catalyst for the acceleration of coal development in the country, the government-owned Philippine National Oil Company (PNOC) was mandated to enter into coal mining and in 1976 started with a supposedly model underground mining operation in Cebu Island. To date, it has expanded into five underground mines which aggregately account for about twenty (20) percent of the total capacity of the country. Its expansion was funded mostly with loans from the Asian Development Bank (ADB).

More than twenty-five (25) percent of the coal output of the country at present come from small underground mines in Cebu Island with production capacities ranging from 50 to 200 MT per day. These underground mines are operated by private firms or by individuals utilizing locally fabricated equipment and reconditioned machines. The island of Cebu has one of the longest and continuous history for coal production and many of the mines have been handed down through several family generations. The past mining activities were characterized by coal extraction from near surface seams at depths from 10-15 meters and applying very crude mining methods. Many operations were merely backyard undertaking by individuals and some members of the family. At present, most of the near surface seams have been mined out and because of its p ucity, the mine operators in Cebu find it necessary to convert to more formalized mining system to continue mining the coal safely and economically. This development however is very slowly taking place as financial institutions in the Philippines still consider coal mining as high risk and therefore deal with loan application for this purpose on a highly conservative level.

Coal mining in the country could be classified into two extremes. The operations in Semirara and PNOC are considered to be highly sophisticated, with the best of Austrian and German technology incorporated in the design of the continuous open pit mining system in Semirara and the various concepts of Japanese, Australian and British consultants employed by ADB, adopted in the design of the long-wall underground operations of PNOC mines. On the other hand, most of the privately owned mines, especially those in Cebu rely only on their retained earnings to fund their operations and still employ very crude mining methods.

Many foreign governments and institutions have shown interest in assisting the Philippines in its thrust to accelerate the development of its indigenous coal resources. The U.S. government thru its Trade and Development Program has provided part of the funding for the evaluation and feasibility study of one of the major coal fields of Semirara. Recently, Montenegrin Mining Corp., a relatively small open pit coal mine in Surigao availed of the U.S.T.D.P. funding for the feasibility study

of its expansion program. The agreement provides that the funding will be converted into a loan should the feasibility study be implemented, otherwise it coverts into a grant, if the feasibility study could not be implemented for some reason. The U.S. program has become popular in the country and presently several private firms has pending application with the U.S. Embassy.

Lately, ADB has recognized that more than the government owned firms, the privately operated coal mines direly need funding inorder to expand. The bank has taken bold steps recently in modifying its policy to enable the institution to extend funding assistance directly to the private sector. Part of its plan was the commissioning of a Canadian firm to conduct a comprehensive study of the Philippine coal industry and to come up with recommendation on institutional modifications required of government to provide the growth environment for the private sector. The ADB has specified that only when these institutional modifications will be implemented that the bank will effect direct funding assistance to the private sector.

TABLE 1

Production of Coal

YEAR	PRODUCTION (MT)
1973	39,004
1974	50,745
1975	105,128
1976	122,000
1977	284,554
1978	254,575
1979	263,393
1980	328,786
1981	384,000
1982	558,000
1983	1,020,000

Source: Ministry of Energy

Utilization

In the Philippines, oil expenditures rarely reached more than 13 percent of total imports before 1973. The oil crisis starting in 1973 has affected the country so grossly that in 1980 the oil bill easily accounted for almost 30 percent of the entire import bill. In 1981, it reached U.S. $2.6 billion, equivalent to about 26.0 percent of all import payments and 36 percent of all export receipts. The leadership of the government announced that the dexterity by which the energy sector was managed would determine how successfully the economy of the country could be improved. In 1976 the government mandated an integrated energy development strategy and organized a separate governmental body to implement its objective, of developing its indigenous wealth of energy resources like oil, geothermal, hydro and coal in the country.

In 1977, a scientific nationwide survey confirmed that the Philippines had substantial coal deposits. A chicken-and-egg situation however prevailed for a while when both the coal miners and prospective coal users were hesitant in committing their resources in pursuing their projects in earnest. The country never had any experience in mining and utilizing coal of such volumes as justified by the coal reserve potential shown by the government sponsored survey and therefore the fear of both the coal producers and users to plunge into unchartered waters is understandable. To break the impasse, the government mandated fuel-intensive industries to convert to coal usage, in phases and with government assistance. The first to be coverted was the cement industry and was supposed to be followed next by the mining industry. Before the mandate, four (4) of the eighteen (18) cement plants were already using coal and the remaining cement plants were supposed to have phased conversion from total oil to mainly coal firing, with government financial assistance. In 1983, all the cement plants has coverted to coal firing, however due to economic difficulties experienced by the Philippines, some of the cement plants either has to operate at less than its rated capacity or to completely close down. From a total of 18 cement plants, only 15 plants are operating presently and another three plants are being planned to be mothballed by 1986. From a yearly coal requirement forecasted in 1973 of 1.2 million MT., the reduced local demand for cement has brought down this requirement drastically to only about 400,000 MT in 1985.

The other measure taken by the government in the past to spur coal demand was to construct coal fired power plants in the country. In 1980, the government targetted 890 MW of generating capacity to be coal fired, but due to the decreasing power demand in the country, only 410 MW is realized. This comprise of the 300 MW Calaca coal-fired plant constructed in Luzon and the two (2) 55 MW coal fired plants located in Naga, Cebu. The 300 MW Calaca plant was constructed starting in 1980 by the Japanese and was contracted to utilize Semirara Coal at about 900,000 MT per annum. When the plant was put into trial in 1984, it was found out that it could not operate efficiently with the use of Semirara coal. Inorder to continue the operation of the plant and to meet its power generation target, the government has to import high-grade coal at a larger ratio, to blend with Semirara coal. The first coal fired plant constructed by the same government firm, the 55 MW Naga I, experienced similar problem and in fact its commissioning in 1981 was protested by coal producers in Cebu as it had to import higher-grade coal for the trial run when by that time coal stockpiles in the mines were overflowing due to lack of market. This was eventually corrected and the plant has been running on purely local coal. Another 55 MW plant is being constructed in the same compound by an Austrian group which also installed the two 7.5 MW captive power plants in Semirara and this is scheduled to be commissioned in 1986. This plant is being designed at much lower-grade, high-ash and high-moisture coal and with the past experiences with the other two power plants, it is envisaged that the Naga II will operate without any problem using locally available coal. The Naga I plant is firing about 140,000 MT coal annually and the Naga II is projected to use about 245,000 MT starting 1986. With the increasing power demand in the Mindanao area and the unreliability of the hydro-powered plants noted when drought was experienced in the country, the government is contemplating of putting up a 100 MW plant near the coal fields in Bislig. Discussions for funding from the Japanese is going on and if this materialize, it would translate to another 460,000 MT of coal demand per annum.

TABLE 2

Projected Generating Capacities for 1986

(In Megawatts, MW)

Hydro	2,114 MW
Geothermal	894 MW
Coal	405 MW
Nuclear	620 MW
Oil/Diesel	2,362 MW

Source: Bulletin Today, December 30, 1985

Two large mining firms in the country, Atlas Consolidated Mining & Development Corporation and Nonoc Mining Corporation have also converted to coal usage. Atlas, a copper mine in Cebu with an annual capacity of about 37 million MT of ore annually constructed the first fluidized bed coal-fired power plants in the country. The two power plants, with a combined capacity of 80 MW, designed by the German, is the biggest operating fluidized bed plant in the world of such capacity. When the power plants were fully operational in 1984, the fuel consumption of the mining firm was reduced by 25% compared to 1983. Atlas coal requirement is placed at 250,000 MT annually. Nonoc is a nickel mine in one of the islands in Mindanao and uses coal for power generation and also for drying of its nickel concentrate. The combined coal requirement of both operation in approximated to be 105,000 MT per year. The mine was beset with financial problems in the past and to settle its obligations with government banks, the firm had to be taken over by the government. A government firm took control in 1984 and restored the mine to produce about 20,000 MT of nickel concentrate per year. To fully resuscitate its financial recovery, the government had to pass a special decree, exempting the firm from payment of taxes. Presently, the firm is importing its coal requirement although the design of its plant makes it possible to use local coal, as the price of imported coal without taxes is cheaper than the price of local coal at equivalent energy content.

Other user of coal in the country is the Visayan Electric Co., Inc. (VECO) and the Lu Do Corp. both located in Cebu. VECO is a private

firm with franchise to generate and distribute electricity in Cebu. It operates coal fired boilers which supplies most of the power to Cebu before the construction of the Naga thermal plants by the government. It still operates its coal fired plants to augment the power produced by the government and its annual requirement is placed at 30,000 MT yearly. Lu Do Corporation operates boilers to produce steam for operation of its electric power and for processing of copra for oil. The total yearly requirement of the firm for coal is about 60,000 MT.

Another major user of coal in the 2-3 years period is the National Steel Corporation (NSC), a government-owned firm which operates an iron and steel manufacturing operation in Mindanao. A direct reduction process is being planned out to utilize locally available coal. When fully operational, NSC would require more than 1.0 million MT per year for iron manufacturing process and power generation.

TABLE 3

Coal Supply-Demand, 1995 Projection

('000 MT)

Demand	4,758
Supply	3,749
Shortfall	1,009

Source: Wardell-Armstrong, B.E.D. Presentation, May 1985

Government Policies

The relative cheapness and the seemingly inexhaustible supply of oil lulled the Philippines into complacency about fully developing its indigenous energy resource before the oil crisis in 1973. The hydroelectric plants in the country was still built in the 1930's. Two years before the oil crisis however, the government opened up the road to geothermal utilization with a proclamation declaring certain areas as geothermal reservations for electric-power production.

Before the oil crisis, the electric-power industry was largely in the hands of the private sector, with preponderance of small private utility firms with inefficient operations. One firm, the Manila Electric Company for quite a time, represented 90% of the power generation capacity and sales but served only the Manila area. The government owned, National Power Corporation played second fiddle to the privately owned generating plants.

There were then four oil refineries operating in the country owned and totally controlled by five multinationals. Another oil company, Getty Oil, had no refinery but sold petroleum products bought from other majors. Except for the Englad-based Shell, all the oil companies were American. Oil exploration had been half hearted for most of the first 100 years since royal concessions were granted by the Spanish court in the late 1800's when the country was still under the Spanish regime. In 1949, the Philippine government promulgated the Petroleum Act of 1949 but was still based on concession system and under this system, company could lease an oil concession with a one million peso (U.S. $50,000) deposit. The concessionaires however were not obliged to work on the areas and therefore most of the concessions remained idle. Lacking the technical expertise and financial capabilities to explore their concessions, the firms sought returns on holding on to concessions through the stock-market trading floors.

Before 1973, the Philippine dependence on imported oil was almost total. Per capita consumption grew from 1.1 barrels per capita in 1965 to 1.9 barrels per capita by 1979. Even before the oil crisis, aware of the precariousness of relying almost totally on imported energy, the government promulgated the Oil Exploration and Development Act of 1972, which shifted from the concession system to the service-contact system for oil exploration. Its immediate effect was the attraction of several multinational energy companies to enter into partnership with the government or organize joint-venture agreement with Filipino firms.

During the oil crisis, in concert the OPEC nations no longer negotiated oil prices with the majors but set the price of oil on a take-it-or-leave-it basis. With the declaration of Martial Law in the country came the power of the President to issue decrees and on November 9, 1973, the Philippine National Oil Company

was created through P.D. 334. A month later after its creation, PNOC purchased ESSO Philippines, Inc. and the biggest refinery in the country. With PNOC as a government owned firm, it had the advantage of dealing with oil producing countries on a government-to-government basis.

As part of the general plan to adopt an integrated energy program, the government issued P.D. 41 in November 1972, directing the National Power Corporation to operate all electric power-generating stations in the country. The private sector however was still allowed to retail the distribution of energy on a limited basis.

With the many activities in the energy sector, it was felt that an umbrella organization was necessary to integrate all the energy related effort and on October 6, 1977, the President created the Ministry of Energy through P.D. 1206, to ensure program consistency, coordination and proper supervision.

Under the supervision of the Ministry of Energy and formally adopting the service-contract system in oil exploration, highly qualified and experienced foreign companies actively participated in the search of petroleum in the country. From 1976 to 1981, there have been sixteen successive oil and gas discoveries. In January 1979, the Philippines joined the ranks of the oil-producing nations when the South and West Cido structures were placed on joint production reaching an average of 40,000 barrels per day from five wells. While this production is modest by world standard, it proved to the government planners that with proper policies and efficient supervision, the development of its indigenous energy resources could be accelerated.

The search for geothermal resources in the country has been going on since the 60's but it was really during the creation of the Ministry of Energy and the PNOC when it was pushed into an unprecended development pace. In 1979, with the geothermal energy production at 446 megawatts, the Philippines overtook Italy to become the second largest geothermal power producer in the world. Then by April 1982, additional geothermal power plant was put into operation bringing the total geothermal production record of 556 MW. What is remarkable in this accomplishment is that most of the geothermal fields were explored and developed utilizing Filipino technology. This feat has been recognized by the Japanese and confirmed its respect for Filipino expertise in this field when it contracted PNOC to explore its geothermal resources. To date, the country has more than 1,500 MW steam field capacity but could not develop all this resources due to decreasing power demand.

Taking off from the decrees passed for the development of the petroleum resources, the President issued P.D. 972 known as "The Coal Development Act of 1976" on July 27, 1976, and amended by P.D. 1174 the following year. Similar to the decree on the development of the oil industry, it also introduced to the coal industry the service-contract system. In a nutshell "The Coal Development Act of 1976" was designed to accelerate production of indigenous coal found in many parts of the country, the installation of logistic networks and the development of the local market. The decree converted leases and permits which were previously handled by the Bureau of Mines of the Ministry of Natural Resources, to service contracts to be administered by the Ministry of Energy. More economic incentives were provided in the decree for both coal producers and consumers. These incentives are tax exemption on imported capital equipment for coal production and conversion to coal of present oil-fired plants and facilities; tax credit on domestic capital equipment; net-operating loss carry-over; exemption from the capital-gains tax; accelerated depreciation; preference in the granting of government loans; and remittance at prevailing exchange rate to cover interest and principal of foreign loans and obligations regarding technological aid relating to coal conversion programs. Since the decree has been patterned after the production-sharing scheme for oil, P.D. 972 similarly provides sharing of production between the mining firm and the government after deducting allowance for exploration and development.

Since the Philippines by-passed the coal fired Industrial Revolution and jumped into the oil age, the logistical network that should link the coal mine to the market had been almost non-existent. P.D. 1722 created the National Coal Authority which was tasked to organize the logistical and distribution requirements

for the development of the coal industry. The NCA was supposed to set up loading terminals near coal mines, operate barging and trucking systems and establish receiving storage and blending terminals, including conveyors to the nearest potential coal users.

Review of Past Performance

The break of the impasse on the "chicken-and-egg" situation that existed between the coal producers and users before the promulgation of "The Coal Development Act of 1976" had been the most laudable accomplishment of the government as regards the development of the indigenous coal resource. With its success in providing incentives for coal conversion of oil-fired plants, various plants and projects which are already in place, would require close to 5.0 million MT of coal in the next 5-10 years which should assure that coal producers of the market. With the projected shortfall in coal production of more than 1.0 million MT per annum, this places the ball in the court of the coal producers, so to say, in the national effort of developing coal resources of the country.

As in most planning experiences, the Philippines had also its share of slippages and miscalculations. When the first coal fired thermal plant of the government was put into operation in Cebu in 1981, it was realized that the average coal from the mines in Cebu did not match the design specification of the plant. While the original idea of putting up the plant in Cebu was to provide the nearest market for the coal mines in that island, only few mines could produce the coal suitable for the thermal plant. PNOC which was tasked to guarantee coal supply to the plant had to resort to blending to come out with the required coal. The mismatch could be traced to the inadequate survey conducted of the Cebu coal. Most of the coal mines at that time were just starting with their small in-seam mining operations and therefore lacked the comprehensive data which could only be derived from past production figures or from a well organized drilling and exploration work that should have preceeded the mining operation.

Ironically the same case occurred again during the commissioning of the second coal thermal plant owned by the National Power Corporation but this time on a grandeur scale as it involved a 300-MW plant and a U.S.$180 million open pit coal mine. In 1978, after a comprehensive drilling and exploration campaign in Semirara Island, a private firm was able to confirm a coal reserve of more than 100 million MT and a mineable reserve in excess of 30 million MT. With this development the government mandated its own firm, the National Power Corporation to construct a 300 MW thermal plant in Calaca, Batangas specifically to utilize the Semirara coal. In 1980, a 15-year coal supply contract was signed between the two parties and agreed to meet regularly to update each other on the development of their individual projects. During the commissioning of the thermal plant it was found out that its design was not in accordance with the specifications as indicated in the contract. It was also observed that the plant design did not allow for the sodium content of Semirara coal and therefore could possibly result to frequent outages for maintenance. The undersigned happened to be employed with Semirara Coal Corporation and was involved in development of the coal project and in the negotiation of the supply contract with NPC. While the mandated transfer of power generation to NPC was based on sound policy, it also resulted to drastic expansion of the government owned firm and with it came the bureaucracy and the difficulty in communicating with its various divisions. The other reason that could be presented is that the technical personnel and consultants that were involved in the planning and design of both the Semirara mine and the NPC thermal plant lacked adequate experience with the climate similar to the Philippines. The coal handling facilities of the NPC plant experienced its worst form during the wet season and in the Philippines this could exist from six to eight months. Lastly, it could be commented and this could serve as a reminder to other developing countries that any plans of adopting highly sophisticated technology from advanced countries should always be approached with caution. The Semirara project

which implemented the highly advanced continuous mining system utilizing conveyor belts and bucket-wheel excavators had its financial projections tightly tied up to the expected sales as contracted with NPC. The design discrepancies in the NPC plants however resulted in lesser lifting of coal from Semirara as higher grade Australian coal was necessary for blending inorder that the thermal plant could run efficiently. Viewing the events at hindsight Semirara could have more flexibility in dealing with the derailment of its financial projections should it incorporated less sophisticated and cheaper equipment in designing its open pit mining operation. As in previous experience with the first power plant, it is envisaged that the existing difficulties could be corrected in time especially since both firms are government-owned.

Since the promulgation of P.D. 972 in 1976, only the government owned firm, namely Semirara Coal Corporation and PNOC has apparently progressed significantly while the privately-owned firms did not really improved as expected. One of the major reasons for the expansion of PNOC operated mines is its access to funding from such financial institutions like the World Bank and the Asian Development Bank. The ADB has recognized this imbalance and is now taking steps inorder that it could provide the necessary funding to the private sector. The other factor for the lackluster performance of the private sector could be ascribed to the Coal Development Act itself. The production sharing scheme which has applied successfully to the oil industry has not provided adequate incentive to the coal industry. It is experienced that as the mines go deeper drastic increases in operating costs are incurred. Inorder that the privately owned coal mines shall advance from the prevalent practices in the country of developing only the near surface seams, substantial profit margin should be provided so that the development risks could be appropriately compensated. The association of the coal producers in the Philippines is presently putting pressure to the government in amending the decree toward this direction. Another major factor which if corrected is envisioned to attract investors to the coal mining industry is the lack of definitive pricing policy for coal in the country. In general terms, the price of coal in the country is tied up to a certain percentage to the equivalent price of oil. In effect, the price of coal in the country is not accorded appropriate protection and is exposed to competition with foreign coal. Owing to the complicated geology of the country and the thin-seam occurrence of the deposit, most of the mines would hardly be developed if they were located somewhere else in the world. Adequate protection should be accorded to the coal mining industry if the country aims to be energy self-sufficient. The inequity of the pricing policy, is reflected in the fact that a government owned nickel mining firm in the country continues to imports its coal due to price advantage over local coal. Ironically, the government passed a decree exempting the firm from paying taxes including that on imported coal.

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POLICY AND PROCEDURES ON COAL DEVELOPMENT IN THAILAND

PRAPATH PREMMANI
SECRETARY GENERAL
THE NATIONAL ENERGY ADMINISTRATION
BANGKOK 10500, THAILAND

ADSTRACT

Most of coal deposits in Thailand are found in tertiary basins scatterly located in the Northern and the Southern part of the country. Their qualities rank from lignite to high volatile C bituminous. Explorations to determine the total reserves are still incomplete. Base on the current available data, it is anticipated that the total possible reserves will be around one billion metric tons.

History of coal development in Thailand can be traced back as far as 1892 when the first coal mine was put into operation. In 1960, the first lignite fired power plant of 12.5 MW was commissioned. However during the cheap oil era, the development and utilization of coal had been very limited. Suffering economic adversity resulting from the oil crises, in 1980, Thailand formulated the fifth-five years national development plan (1982-1986) aimed at reducing the dependency on imported oil from 75 to 46 percent partly by the extensive development of indigenous energy sources. In this plan indigenous coal was listed as one of the top priority and is aimed at increasing the annual production to about four folds from around 1.4 million ton in 1980 to 5.5 million ton in 1986. Most of this coal will be used for power generation, the installed capacity of which will be enlarged from 210 MW to 885 MW. It is planned that, by the end of the Sixth Plan (1991) its capacity will further increase to 1800 MW or about one-fourth of the country's installed capacity and will consume about 12 million ton of lignite annually. At the same time, about one million ton of lignite will replace heavy oil in small industries. This amount accounts for only two-tenth of the potential users.

Such drastic increase needs substantial investment for development, to alleviated its burden, the government has laid down a policy encouraging the private sector in mine developments. Domestic coal will be allocated for development according to their qualities. High quality coal will be mined under concession by private sector for serving industries. The ability and flexibility of the market-oriented private sector provide better mobilization of resources and price competition and hence expediting the development and utilization. On the other hand low quality coal, unsuitable for industrial use, will be mined for power generation by state enterprise responsible for the same. The government has also put up measures include among other, price structure, tax increase on imported coal, tax reduction for equipments which use coal, soft loan for retrofitting equipments to use coal, prohibition on the export of local coal etc. In addition, research and developments on the means of coal utilization other than above mentioned are being undertaken to find out the most economic and efficient use of coal. In parallel, the adverse effect on environment resulting from the development, handling, utilization of coal and ash disposal are also being studied.

1. BACKGROUND

1.1 Geology and Reserves

Most of coal deposits in Thailand were formed in the Cenozoic era. The exact ages of most of them have not yet been identified owing to insufficient study, but by means of paloconto-logy, some can be estimated to lie somewhere in the Miocene epoch. They have been found mostly in Tertiary basins throughout the country. About 80% of their seams are stratified in small structural basins scattering in the Northern Region. Their quality are low grade, ranking from lignite to high volatile bituminous C according to the American Standard (ASTM, Part 26, 1977). The majority of these resources are lignite of low calorific value (2,500-3,000 kcal/kg) due to its high water content (20-35%) and high mineral ash (10-47%). Though the overall investigation has not been accomplished, the executed works revealed 49 localities of coal deposits with probable reserves of at least 1,200 million tons. Among these sources, the reserves of sub-bituminous coal are relatively small in comparison with lignite, their heat content range lies between 5,500-6,000 kcal/kg with about 8% ash. At present, only eleven deposits are being actively mined, four belonging to state enterprises and the rest to private sectors (Table 1 shows major coal deposits in Thailand).

1.2 Evaluation of lignite development in Thailand

Thailand, like many others countries which heavily depended on import oil, has been severely affected by the oil crises. In 1980, the share of imported oil in the country's energy supply was recorded at 75 per cent and consumed more than one-third of the country's foreign earning. It is thus evident and is eminent the country to speed up the development of her indigenous sources of energy at a full pace. Lignite was listed as one of the top priorities.

The development of lignite in Thailand has a long history. In 1892, the first production of lignite took place in Krabi South of Thailand but ceased its production four years later due to limited market and poor qulaity of lignite. The chronicles of later development are as below.

1912	Department of Mines (former name of the Department of Mineral Resources) carried out detailed exploration in the vicinity of the forementioned lignite mine and later on gave a concession to a Penang-based Englishman to mine lignite at Pangpoo-dam, Krabi.
1911-1917	A state-own company named Siam Coal operated a lignite mine at Kiansa, Surathani.
1917	Royal Siam Railway conducted coal exploration to fuel its locomotives and discovered substantial lignite reserves at Mae Moh Lampang, North of Thailand and Pangpoo dam, Krabi South of Thailand. The exploration program ended in 1932.
1927	King Rama the Seventh, ordered his privy minister to reserve the Kiansa, Pang-poo dam and Mae Moh lignite deposits for government operation for the benefit of the country.
1950-1954	The Department of Mine with the co-operation of the United States Operation Missions conducted extensive exploration in Mae Moh and Krabi basins and concluded that the estimated reserves of Mae Moh and Krabi basins are not less than 120 and 100 million tons respectively.
1951	Krabi Mine commenced its operation.
1954	The government established a state own mine at Mae Moh. Six years later it was transformed to the "Lignite Authority of Thailand". In 1969 it was amalgamated with other public utilities into the Electricity Generating Authority of Thailand (EGAT) which then fully controlled the development of Mae Moh and Krabi Lignite for power generation.
1967	The National Energy Administration, in response to the demand of tobacco-curing industry for alternative fuel to replace the scarce fuelwood opened its lignite mine at Ban Pa Kha, Lampoon. With its high quality (sub-bituminous C) the utilization was expanded to other small and medium industries, including cement industry.
1976	Attracted by the drastic increase in demand, the private sector opened several lignite mine in the North and the South regions.

All lignite mining in Thailand are limited only to open pit mine employing excavator and trucks but in some particular cases blasting may be needed to ease the operation.

2. ROLE OF LIGNITE AND COAL IN THAILAND'S ENERGY SCENARIOS

2.1 Past and present utilization

Coal has been consumed in Thailand since the early 1900's. Domestic lignite is used for power generation and in small industries but at a limited scale. However, after the oil crisis the amount of imported steam coal for cement industry has been increasing rapidly.

Demand for domestic lignite has increased four folds in the last eight years from 0.5 mtpa in 1975 to 2.2 mtpa in 1983 in 1985, the lignite demand totalled 3.3 mtpa. EGAT's mine mouth power plants at Mae Moh and Krabi supplies approximately 80% of the demand. The quantity of imported coal has increased by 7.3 folds in the last seven years from 31,798 tons in 1977 to 225,096 tons in 1983.

2.2 Future trend

Lignite

With the expansion of EGAT programme at Mae Moh from the existing 825 MW to 1,725 MW, cement plants and tobacco curing and other small industries, demand for lignite is rapidly increasing. It is envisaged that the demand of local lignite will reach 10 mtpa by the early 1990's. The demand in cement industry is expected to increase from 0.3 mtpa to 1.7 mtpa by 1995. The tobacco curing and small industries are expected to ho a share of 0.23 mtpa by 1991.

Future trend of lignite demand are as follow

(10^6 TONS)

	1986	1987	1988	1989	1990	1991
POWER GENERATION	5.551	5.728	5.917	6.425	8.946	10.444
CEMENT INDUSTRY	0.490	0.620	0.810	0.890	0.960	0.990
OTHER INDUSTRIAL (TOBACCO CURING, PULP PAPER etc.)	0.155	0.165	0.165	0.165	0.175	0.230

Imported Coal

Most of the imported coal is steam coal which is used for power generation and cement industry. Steam coal imports are forecasted to increase from 150,000 tpa in 1984 to 495,000 tpa by 1991 to meet partial fuel requirements of the cement plants. Steam coal use is expected to climb up to 3.7 mtpa by 1995 with the commissioning of the first 600MW Ao Phai and 150 MW Krabi coal-fired power plants. However, if more natural gas is available for power generation, the 1995 demand for steam coal could be as low as 0.5 mtpa. Demand for coke and coal products is estimated to grow at moderate rate at about 12 per cent per annum. Forecast coal demand are as follows :

	1986	1987	1988	1989	1990	1991
	(10^3 TONS)					
POWER AO PHAI (4 x 600 MW)	-	-	-	-	-	-
POWER KRABI (2 x 150 MW)	-	-	-	-	-	-
CEMENT PLANTS	200	280	335	365	395	495
TOTAL COAL (INTENSIVE COAL)	200	280	335	365	395	495
TOTAL GAS (INTENSIVE GAS)	200	280	335	365	395	495

The coal forecast was based on a detailed analysis of the coal requirements by sector and an assessment of economic conditions, commercial energy trends, fuel prices, national policies, and alternate fuel supplies, in particular, natural gas.

2.3 Competitive fuel (Natural gas and fuel oil) and prices comparison

For a clearer view on the role of lignite and coal in Thailand's energy scenarios, the supply and price of all competitive fuels namely heavy, oil, natural gas, imported coal and lignite are discussed as follows.

Heavy Oil

Only about 10 per cent of oil supply are being produced domestically. The rest are imported from the the Middle East and East Asia. The current production of heavy oil from local refineries exceeds the demand. To trade-off the potential loss in exporting the surplus, the Government encourages the use of heavy oil for power generation to the maximum possible extent, by subsidizing the price of heavy oil for power generation. At present the price of heavy oil is 4.08 and 4.09 Baht per litre for power generation and for industry respectively or about 0.415 and 0.416 Baht per thousand kilocalories.

Natural Gas

The recent discoveries of natural gas both off-shore and on-shore has substantially alleviated the country's dependency on imported oil. The current production amounted to 350 MMScfd and contributed about 70 percent of the country's energy demand. It is envisaged that the production may rise to about 500 MMScfd by year 1990. The main customers are EGAT, cement industries and petro-chemical plant. The potential use of natural gas for other industries is limited due to demand and recticulating system constraints. Till the middle of this January, natural gas is being sold to EGAT at 87 Baht per million Btu (0.345 ฿/thousand Kcal) and 92 ฿ per million Btu (0.365 ฿/thousand Kcal) to cement industry.

Coal and Lignite

Steam coal is being imported, mostly from Australia. With the import duty of 10 percent on CIF value, the price of coal in Bangkok is about 1660 baht per ton or 0.278 Baht per thousand kilocalories. The price of local lignite for industry varies from 260 to 500 Baht per metric ton (0.072-0.111 Baht per thousand kilocalories). The cost of haulage is about 1.40 Baht per ton-kilometre.

It is clearly evident that the current lignite price is for too low while the price of natural gas was not really attractive for the industry in comparison with the imported coal. Therefore, in the near future, unless some corrective measures are undertaken, the importation of coal is likely to increase and the situation where imported energy dominates the energy scenarios will be on the rise again.

3. POLICY

3.1 The Fifth and The Sixth National Economic and Social Development Plan (1982-1986 and 1987-1992)

As mentioned earlier, the oil crises has forced Thailand to accelerate the development of its indigenous sources to reduce its dependency on imported energy. This can be witnessed by the Fifth five year National Economic and Social Development Plan currently in force (1982-1985) which called for accelerating the development of indigenous sources namely, oil, natural gas, hydro power and lignite to reduce the dependency on imported oil from 75 to 43 percent by the end of the Plan. Lignite supply in particular, was aimed at four folds increase to meet the requirement of the expanding lignite-fired power plants from 210 MW to 885 MW.

The new Sixth Plan (1987-1992) which is being formulated is expect to follow the same trend. In this Plan, the lignite power generation will further expand to 1,725 MW. Additional goals on the promotion of lignite use in industry and the role of private sector in coal exploration and mining activities are also envisaged in combination with corrective measure to discourage coal import and incentives to promote wider use of lignite.

3.2 Policies on Coal and Lignites

To enhance the above mentioned objectives, several policies on coal and lignites have been laid down in the following areas.

3.2.1 Utilization

Since coal deposits in Thailand are mainly of low quality ranking from lignite to high volatile bituminous C and varies from place to place depending on the environments of deposition to maximize benefits, due consideration have been given to the allocation of their utilization according to qualities, reserves, market and hauling distance.

As such, poor quality lignites which do not meet the requirement of the industry are thus allocated for power generation and consumed at mine mounth to reduce hauling cost. While higher quality lignite, for instant sub-bituminous, which can compete to a certain extent is the natural gas and fuel oil will be promoted for industrial use at a higher price. The moderate quality lignite is meant to substitute fuelwood in tobacco curing industries and small industries at competitive price. In addition, briquetting of fine lignite for domestic use to replace charcoal in rural area is also being undertaken.

3.2.2 Production

To support the objective on utilization, policy on production was formulated. In the case of production of lignite for power generation, a state enterprise was given the responsibilities. The reason is power development required enormous financial investment but very modest return and this is oriented towards national stability, the operation under state enterprise is deemed more appropriate. On other hand, supply of lignite to industry is purely market-oriented which is aimed at competing with other alternative fuels, hence it requires more flexibility and marketing techniques which the private sector is better equipped with. Therefore, the private sector is being encouraged to participate in the production. The government will however, be still in charge of the exploration activities to investigate the reserves and quality for production allocation. However, detailed investigations will be undertaken by the concessionnaire, of each deposit.

3.2.3 Administration and Control

To administrate and control the activities on lignite development to follow the same direction, a national administrative board named the National Committee on Coal Policy is being established. This Committee shall be responsible for coal activities including overall planning for both coal demand and supply, exploration, mining, coal handling and transportation, authority to carry out utilization studies and coal imports to maximize the use of local supply, appropriate economic terms, for increase tax on imported coal, granting of lignite concessions to the private sector, encouragement of the private sector to accelerate lignite production, encourage the utilization of lignite to replace fuel oil and imported coal by tax or other government incentives and prohibition of exporting local coal for the maximization of benefit of the country.

3.2.4 ASEAN Co-Operation in Coal Area

Besides the indigenous lignite activities, Thailand has joined with her neighbouring countries in coal development through the Association of Southeast Asian Nations (ASEAN). The Association was established in August 1967, initially consisting of five countries in the region namely Indonesia, Malaysia, Philippines, Singapore and Thailand. Later in January 1984, it expanded to six, when Brunei joined the Association. Under the umbrella of ASEAN Concord which called upon the ASEAN Member Countries to assist each other by according priority to the supply of individual country's needs in critical circumstances and priority to the acquisition of reports from Member Countries in respect of basic commodities particularly food and energy, the ASEAN Expert Groups or Coal was established to discuss and draw up programme on coal co-operation. As a result several area of coal activities have been considered and studies undertaken namely.

- Establishment of Coal Information Center in Thailand
- Joint Coal Market Survey
- Studies on Distribution and Utilization of Coal
- Joint undertaking in survey and exploration
- Joint undertakings and Joint ventures in Coal Mine Development
- Joint Cooperation with Third Countries,
- Long,term projects.

Also the ASEAN Agreement on Energy Co-operation has been drafted and expected to be signed in the very near futures this will offer a good opportunity to Thailand to secure the supply of coal in the future.

3.2.5 Research and Development

In addition to the above activities on development of indigenous coal sources and security of supply of coal, Thailand, NEA, in particular, has carried out research and development on the utilization of local coal to maximize the use of its low grade lignite especially to produce fuel suitable for industrial and household use. Even though the quality from some of these mine rank as high as 5,000 Kcal/Kg, delivered quality has been inconsistent. For the cement plants some of the lignite delivered has been as low as 2,300 Kcal/Kg and accordingly, the industry is looking to import more higher quality coal. It is believed that only benefication will provide better utilization.

Lignite gasifications and synthetic chemical processing technology is being developed. Among several other synthetic products developed, the production of nitrogenous fertilizers using lignite as the feedstock has also proved feasible. However, the lignite gasification and gas purification processes are cost intensive and constantly pose technological problems.

Research and development on utilization has been actively under taken. On the government side, Laboratory tests are being carried out in search of the best binder, economically and technically to be used in briquetting local coal which has non-caking characteristic. Carbonization of lignite for cooking fuel to substitute charcoal is also being studies. The disposal of ash by producing construction materials is also under investigation by EGAT.

Private sector has also actively undertaken research and development on the utilization of lignite. For instance the cement industry used their run resources, manpower and financial, to develop technique of firing system and modifying the kiln to accommodate lignite to the maximum possible extent. The research on the efficient use of lignite in tobacco curing barns has also been undertaken. Several boiler manufacturers have started programmes to produce boilers and furnaces using lignite as fuel.

Those research and development programmes support and help accelerating the production and utilization of lignite substantially and thus will facilitate future prospect of lignite development.

4. PROCEDURES

One of the key factor in the achievement of coal development is the role of the National Committee on Coal Policy which will manage and regulate the coal activities. Procedures which the Committee will undertake can be divided into two stages, i.e addressing issues and policy formulation.

UTILIZATION OF TEXAS LIGNITE FOR THE GENERATION OF ELECTRICITY

C. W. Garrard, Jr., Ph.D.
Basic Resources Inc.
2001 Bryan Tower • Suite 2070
Dallas, Texas 75201

ABSTRACT

Use of Texas lignite for power generation has had its ups and downs during the twentieth century. Its first application began in 1926, but was soon replaced by a plentiful supply of natural gas in 1940. As a result of this early application however, it became a logical choice for an energy source for the Texas Utilities boilers when natural gas was in short supply during the 1960's and early 1970's. Today approximately half of Texas Utilities' 71,906,144,000 kilowatt-hours is generated from the use of Texas lignite. The large scale utilization of lignite has presented some interesting challenges in the areas of strip mining, reclamation and air and water effluent management.

INTRODUCTION

Due to the short period of time available today, I will give a brief overview of the Texas Utilities' lignite program and invite anyone who wishes to discuss it in more detail to visit with me later during the conference.

The Texas Utilities Company System provides electric energy in 87 counties in north central, east and west Texas which covers about one-third of the state's area and approximately 4,850,000 people. In addition, Texas Utilities is the fourth largest coal mining company in the U.S.A. Natural gas was the principal fuel for the system until 1971. With the conversion to lignite, natural gas was used to produce about 48% of our electricity last year with lignite producing about 51%.

Texas lignite is a grade of soft coal with a heat content of 2,200 to 4,000 Kg-cal/kg. The lignite is low in sulfur content - about 0.6 to 1.2 percent, but high in ash content - 12 to 20 percent and is difficult to store or transport over long distances due to its high reactivity and friability. With Texas heat and wind, it will burn spontaneously or blow away. Therefore, careful planning must be utilized for it to be a viable energy resource. Lignite is found in a broad band stretching from Texarkana down to Laredo (Figure 1). It is estimated that there are over 100 billion tons of this resource available in the state. However, using current economic mining methods, only about 10 percent can be recovered. The unconsolidated nature of the overburden in Texas dictates that surface mining techniques be used to extract the lignite and, in general, only that which is within 70 to 80 meters of the surface due to the thin seams. Lignite seams have been logged as deep as 1,500 to 2,000 meters but presently are not economically recoverable.

Why use lignite? Although characterized by many people as simply a poor grade of dirt (some refer to our lignite plants as dirt burners), lignite can be a relatively inexpensive fuel. Our company has seen the cost of natural gas and oil increase dramatically since the late 1960's. The cost of lignite is relatively stable when compared to the other fuels, because the Texas Utilities System has sufficient lignite reserves under lease to cover the lifetime operation of the power plants. Many of these reserves were obtained in the 1940's and 1950's when no one else was really interested in lignite. Thus far, System customers

have saved about 3-1/2 billion dollars due to replacing natural gas with lignite.

Lignite is not a new energy source in the State of Texas. One of Texas Utilities' subsidiaries, Texas Power & Light, opened a plant at Trinidad in 1926 to burn lignite coal from the nearby Malakoff mine. Figure 2 shows a stripping shovel at the original Malakoff mine. It had a six cubic meter bucket. You can judge how large this shovel was by the size of the men standing at its base. Lignite was loaded by a 1.2 cubic meter shovel into rail cars. The railroad carried the lignite on tracks laid directly into the pit of the Trinidad Power Plant a few miles away.

In the mid 1920's about 2 million tons of lignite were mined a year in the State. After an almost void period in the 1940's, production had risen to 32 million tons a year in 1984. The plant at Trinidad produced about 40 megawatts of power from lignite and required almost three times as much fuel per unit output as does one of our modern lignite units. In the late 1930's, Trinidad was converted to natural gas. Natural gas was being flared as a waste product in those years and was therefore available as a cheap fuel.

Fortunately, one of the managers remembered the successful utilization of lignite in the 1920's and 1930's and continued to acquire mineral leases during the 1940's and 1950's for the Company. This activity provided an extremely economically attractive fuel source once the price of oil and natural gas started to rapidly increase in the late 1960's. When the Company returned to the use of Texas lignite in the late 1960's, the need for generation was much larger than it was in the 1930's. The System Expansion Plan called for the addition of units in the 500 MW size range. There was some question as to whether a lignite furnace could be built to handle this quantity of lignite since it would be equivalent in size to a 700 - 800 MW bituminous coal furnace. Although several new problems were encountered with the construction of the first large lignite fired plants, they have been resolved and today the lignite units serve as the backbone of a 17,804 MW system. Big Brown Steam Electric Station near Fairfield is one of Texas Utilities' first modern lignite fueled plants. It has two 575 megawatt units and started operation in 1971. At the present time, there are three lignite plants operating for a total of eight units and two units under construction.

MINING

One of the big questions for a lignite plant is how to provide the enormous quantities of fuel required on a daily basis? Big Brown must be supplied with over 20,000 tons of lignite a day. The enormous quantities of lignite needed for the plant are obtained by strip mining. This means that over 140,000 cubic meters of overburden must be removed just to get to the lignite seam.

Lignite is recovered from seams about one to four meters thick. Mine depth will vary from the surface outcrop to about 60 meters. The lignite seam is uncovered with a dragline that cuts a swath about 40 meters wide and as deep as the lignite seam. The heart of the mining operation is a dragline that removes overburden. Figure 3 shows a dragline at our Martin Lake facility in far East Texas. It weighs six thousand tons, has a boom 110 meters long and costs about $25 million. The bucket on the dragline can hold 72 cubic meters (130 tons of dirt) and can remove about 20,000 cubic meters in eight hours. Remember, the bucket at the Malakoff mine was only six cubic meters. The dragline is electrically operated with power supplied from the power plant. Figure 4 shows a full size pickup truck in a bucket to give a perspective of size. The links in the chains are bigger than a man's leg. The dragline has over 10,000 horsepower in motors and consumes about as much electricity in a day as an average Texas home would

consume in six years. The overburden that is removed from the top of the lignite seam is placed in the previous pit that had been dug. It is not necessary to separate the top soil and sub-soil in Texas since experience has proven that revegetation is excellent.

The latest addition to the mining efforts is a cross pit spreader which will permit us to mine deeper more efficiently (Figure 5). It has a boom that is about twice as long as our regular dragline --- 205 meters. Its overall length is about 300 meters and its center tension mast is over 60 meters tall. The cross pit spreader will use two bucket wheel excavators which will dig at a rate of about 6,100 cubic meters an hour.

Once the overburden is removed, a smaller shovel is used to remove the lignite and place it in 100 ton haulers (115 cubic meters) for the trip to the power plant. The loading shovels are about ten times larger than the loading shovel used in the old Malakoff mine at Trinidad. The haulers are powered by 755 horsepower diesel engines and cost about $400,000 when new. A set of tires alone for this vehicle costs $25,000. At Big Brown haulers take the lignite from the mine to the plant and then dump it into primary crushers.

At Monticello and Martin Lake, haulers carry the lignite to a loading silo where lignite is crushed and loaded aboard 15 car - unit trains for the trip to the power plant. All loading operations are automatic and controlled by a single train operator. The loading silo holds 5,000 tons of lignite and can load a 100-ton car in about a minute. Figure 6 shows a unit train approaching the Monticello Steam Electric Station which has traveled about 24 Km from the loading silo to the power plant over Texas Utilities Company railway systems. These 15 cars loaded with lignite will provide fuel for this power plant for just over an hour.

GENERATION

The Big Brown Steam Electric Station is typical of the lignite plants in East Texas (Figure 7). It is a super-critical, lignite-fired station consuming up to 20,000 tons of lignite a day. (That's about 1 ton every 4 seconds at full load.) Lignite delivered to the plant is crushed and stored for use as required. A mass of conveyors carries the lignite to secondary crushers and then to the boilers for consumption. Once reaching the boilers, the lignite is stored in silos along the sides of the boiler. There is sufficient lignite in these silos to operate the unit for 8 hours. The lignite from the silos is pulverized to the consistency of face powder before it is blown into the furnace for combustion. The furnaces operate at about 1,371°C and slightly negative pressure and supply steam at 270 Kg/Sq-Cm pressure at a temperature of 543°C.

A major portion of a lignite plant is made up of environmental controls. There are several by-products of lignite combustion that must be removed from the flue gas before it leaves the stack. One of these is fly ash, a powder-like ash that can be removed from the flue gas by electrostatic precipitators such as this one under construction at our Martin Lake Plant (Figure 8). Electrically charged plates collect the fine ash particles with an efficiency of 98%. The 1,200 tons of fly ash collected per unit per day have commercial value as a concrete add mixture, but much more is produced than can be sold resulting in a significant disposal problem.

To meet the current, more stringent emission standards, limestone scrubbers have been added to recent units (Figure 9). The scrubbing process involves the use of a limestone slurry to absorb SO_2 from the flue gas. Each scrubber requires 280 tons of limestone per day and produces about 400 tons of waste sludge. The sludge is a toothpaste-like mixture of calcium sulfite and becomes a considerable disposal problem.

In a year, the sludge from one unit will cover a 2,500 sq. km. site to a depth of three meters. The scrubber at the Martin Lake Plant cost about $23 million and consumes a quantity of electricity that in a year could supply a Texas town of 7,200 homes. Approximately thirty percent of total maintenance effort at the plant is spent on the scrubbers and ash handling equipment.

At Monticello an additional environmental problem concerning fly ash developed. Characteristics of the lignite burned at this site have resulted in electrostatic precipitators not being able to meet design specifications. An additional fly ash removal system, bag filters, has been installed to insure air quality standards are met (Figure 10). This facility has been called the largest vacuum cleaner in the world. The bag filter system is made up of 7,344 fiberglass bags in 36 separate compartments. The bags are graphite impregnated fiberglass, one-third meter in diameter and 10 meters long. Each bag costs nearly $40 and will last about two or three years. (This is the most expensive vacuum cleaner in the world - almost $300,000 worth of bags.) Flue gas passes through the bags where fly ash is deposited. About every hour and a half the bags in a compartment are emptied much like you might empty any vacuum cleaner bag - they are shaken. (Throw-away bags are not practical.)

RECLAMATION

And, last but certainly not the least, comes land reclamation which has always been a very important part of our overall operation (Figure 11). First, the land is returned to its approximate original contour and th t is prepared for planting. (Since we a not farmers, all farming is contracted with local citizens.) Various types of grasses and trees are planted on the reclaimed land to both help stabilize it and provide useful forage for grazing.

Tests performed on the reclaimed land have shown it to be more productive than the land previously unmined. In fact, when we began baling hay on reclaimed land at the Big Brown mining operation, land proved so productive that more hay was produced than could be disposed of easily. Much of the land has now been turned over to cattle grazing.

Texas Utilities mining operations have been recognized by environmental groups for significant achievements in land reclamation. In fact, many of the strip mining laws in the state of Texas were modeled after operations at Big Brown.

BY-PRODUCT DISPOSAL

In addition to land reclamation efforts, there is the problem of handling large quantities of fly ash, bottom ash and scrubber sludge. Fortune sometimes comes in strange packages. This past year we sold nearly 433,000 tons of fly ash and 54,000 tons of bottom ash. That's still a small percentage of the total amount produced (less than five percent), but it represented $1.8 million in revenues. The savings, however, are substantially more than that. The savings in equipment, hauling and waste site maintenance, had we handled these wastes, are estimated at three times that amount. As a consequence we have a senior manager whose primary responsibility is the development of markets and applications for our waste products: fly ash, bottom ash and scrubber sludge.

Fly ash has numerous commercial applications. A substantial quantity of it is used in the manufacture of ready mix concrete, blocks, pipe and stabilization products. The products made from fly ash are lightweight and structurally strong (Figure 12). Texas Utilities is currently working with manufacturers to determine the feasibility of using fly ash for making Rockwool insulation.

Traditionally, the plants have been able to sell only very small percentages of the bottom ash it has produced. But little by little that's changing. Currently, bottom

ash is provided to the brick industry. The ash is used as a dewatering material in the manufacture of clay brick, increasing the efficiency of the process by at least ten percent. The company has also used bottom ash on its own haul roads, but bottom ash is now finding its way onto public roads as well (Figure 13).

For the past several years, the Texas Highway Department has been testing Monticello bottom ash for the repaving of state and federal highways. The bottom ash permits the use of less asphalt than normal, making it more economical. Yet the road surface has better skid resistance because of its gritty nature. The bottom ash is very resistant to the polishing effects of heavy traffic over hard surfaces that normally make a road slick and result in hydroplaning.

Last year, a small building supply manufacturer produced what is believed to be the first 100 percent synthetic gypsum wallboard ever made in the U.S. It was done on a test production line using Martin lake scrubber sludge which had been converted from calcium sulfite ($CaSO_3$) to calcium sulphate ($CaSO_4$) by the forced oxidation systems installed there in conjunction with the retrofitting of additional scrubber modules on all three Martin Lake units.

The wallboard manufacturer's test results have continued to be very favorable, leading to the hopes that commercial markets can be found for much, if not all, scrubber sludge produced at Martin Lake. Natural gypsum must be mined and, although abundant, the costs of mining and transportation add significantly to its price. A source of synthetic gypsum located close to markets is therefore economically attractive. Martin Lake, with the world's largest scrubber operation yielding nearly a half million ton of wet scrubber sludge per year, would be a steady supply source of synthetic gypsum.

In closing, the large scale utilization of Texas lignite for the generation of electricity has presented many new and intriguing problems. Over the past fifteen years most of these problems have been successfully addressed, and today Texas Utilities is extremely pleased to have 5,845 megawatts of lignite fired generation to provide its most economical source of power.

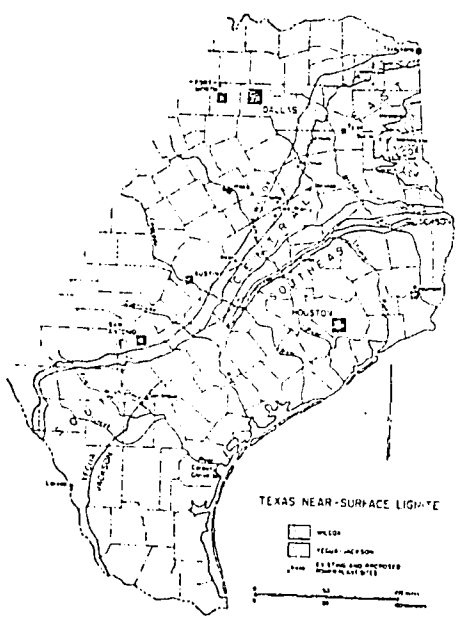
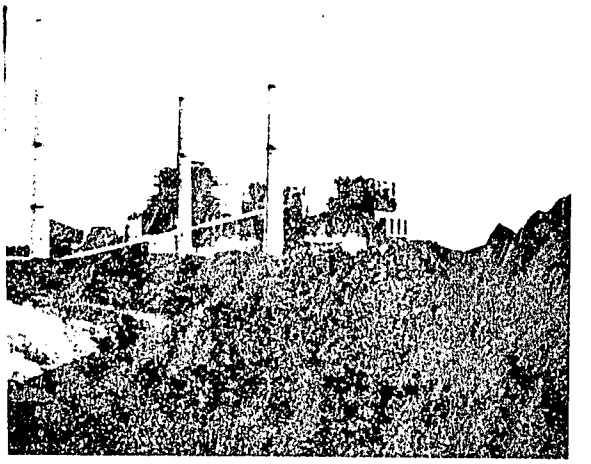


Figure 1

Figure 2

Figure 3



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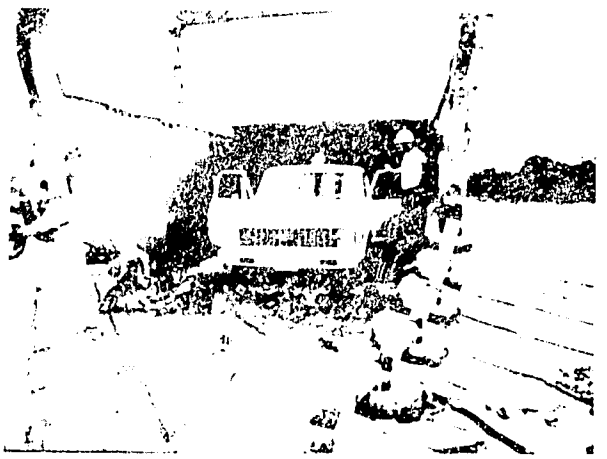
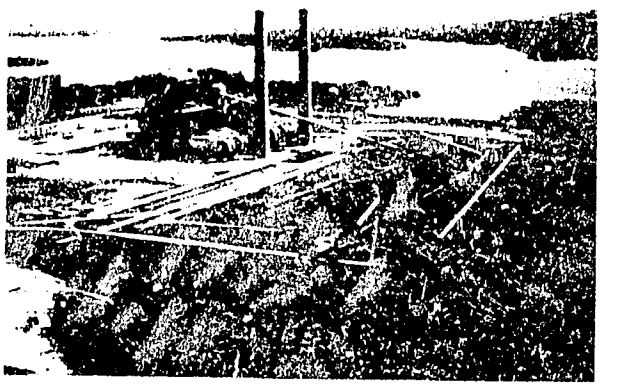


Figure 4



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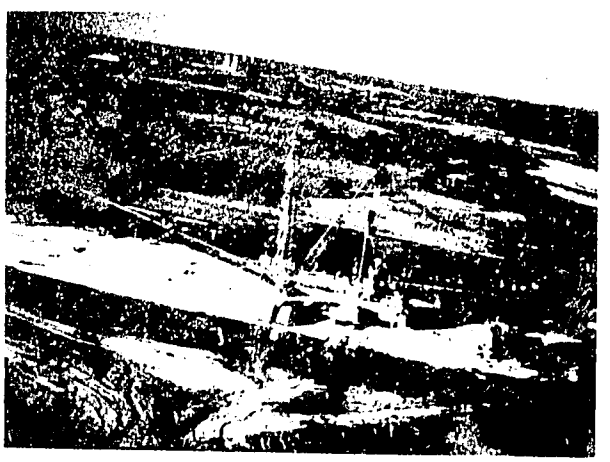

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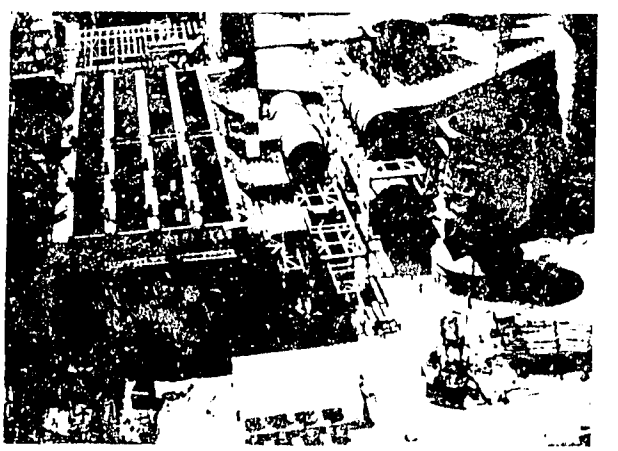

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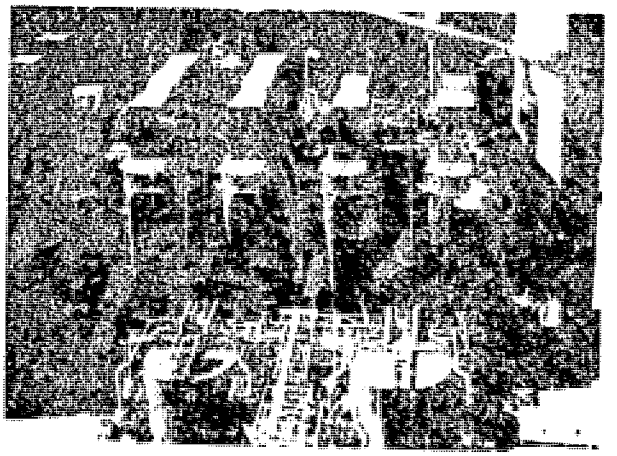

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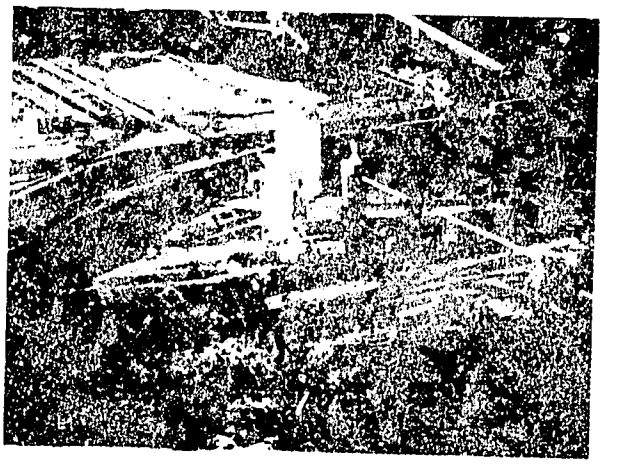

Figure 12

Figure 10

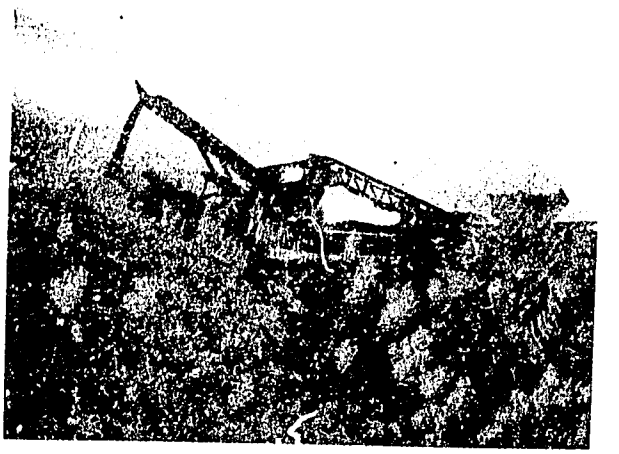

Figure 13

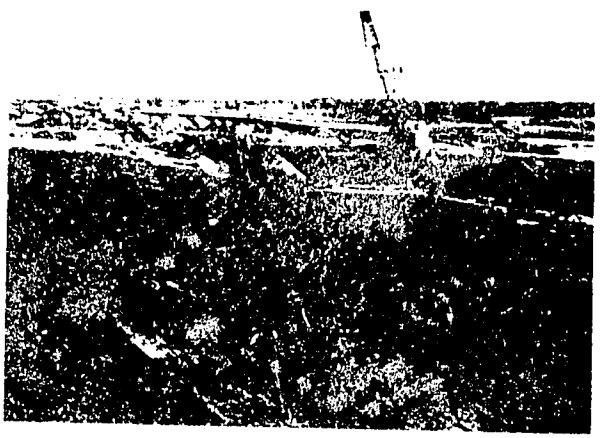

Figure 11

COAL IN ENERGY SECTOR IN PAKISTAN

ABU MOHAMMAD IZHARUL HAQUE

ABSTRACT

Coal is to play an important role in Pakistan's energy sector. This calls for proper policy and institutional framework and joint efforts by both public and private sectors. This paper outlines the historical development of coal, its status and future prospects as an important factor in the country's energy sector, at the same time highlighting the correlationship of the growth of the economy with the development of this sector during the decade 1973-83. The challenge thrown up by the internationale energy crisis of the mid 1970s and its impact at home have also been dealt with.

Pakistan has ever-since its birth been an energy deficient country. Although the demands of rapid industrialisation, modernization of agriculture, increasing urbanisation, rural development and the commitant expansion of the transport system require greatly increased supply of energy, the country has yet to reach the stage where it can be claimed that the supply is enough to cope with the increasing demands.

Even compared with the developing countries, Pakistan's position in the matter of energy consumption is not very impressive. In 1979, its commercial energy consumption per capita (166 k.g. of oil equivalent) was only half of the average of all developing countries. It was worse compared with the world average and the average consumption in USA i.e. 1/9th and 1/48th respectively. Due to the international hike of oil prices, Pakistan was further adversely affected in this connection.

Abu Mohammad Izharul Haque, B.Sc. (Engg), Fellow of the Economic Development Institute of the World Bank, Fellow I.E., Fellow I.E.E. Deputy Managing Director, Energy Planning and Development Project, Planning and Development Division, Government of Pakistan, Islamabad.

The views expressed in this paper are those of author.

The import bill of oil and petroleum products, which was $ 152 million in 1973-74, rose to as much as $ 1.7 billion, in 1981-82 and was no less than $ 1.44 billion in 1984-85. In 1981-82 it was equivalent to 68.7% of the country's foreign exchange earnings from exports and 57.6% in 1984-85.

When Pakistan gained independence, in 1947, the main source of commercial energy was coal which contributed 59.1% next was oil which contributed 37.8% and 3.1% was contributed by hydro-electricity.

Gas was discovered in 1952 and was quickly developed with the result that in 1964, the contribution by coal in the commercial energy went down to 5% and gas went upto 22.8%.

In 1971-72 the percentage of coal went up to 8.3% and gas went upto 33%.

In 1982-83 the total primary energy was estimated at 23 million tons of oil equivalent 1/3rd of which came from non-commercial energy resources like firewood, charcoal, cow-dung and the like.

The contribution from coal in the remaining 2/3rd of the primary commercial energy, estimated to be 15 MTOE, went down to 5.1% and the percentage from gas went upto 38.7%. Contribution from oil was 39.0%, hydro-electricity 16.6% and nuclear and LPG 0.6%.

In 1984-85 the commercial energy supply was estimated at 17.5 MTOE, with the share of coal at 8.4%. The share of gas was 39.7%, oil 34.4%, hydro-electricity 16.6% and nuclear and LPG 0.9%.

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The first few years, after the achievement of indipendence by Pakistan, in 1947, were of formative nature and the 5-Year Plan cycle started in 1955. The development of energy sector continued within the framework of the overall development strides envisaged and developed during the various 5 year Plans.

The period from 1970 to 1978, which included the 4th Plan period (1970-75) was, in essence, a period based on Annual Plans. There was stability in international oil prices in the fifties and sixties. However, a spate of price hikes started after 1972, when the cost of oil per barrel went up from $ 2 in 1972 to around $ 12, in 1974.

The 5th Five-year Plan was started in 1978-79. The main objectives of the 5th Plan were to improve the overall economic condition. The prioirty was given to the completion of the massive projects like Karachi Steel Mill, Khanpur Dam, Hub Dam and Port Qasim. The diversion of sizeable capital resources to complete such big projects, reduced the availability of funds for many other sectors, including the energy sector.

The 5th Plan envisaged the streamlining of growth of different sectors of economy and the maintenance of balance between growth of sectors of economy and infrastructure. During this period, i.e. in the late 1978 second round of oil price hike started and the price at official level went upto $ 34 per barrel with higher spot prices.

The comparative position of growth in different major parameters of the economy during this period compared with the previous one is reflected in the following table:-

	Years			Annual growth rate (%)	
	1972-73	1977-78	1982-83	1973-78	1978-83
Population (10^6)	65.9	76.6	89.1	3.05	3.07
GDP (10^6 Rs. 1959-60 prices)	35,179	45,054	61,600	5.07	6.46
GDP per capita (Rs)	534	588	691	1.95	3.28
Manufacturing sector GDP(10^6 Rs. 1959-60 prices)	5,678	6,996	11,445	4.26	10.35
Agriculture sector GDP(10^6 Rs. 1959-60 Prices)	12,821	14,368	17,609	2.30	4.15
Primary commercial energy supply (MTOE) excluding feedstock	7.33	10.11	15.72	6.64	9.23
Primary energy supply per capita (K.G. of O.E.)	111	132	176	3.53	5.92
Electricity (10^6 kwh) generated	8,377	12,375	19,697	8.12	9.74
Electricity per capita (kwh)	127	162	221	5.00	6.41

The annual compounded rate of growth of GDP during the 5th Plan (1978-83) was 6.46% whereas in the earlier 5 years, i.e. from 1973-78 the rate of growth was 5.07%.

In the manufacturing sector, the rate of growth of GDP was 10.35% whereas in the earlier five years period this was less than half at 4.26%.

Similarly, in the case of agriculture sector, the annual compounded rate of growth was of the order of 4.15% whereas in the earlier five years it was almost the half, i.e. 2.30%.

Naturally this indicates that an impetus was given in the manufacturing and agriculture sectors during the 5th Plan period with the result that the rate of growth of commercial energy supply during the 5th Plan period (1978-83) went upto 9.23% per annum against 6.64% in the earlier five years.

In case of electricity generation also, the rate of growth was recorded as 9.74% whereas in the earlier five years period it was only 8.12%. This was mainly due to the increase in the production of hydel energy which has since 1969-70 accounted for more than 15% of the commercial energy supply as against only 3.1% at the time of Independence in 1947.

In addition to hydel energy, thermal energy was generated mainly by using gas, which was cheaply available supplemented by the furnace oil and, to some extent, high speed diesel oil. Coal played only an insignificant role in power generation.

Efforts were made to match the supply with demand but at the last part of the 5th Five year Plan, it was seen that power loadshedding had to be resorted to. The factors contributing to power load shedding included the deferment of Tarbela unit 9 and 10 of 350 MW capacity for a study to instal bigger units, delay in the completion of Bin Qasim unit No.1 of 200 MW capacity due to financial difficulties, the hydel generation was less than the envisaged and the uncertain supply due to fuel difficulty from 137 MW nuclear power station in Karachi also added to the power deficit. In case of gas, during winter months when thermal generation is much needed, it was difficult to meet the daily peak demand necessitating gas load-shedding.

The 6th Plan launched in July 1983 envisages the rate of growth of 9.6% per annum in primary commercial energy i.e. from 15 MTOE, in 1982-83, to 23.74 MTOE, in 1987-88. In 1987-88, the composition of commercial energy is envisaged to be 42.2% oil, 35% gas, 4.5% coal, 16.9% hydel and 1% nuclear and LPG. The main strategy is to make necessary adjustments to high energy prices at

international level.

BASIC OBJECTIVES

The basic objectives of the Plan include the development of demand management through efficient use of energy and conservation, inter-fuel adjustments with the objectives of minimising import dependence and,among others, to develop known indigenous resources, including coal. The coal can be a viable and promising source of fuel for generation of thermal energy, if properly explored, developed and exploited. Let us examine the position of coal as a source of power generation.

The availability of coal in the country was known since the last century. However,it was with the starting of railway system at the turn of the last century that the exploitation of coal got impetus. Between 1880 and 1890 limited coal requirements of North Western Railways were met from coal mines located in the Punjab and Baluchistan.

During the second world war (1939-45) the coal mines in Punjab and Baluchistan were further exploited and the coal was used as fuel in the locomotives despite its inferior grade. After World War two, theproduction again declined.

Commercial deposits of coal are available in the Salt Range Potowar area of Punjab and in Baluchistan and parts of Sind. The important coal fields in these areas are:

(1) Sore Range and Sharigh.

(2) Makarwal-Salt Range

(3) Lakhra-Jhimpir.

Apart from the above, coal was also found in several other locations like Chhoi, in Kalachitta Range, on Chirat Hills near Nowshehra, in Gulla Khail near Kalabagh, in Mianwali District, in Pir Ismail Ziarat,Behlot and Darki areas near Loralai, at Johan near Kalat, in Kotli area of Azad Kashmir, etc.

The following may be categorised as the major coal fields of Pakistan.

a) Baluchistan

(i) Sor Range - Sinjidi Degari.
(ii) Pir Ismail Ziarat.
(iii) Mach-Abegum.
(iv) Kohst-Shahrig-Nakus-Harnai.
(v) Duki
(vi) Chamalang.

b) Punjab

(i) Eastern Salt Range
(ii) Central Salt Range.
(iii) Makerwal - Gulla Khel (extending into NWFP).

c) Sind

(i) Lakhra
(ii) Jhimpir - Meting
(iii) Sonda

COAL RESERVES

For the first time, in 1949, the Powell Duffryn Technical Services Ltd. assessed the reserves of coal in Pakistan on the basis of their survey of coal fields and examination of geological data available at the time and they estimated the coal reserves at 168 million metric tons.

In 1959 the same firm reviewed and confirmed their earlier estimates. In 1960 sizable deposits of coal estimated at around 244 million metric tons were found in Lakhra,in Dadu district.

Recently Geological Survey of Pakistan came up with a coal reserve figure of 796 million tons. In 1985, the Chemical Consultants Pakistan Ltd. reviewed the coal reserves and they came up with 770 million tons with 90 million tons as measured, 160 million tons as indicated and 520 million tons as inferred. (For details see Table-1)

These reserves figure include the coal reserves now measured, indicated and inferred to be 498 million ton in Lakhra, 8.6 million tons in Duki and 57 million tons in Sonda. At Lakhra the proven reserves were shown to be 62 million tons. However,subsequent investigations have revealed that in Lakhra, the measured and proven quantum of coal are

now estimated to be over 110 million tons; measured, indicated and inferred coal reserves in Duki, 44 million tons and in Sonda (Thatta) 500 million tons.

It is thus seen that the quantum of coal, including the proven ones, indicated and inferred would exceed 1,200 million tons. However, geologically coal reserves are considered to be about 2 billion tons.

The quality of coal varies in different geological structures, from lignite to sub-bituminous with calorific value ranging from 5,000 BTU per pound to 12,000 BTU per pound. Sulphur content varies from 5% to 10%, ash content from 7% to 50% and volatile materials from 25% to 38%. The moisture content varies from 3.5% to 27%. (For details see Table-2).

During the recent years the production of coal has remained steady and has ranged from 1.5 to 1.9 million tons per annum. In 1984-85 the reported production of coal was 2.24 million tons and imports were estimated at 0.72 million tons bringing the total to 2.96 million tons. There is an element of unreported coal also for which authentic figures are not available but may be estimated around 0.5 million tons, thus the total consumption of coal works out to about 3.5 million tons.

The imported coal is being used in Karachi Steel Mill. In 1984-85, of the reported production of coal, 97% was used in brick industry, about 1.5% (32,000 tons) in power generation at Quetta and the remaining 1.5% in household, cement industry etc. Power generation at Quetta, based on coal, comprises two units of 7.5 MW each with a total derated capacity of 12 MW.

Coal can be used more and more for power generation, in substitution of furnace oil, in cement plants, as a substitute of bagasses, in Sugar mills, as fuel, in other industries. However, the major prospects of coal consumption are in the field of power generation.

Based on a detailed study conducted by Chemical Consultants Pakistan Ltd., they have come up with the feasibility to use 0.4 million tons/annum of coal in sugar industry based on Pir Ismail Ziarat and 1.25 million tons in Cement Industry (Possible sources 0.5 million tons from Lakhra, 0.65 million tons from Baluchistan and 0.100 million tons from Makarwal).

To get an idea of the likely power generation based on coal in future very briefly it can be said that the diversified power demand in 1984-85 comes to 4,481 MW and after the rate of growth of 9.6% per annum, as envisaged in the 6th Plan, is applied, by the end of the century, i.e. by the year 2000 the demand works out to 19,000 MW.

Taking into consideration the maintenance reserves, spinning reserves, and the effect of seasionality in case of hydel generation the total required installed capacity works out to 25,000 MW. The installed capacity in December, 1985 was as shown in table given below.

	MW				
	Hydel	Steam Turb-ines	Gas Turb-ines	Nuclear	Total
WAPDA System	2897	930	512	-	4339
KESC System	-	913	225	137	1275
Total	2897	1843	737	137	5614

It means that during the next 15 years we should provide for the installed capacity of 20,000 MW taking into consideration retirements and derating effects of old generating units.

A detailed power supply and demand study, taking into account the monthly power demand, thermal generation, hydel availability due to seasional fluctuations, maintenance and spinning reserves and also the viability of installing different generating units,

In the 15 years period from January, 1986 to December, 2000 the following generation is envisaged:

	MW
Hydel	8935
Steam	6480
Gas Turbine	1100
Nuclear	3600
Total:	20,115

Out of 6,480 MW from steam it is estimated that 2,700 MW can be produced by using coal - 900 MW on Lakhra coal with three units of 300 MW each and 1800 MW on a suitable location with 3 units of 600 MW each. For 900 MW Lakhra coal units the requirement works out to 5.4 million tons per annum (average calorific value 5,120 BTU/lb) and the quantum of coal for 30 years life of the plant works out to 162 million tons while for 1,800 MW to be based on better quality of coal (say average calorific value 8,500 BTU/lb) the requirement of coal estimated at 6.5 million tons per year and quantum of coal for the life of the plant is 195 million tons. Therefore, the total requirement of coal for the generation of 2,700 MW by the end of the century will be 11.9 million tons per annum with a proven reserve of 357 million tons.

Development of Lakhra coal and Power Generation Project

Under the Energy Planning and Development Project (ENERPLAN), with the assistance of USAID, the investivations have been updated and the latest feasibility study shows the availability of coal to the extent of more than 110 million tons, average calorific value being 5,120 BTU/lb and rate of production 4.3 million ton per annum. This can sustain two units of 350 MW each. Further confirmation of reserves will provide more generation.

Other Power Projects

With the assistance from the World Bank, exploration in Duki area has been carried out, preliminary geological evaluation was also carried out by GSP and WAPDA and their report dated May, 1985 has come up with the reserves of coal estimated to be about 44 million tons out of which about 2 million tonnes have a seam thickness of 73 centimetres and for the rest 42 million tonnes, the seam thickness is 30 centimetres. Average calorific value is about 11,000 BTU/lb. The use of Duki coal for power generation is being investigated by WAPDA.

In Sonda Thatta where inferred and indicated reserves are estimated to be about 500 million tonnes, with some intensive drilling and proving of the reserves it is expected that generation to the extent of 600 MW can be based.

Detailed feasibility studies will further open up the feasibility of adding power generation to the extent of 3,000 to 3,500 MW on coal may be possible by the end of the century if concerted efforts are made.

Coal Resource Assessment

In order to explore and develop coal on proper lines under the Energy Planning and Development Project, coal assessment is being carried out by the Geological Survey of Pakistan. Work is based on carrying out systematic integrated studies to assess the grade reserves and potential of coal which will help in achieving the coal production and utilization during the 6th Plan and subsequent plans.

Under phase-I, National Coal exploration Plan is being developed by GSP, in collaboration with the experts of USGS, which will make proper assessment of coal resources of Lakhra, Sonda-Thatta, Coal fields and will develop National Coal analytical laboratory system, particularly under PCSIR, and a National Geo-data Centre will be developed and upgraded.

Proper emphasis has been laid to train geologists, chemists and computer specialists in order to implement the above Plan. The National Coal Exploration Plan, in its second phase, will also look into the priority of undertaking investigations in other structures.

Coal briquetting

Under the Energy Planning and Development

Project, Pakistan Council of Scientific and Industrial Research (PCSIR) is responsible for the component pertaining to coal briquettes. Coal briquettes will be used to substitute scarce firewood and kerosene in domestic, commercial and small industrial sectors.

A market survey for the use of coal briquettes has been conducted. A Fuel Research Centre has been established by PCSIR which is being further expanded so that different types of tests on coal and other R&D activities in respect of briquetting of coal and production of smokeless briquettes can be done by PCSIR.

Besides PCSIR, Punjab Mineral Development Corporation (PUNJMIN), Pakistan Mineral Development Corporation (PMDC) ar also working on coal briquetting.

In Quetta, coal briquettes (non-smokeless) have been produced by PMDC since 1942, current production is about 10,000 metric tons per year.

National Coal Authority

The Sixth Plan envisages the exploring of the possibility of setting up of National Coal Authority which will be the focal point for management and coordination of policies relating to exploration, prospecting and development of coal resources and its use for generation of power and substitution to other energy resources. The authority is envisaged to be set up in the Federal Government and Board of Governors will be having the members from the provinces.

Institutional arrangements

Pakistan's 1973 Constitution postulates geological survey, mineral investigations and assessment of coal to be a Federal subject. The Provincial Governments determine and control the management and rate of development of coal.

Government attaches the highest importance to the participation of theprivate sector in the economic development of the country. The public sector is already over burdened with the demands of the infrastructure in the form of energy, road, communication, etc., besides the requirements of the social sector comprising education, health, rural uplift and urban development.

Moreover, irrigation and management of basic industries consume a large proportion of the limited resources of the private sector. Therefore, it is essential that the private sector plays an increasingly greater role in economic development and reduces the burden on the public sector to enable the latter to attend to more pressing needs of the infrastructure and social services.

In the Sixth Five-year Plan, Government of Pakistan has laid special stress on the participation of the private sector in the field of energy development. Pakistani and foreign entrepreneurs may take part in the development of energy sector, including coal. Foreign entrepreneurs can also form joint ventures with Pakistanis for the development of coal and/or for the entire complex of coal development and construction of power station based on coal.

The difficulties that the coal-mine owners generally experience include the lack of assured and sustained demand, lack of funds, difficulties in infrastructure facilities, lack of modern mining technologies. Due to shortage of funds the private mine-owners also experience difficulties in carrying out exploratory work to find out the quantum of coal and quality of coal. Lack of proper equipment and accessories also pose serious problems.

As we have seen earlier development of coal, apart from other aspects, particularly for power generation has to play a very important role and, therefore, it provides a very good opportunity to theprivate sector mine-owners, both local and foreign, to come up and help develop coal sector.

Suggestions

A well coordinated plan of action is needed to optimally exploit the national coal resources. We have already seen that it is possible to substantially increase the use of indigenous coal for power generation. For achieving this, the following steps are

considered essential:

(1) The exploratory activities being conducted by GSP need be accelerated so that the known resources of coal are firmed up in terms of quantum and also their characteristics be properly found out. Efforts to find out new coal-fields also need be accelerated. For carrying out these activities GSP should be properly strengthened and should be provided with exploratory rigs and training of personnel for this work need be expedited.

(2) In view of the dearth of trained personnel and technical know-how in the field of exploration and the preparation of feasibility reports, the Geological Survey of Pakistan should extend all technical assistance to the private sector also in this behalf.

(3) The laboratories, which are being set up by Pakistan Council of Scientific and Industrial Research, in Karachi, for coal analysis and R&D work should be provided with the latest equipment and adequate arrangements be made to train sufficient number of experts to man the same. It may be worthwhile to have similar laboratories in two more places namely, Quetta and Lahore,to take care of the analysis and R&D work in the region.

(4) As improvement in infrastructure facilities with respect to the private mines is essential for increasing production, Provincial Governments may lay special attention on this work. In this connection some formula may be evolved for the sharing of the capital cost between the private mine-owners and the provincial governments. Assistance in this behalf by the Federal Government may also be considered.

(5) To help the mine owners in their day-to-day work, it would be helpful to have one or more pools of mining and allied equipment for supply, on rental basis or for sale, against easy instalments,to parties requiring them.

(6) Maximum use of indigenous coal be made for the purpose of power generation. If the coal has to be imported for power generation, due to the non-availability of the indigenous coal in quantum needed or quality desired or due to financial/economic considerations it need be ensured that the import of coal in no way hinders the progress of the development of indigenous coal.

(7) Commercial banks should be liberal in providing credit facilities in the energy sector in general and for the development of coal in particular.

(8) As a step towards self-sufficiency serious consideration need be given for the manufacture in the country of modern plant and equipment for exploration and development of coal.

Table-1

SUMMARY OF COAL RESERVES

(Current Recoverable Reserves)

(Million tons)

Major Coalfield		Measured	Indicated	Inferred	Total
Punjab/ NWFP	Makerwal - Main	3.0	7.0	2.0	12.0
	- New seam	-	-	5.0	5.0
	Gullakhel	-	-	2.6	2.6
	Eastern & Central Salt Range	4.0	36.0	13.0	53.0
	Western Salt Range	-	-	0.36	0.36
	Misc. Cherat	-	-	0.04	0.04
Baluchistan	Sor Range-Sinjidi-Deghari	7.6	22.9	-	30.5
	Khost Shahrigh-Nakus-Harnai.	0.3	8.3	19.4	28.0
	Mach	0.5	5.5	7.5	13.5
	Abegum	0.1	2.4	6.5	9.0
	Pir Ismail Ziarat	0.1	1.7	2.7	4.5
	Duki (Private)	0.1	2.0	3.9	6.0
	Duki (public)	-	-	2.6	2.6
	Chamalang	-	-	6.0	6.0
Sind	Lakhra - Main Area	62.0	44.0	274.0	380.0
	- Subsidiary Area	-	-	118.0	118.0
	Jhimpir/Meting	5.0	10.0	25.0	40.0
	Sonda	6.0	19.0	32.0	57.0
	Total:	88.7	158.8	520.6	768.1
	Rounded-off	90	160	520	770

Source: Feasibility study on the utilization of coal substitution of other fuels by Chemical Consultants (Pakistan) Ltd. January, 1985.

Table-2

REPRESENTATIVE ANALYSIS OF PAKISTANI COALS

Field	Proximate Analyses				Ultimate Analysis %				Calorific Value (Btu/lb)		Analyzed by
	Moisture	VCM	Ash	FC	C	H	Sulphur	Chlorine	Gross	Net	
Baluchistan											
Sor Range	14.7	36.4	7.1	41.8	51.2	4.1	5.0*	0.02	9969	9431	(A1)
Sinjidi	10.6	25.9	19.8	33.7	51.2	3.9	4.0	0.01	8764	8290	(A1)
Deghari	12.1	35.5	18.0	34.4	50.9	4.2	2.2	0.02	8840	8326	(A1)
Pir Ismail Ziarat	10.7	38.1	8.1	43.1	60.2	4.5	4.1	0.02	10566	10036	(A1)
Dukki	6.2	33.4	17.6	42.9	57.6	4.2	6.0	0.03	10636	9577	(A1)
Punjab											
Makerwal	3.6	37.6	20.8	38.0	-	-	6.11	0.08	10065	-	(A2)
Padhrar (Cent. Salt Range)	4.2	33.5	21.8	38.7	-	-	9.96	0.04	9942	-	(A2)
Katha	5.2	31.8	32.0	31.0	-	-	5.64	0.06	8024	-	(A2)
Nili	3.5	25.0	47.0	24.5	-	-	5.26	0.05	6121	-	(A2)
Ratucha	3.9	23.2	50.0	22.9	-	-	7.82	0.07	5147	-	(A2)
Sind											
Lakhra (North)	26.9	25.9	24.3	22.9	34.4	2.9	4.3	0.05	5804	5251	(A1)
Lakhra (Central)	24.9	30.3	17.4	27.5	41.4	3.2	4.2	0.11	7073	6516	(A1)
Lakhra (South)	22.7	32.0	14.2	31.2	45.1	3.3	6.1	0.28	7732	7190	(A1)
Jhimpir-Meting	12.25	33.98	31.23	22.54	-	-	-	-	7136	-	(A3)
Sonda	13.4	30.3	27.5	26.7	NA	NA	NA	NA	NA	NA	GSP

Analyzed by (A1) - Holderbank A.G. Switzerland
Analyzed by (A2) - N.C.B. Yorkshire Regional Laboratory U.K.
Analyzed by (A3) - PCSIR Lahore

* Differs from Chemcon's 1 - 4 percent analytical results.

Source: Chemical Consultants (Pakistan) Ltd., 1984

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COAL EXPLORATION TECHNIQUES

E. R. Landis
U.S. Geological Survey
Branch of Coal Resources
Box 25046, MS 972
Denver, CO 80225

Exploration has been defined as "searching through or into, penetrating or ranging over for discovery, examining throughly, striving to attain by search." In analogy with research, exploration may be basic - with few or no preconceptions about that which may be found, or, more commonly, applied - designed to yield information of certain types about particular subjects. In practice, exploration consists of a great number and variety of physical and mental activities conducted over a broad spectrum of information creation.

Coal exploration generally begins when a material believed to be coal is observed and reported in some manner. Verification of reports of coal is usually required and may constitute the begining part of a phase or stage (Standards Associated of Australia, 1982 and Sauders and Brown, 1981) of exploration activity that is commonly referred to as the "Reconnaissance Stage." The Reconnaissance stage can be defined as: the establishment of the presence of coal in a geographical area and the gathering, compilation, and synthesis of enough information to allow reasonable inferences to be made about the location and general distribution of coal-bearing rocks and coal beds in the area.

The Reconnaissance stage may lead to an "Early Exploration Stage" which can be defined as: a research stage during which the pre-existing data base is evaluated, information gaps are identified, and existing information supplemented by traditional geologic surface methods such as geologic mapping, detailed stratigraphic description and measurement, and structural analysis. In addition to ground surveys, remote sensing applications of all types are commonly applied during this exploration stage. Both drilling and geophysical studies may be made during this stage for establishment of the stratigraphic and structural framework of the area. The aim of this stage is to determine the feasibility of proceeding with further exploration and if that is warranted, to allow intelligent planning of subsequent exploration activities.

The same type of information-gathering activity may occur during both "Early

Exploration" or in the succeeding stage here designated "Exploration Stage I." However, the major difference in the two stages is the information, or resource assurance-category that is desired at the end of a particular stage of exploration. For example, the bulk of resources estimated during "Early Exploration" may be in the inferred (possible) assurance-category while the bulk of the resources estimated during an "Exploration Stage I" study should be in the demonstrated category (Wood and others, 1983 - measured plus indicated or proven plus probable)."

Consequently "Exploration Stage I" is defined as "the stage during which correlation and lateral continuity of the coal seams and strata are determined along with preliminary information on possible exploration methods and utilization potential. This is commonly largely achieved by the drilling of exploratory bore holes on a relatively widely spaced pattern. Surface studies including geophysical applications may also be conducted during this stage. The aim is to define potentially economic coal resources and estimate available quantities to an assurance-category of indicated (probable).

Exploration Stage I can be succeeded by Exploration Stage II, which is defined as: those activities that raise information to higher confidence levels to provide the basis for evaluation of mining methods, costs, and potential markets by mining engineers and mineral economists. Commonly, an increased density of information points is required, as well as such studies as pilot and preparation utilization and costing studies and market surveys. As defined, the bulk of the estimated resources of an area at the end of Exploration Stage II will be in the assurance-category of measured (or proved). Information creation activities that follow exploration Stage II are usually considered to be in the category of development or mine planning. Considerable more information can be required, particularly in areas of geologic complexity, but most authorities do not include those activities in exploration."

Exploration, to be intelligent, effective, and economical must be conducted in such a manner that as each piece of information is gathered it is integrated, synthesized, and summarized with all pre-existing information (Sanders and Brown, 1981,

and Mathewson and Gowan, 1981). Consequently, resource hypotheses are commonly in multiple, flexible, and constantly changing formats as information is created during exploration. The geologist or engineer actually conducting the exploration must be able to change or modify the exploration plan as new information changes the hypothesized stratigraphic and structural framework, geometry, and depositional environment of the coal deposit being investigated.

Coal resource assessment has a long history of attempts to standardize the philosopy, methods, and techniques of resource assessment. In the United States, general approaches to resource estimation had been formulated and followed, but standardization in pursuit of comparability was initiated in a national assessment program by Paul Averitt of the U.S. Geological Survey in about 1948.

Beginning in about 1972, vastly increased interest in the use of coal in place of oil and gas led to further development of standardized approaches to coal resource assessment. Much discussion and preliminary working documentation recently culminated in USGS Circular 891, "Coal Resource Classification System of the U.S. Geological Survey" (Wood and others, 1983, and Grace, 1984). The described system is usable for traditional hand-methods of coal resource evaluation and also for the use of computerized approaches. Standardization of methods of coal sample collection, description (Chao and others, 1983), and coal analytical methods received further impetus in the United States by inaguration of a program to create and organize, for computerized data-handing, the coal analytical information resulting from a widespread program of standardized sample collection, description, packing, handling, and storing followed by detailed analyses to yield standard proximate and ultimate analyses plus determinations of heat value, forms of sulfur, Hardgrove grindability, free-swelling character, ash-fusion temperatures, specific gravity and equilibrium moisture. Not all tests were done on all samples but most were done on all. In addition, major, minor, and trace element analyses were done on the coal and/or the resulting ash for a variety of uses ranging from the chemical character of the ash for prediction of slagging and fouling characteristics to determination of such elements as mercury which might be pollutants. To date, about 12,000 of these modern detailed analyses have been completed and have been

computerized for use. Swanson and Huffman, 1976, established the guidelines for sampled collection and analytical methods for this coal quality program.

Coal exploration programs can yield a great variety and quantity of information that is desired or necessary for complete geologic and economic assessment of the coal resource potential of an area. A cost-effective exploration plan should attempt to satisfy a wide range of data-needs for a broad range of disciplines. For example, geologists, geophysicists, mining engineers, mineral economists, and civil, mechanical, and chemical engineers, and probably others, can all derive useful facts from a drill-hole if they are aware of, and involved in, the planning at an early enough stage. The information could cover the whole broad spectrum from geologic setting to utilization.

During the course of exploration it almost always becomes necessary to develop subsurface information about the coal and coal-bearing rocks. In most parts of the world, subsurface information is most economically created in a timely manner by drilling exploration bore holes. The classical form of bore-hole drilling is done with drill rigs designed to recover cores of the material penetrated by the borehole. Coring from "the grass roots" to total depth is commonly done. In relatively recent years, much exploratory drilling for coal has been done with rotary-type drill rigs designed to make only a hole (while also yielding rock cuttings as drilling progresses) and not to recover cores. In essence, core drill rigs are designed to make a hole while recovering a sample of the material penetrated; rotary drill rigs are designed to make solely the open hole in the material penetrated. However, to complicate matters, core drill rigs <u>can</u> drill open holes and not recover cores, and rotary drill rigs <u>can</u> recover cores. Both drill rigs do produce cuttings of materials penetrated regardless of whether they are coring or making open hole, and with both types of drilling, core-recovery is seldom 100 percent and may be much less (particularly in coal). Both types of drill rigs have advantages and both types have disadvantages (Hobbs, 1979, and 1979B, and Australian Institute of Mining and Metallurgy, 1977).

In modern practice, geophysical methods are used as supplements to both forms of drilling. Geophysical bore-hole logging supplies much information about the rocks

penetrated by the drill holes. For example, the geophysical log can often identify where loss of core has taken place and also what rocks were not recovered during coring. In rotary drilled open holes, the geophysical bore-hole log can establish the location and thickness of particular rocks in the sequence that was penetrated. Obviously, geophysical logs can be of crucial importance in activities such as coal exploration where "quantity" information - presence, depth, thickness - is vital. Geophysical logs also can be used for prediction of some "quality" factors such as ash content, and much research is underway for other applications. A great variety of these geophysical methods have been employed in coal exploration. Electrical sounding and both high-resolution and conventional seismic methods are used to help define the stratigraphic and structural setting of coal beds, zones, and coal-bearing rocks. Magnetic methods have been applied with considerable regional and local success in areas where coal beds have burned in place, and both gravity and magnetic methods have been used to delineate intrusive rock masses and buried hills. Satellite imagery, particularly with computerized enhancement, has been widely used to determine the extent of coal-bearing and related rock units and to locate faults and fracture systems that are not observable to their full extent in ground or lower level photographic studies. New techniques such as side-looking airborne radar imagery may help in studies of structurally and stratigraphically complex areas. In essence, almost every method of study applied to other geologic problems either has been, or will be, applied in coal exploration (see Argall, Jr., 1983, 1981, 1978, Muir, 1976, and Knutson, 1983).

The discussion herein is very wide ranging and non-comprehensive in scope or depth. The major point to be derived is that coal exploration is far from mundane. The most successful explorationists are those with the most imagination, cooperative practices, and applied energy.

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SONDA, THE FUTURE COALFIELD OF PAKISTAN

Farhat Husain
Geological Survey of Pakistan

ABSTRACT

Geological Survey of Pakistan has established Sonda-Thatta Coalfield during the last five years by drilling 23 core holes with a cumulative [illegible] drilling in an area of about [illegible] kms². It is located on the both sides of National Highway between Thatta and Hyderabad towns and is 130 kms² from Karachi. Main Railway line passes through west of the coalfield.

Lignitic coal and carbonaceous shale bands are developed in the Jara Formation of Paleocene age at Lakhra, Thatta and Sujawal. Number of coal beds are encountered in the drilling and range in thickness from millimetres to 7.4 ms. The main coal bed is named "Sonda Seam" which is probed in most of the drill holes and is considered to have reasonable consistency in its extension. Pinching and swelling of Lensoid coal beds are pronounced which make the correlation of beds difficult in the southern part of the explored area whereas in the northern part, the coal beds can be correlated on the basis of their position in the geologic/stratigraphic column. Coal beds have greater thickness and better continuity with increased depth in the northern area.

Coal reserves are estimated to be more than 230 million tonnes in the explored area of Sonda-Thatta Coalfield.

LOCATION AND EXTENT

Sonda, is a village located on the National Highway, 3[illegible] kms² from Thatta and 130 kms from Karachi towards Hyderabad. It is the centre of activities of geological exploration for coal by the Geological Survey of Pakistan since 1981. In general, the area lies in the east and north-east of Kalri lake in District Thatta and falls in Toposheet No. 40-D/1 and C/4 (Fig.1). It extends from Jherruck to Thatta in north-east and south-west direction and Jhimpir to Sujawal in north-south direction. Pakistan Railways mainline passes along the northern side of this area.

Previous Investigation

Mr. Waheeduddin Ahmad presently Director General of Geological Survey of Pakistan mapped the area geologically on one inch to one mile scale in the field season of year 1951-1952. Again in 1981, he was responsible for initiating the drilling activities in the area which resulted in establishing Sonda-Jherruck Coalfield.

Acknowledgement

Number of geologists and drillers of the Geological Survey of Pakistan have participated in this investigation. Initially the investigations were restricted to sub-surface information through drilling operations to test the structure, depth and thickness of coal and associated rocks. Later geologists were also associated with the project to prepare a detailed geological map of the area.

The author expresses his appreciation for the cooperation and effective efforts of all those who have participated in these investigations specially

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Iqbal Ahmed Khan and Mohammad Siddiq Khan. Mr. Waheeduddin Ahmed deserve special thanks for his personal interest in this project. His dynamic leadership made it a success.

WAPDA is thanked for providing finances without which drilling of so many holes would not have been possible.

District Authorities provided well located and comfortable camp shelter which is gratefully acknowledged.

Physiography

The mapped area is a part of deltaic plains mostly covered by alluvium and low lying hills. Mangroves, swamps, mud banks and sand bars characterised by changing out-let of the River Indus are part of deltaic area. River Indus has left many imprints on its alluvium in the form of cut-off meanders, bar-uplands, erosion scars; sand levels, meander scars and old flood plains.

Structure in this area plays an important part in the evolution of land forms and drainage pattern as the dips are low and beds are almost horizontal with minor fold structure and flatten out forming vast plateaus like surface.

Due to wind action, sand bars are formed in the plains which are in active form.

Relief in this area is mostly depositional due to fluviatile processess but wind action has also played part.

General Geological

Stratigraphic units in and around Sonda area range in age from Paleocene to Recent. From oldest to youngest, the bed rocks units are Bara Formation, Lakhra Formation and Laki Formation. Surficial units include only alluvial deposits in general.

A generalised table of the rocks exposed in Sonda-Thatta-Jherruck area is as under:-

Unit	Thickness	Lithology
Alluvium	------?	unconsolidated strata, alluvial and eolian deposits of sandstone, siltstone and claystone with limestone and sandstone pebbles beds.
.....Unconformity.....		
Laki Formation (Laki Limestone, Metlai shale, Metlai Limestone Sonhari beds)		
Eocene	125 metres	limestone, clays, sandstone, Marl Lateritic Clays and Lenticular coal in the basal part.
.....Unconformity.....		
Lakhra Formation (Upper part of the Kani-Kot Formation)		
Paleocene, Montian to Landimian	100 metres	Fossiliferous, Limestone, Sandstone, Claystone or Shale.
Bara Formation (Lower part of the Kani-Kot Formation).		
Domian to Montian	9 metres	Sandstone, Shale or Claystone, coal, devoid of mega fauna.

COAL EXPLORATION

Lignitic coal and carbonaceous

shale bands are developed in the Sara Formation (ec Lower Ranikot) of Paleocene age at Ranikot, Lakhra, Thatta and Sujawal. Sara Formation which hosts coal beds has an exposed thickness of 9 metres at Dhaduri. Regional geology of this extensive coal basin of "Hyderabad-High" indicate that in the northern region of Lakhra, coal is formed in "back-barrier" environment, whereas in the southern region in Sonda and Sujawal the coal beds are deposited in Lower deltaic plain. Immediately afterwards the Indo-Pakistan Plate and Eurasian Plate collided in the Late Paleocene time. Based on this assumption, total area of coal bearing basin is considered to be more than 1500 sq.kms. Target in the 1st-Phase of exploration was 650 sq.kms., on the western side of the River Indus (Fig.2). In the exploration area of the 2nd-Phase towards east of the River Indus 30 to 60 metres alluvium covers the bed rock. In the first phase of coal exploration, Geological Survey of Pakistan drilled its first bore hole near Dhaduri ridge along the River Indus, where the exposed thickness of Sara Formation which hosts the coal beds is only 9 metres (Fig.3). Eleven lignitic beds of variable thickness were proved within a depth of 144.70 metres in DH-1. Maximum thickness of the coal bed in this drill hole was recorded 1.32m at the depth of 188 metres. Seventeen bore holes drilled south and west of Sonda proved coal seams from millimetre to more than a metre in thickness (Table II).

The broad strategy of the exploration was to cover the maximum area by drilling bore holes in the least amount of money spent, therefore closed drilling on grid pattern was avoided. About 250 sq.kms.area has been geologically explored for coal by drilling 23 bore holes with a cummulative depth 5056 metres drilling until the end of 1985. The maximum depth of a hole in the area was 365.74 m in DH-18, three kilometres south east of Meting.

Six holes drilled north of Sonda between Meting and Jherruck show better results than the seventeen drill holes probed around and south of Sonda towards Thatta side. The thickness of the coal bed, its continuity and the quality of coal has improved north of Sonda.

Geophysical logger has been used for the first time by the Geological Survey of Pakistan in drill holes 20, 21 and 22 which counter-checks the core logging done physically and the core loss during drilling. Three logs, Gamma HRD, 4π density and Gamma Neutron were used.

The exact thickness of coal beds in many holes is not known because of core loss. In general the core loss occurs at the top of the core because it is subjected to a longer period of washing by drilling water. In some holes however, core loss may have occured at the bottom or middle of the cored section. Core recovery in claystone, shale and coal was about 90 percent. In friable sandstone beds, it was less than 15 percent.

For future coal exploration in Sonda-Jherruck Coalfield, Phase-I area is divided into three segments on the basis of dip depth. These segments are named as Feasible High, Feasible Medium and Feasible Low (Fig.4..).

Proposed bore holes by Geological Survey of Pakistan for Sonda-Jherruck Coalfield in the first phase of exploration are fifty in number which are located 3x4 kms., apart in a grid pattern. Drilling of these bore holes

would enable the GSP to estimate the geological coal reserves with reasonable control of data. More bore holes would be required for converting and proving the geological reserves into mineable reserves.

Coal Characteristics

Sonda coal may be called as good quality lignite and is brownish black to black in colour. It has dull black lustre and black and brown streak. It is soft, flaky, brittle and breaks into small chips. In some places, the coal is medium hard, flakes and fills of purities and resins are irregularly distributed. The depth at which coal seams are encountered, their thickness, and chemical composition is given (Table II). The grade of air-dried coal of Sonda coal seam varies as under:-

Moisture %	9.0 - 39.43
Volatile Matter %	15.54 - 44.5
Fixed Carbon %	15.02 - 58.8
Ash %	1.29 - 39.2
Sulphur %	0.45 - 5.45
BTU/Lbs.	6570 - 9599

Coal beds

In addition to being generally thin, the coal beds of Sonda are also commonly lenticular, partly as a result of original deposition and partly as a result of post deposition erosion, and partly as a result of folding and faulting during which the coal beds are bent, squeezed and broken into complex, distorted, discrete lenses and isolation patches.

Pinching and swelling of lensoid coal beds are pronounced which make the correlation of seams difficult. The beds are almost horizontal to 2 degree dipping towards west.

In general the number of coal seams encountered in the bore holes are placed in three(3) different coal zones like Upper, Middle and Lower on the basis of their position in the geological/ stratigraphic columns (Fig.5,6). The main middle coal seam is termed "Sonda seam" which is considered to have a reasonable consistency in its extension although it could be discontinuous or change to carbonaceous shale and may wash out between the widely spaced drill holes. The coal seams in the upper zone and the above Sonda seam in the geologic column are termed as "Bhaduri Seams", whereas the name "Jherruck Seams" is assigned to the coal seams falling in the lower coal zone below the Sonda seam in the geological column. Three other seams encountered only in DH-20 and position-wise lying just above the Sonda coal seam and falling in middle coal zone are "Bhayatabad Seams".

Coal Reserves

Coal reserves of Sonda seam mostly of " Indicated" and Inferred" categories as a influence in each bore hole. Zero to 500 metres radius is considered for proved reserves, 500 1000 metres for indicated and 1000 to 1500 metres radius for inferred reserves. Area outside 1500 metres radius which can be geologically linked with the extension of Sonda Coal seam is considered for the category of hypothetical coal reserves.

Sonda coal is established from the depth of 117 metres at Bhaduri DH-1 to 240 metres at Meting in DH-[illegible] For commercial exploration, a cut-off thickness of 0.60 metre is considered for the reserves calculation. Sonda seam alone has a total of about 140

million tonnes of coal in an area of about 250 sq.kms; Out of which 15.58 million tonnes are proved, 46.69 million tonnes indicated and 77.74 million tonnes inferred reserves. An additional hyphothetical reserves of 32 million tonnes are worked out for the Sonda Coal Seam with the cut-off thickness of 0.60 metre: within 97 sq.kms area. (Table I).

Coal reserves from Enayatabad seams (middle coal zone) are estimated to be 2.7 million tonnes proved, 8.14 million tonnes indicated and 13.54 million tonnes inferred where more than 0.60 metre thickness of three(3) seams is taken into account. Total coal reserves from Enayatabad coal seams would amount to 24.38 million tonnes.

The Dhaduri Seams (Upper coal zone) with 0.60 metre thickness has proved reserves of 2.35 million tonnes, indicated 8.63 million tonnes and inferred 14.36 million tonnes, totaling 25.84 million tonnes of coal which would be available from upper zone coal seam. Also Dhaduri seam with 0.3 to 0.6 metre thickness would give 4.05 million tonnes proved reserves of coal 12.34 million tonnes indicated reserves and 20.53 million tonnes inferred reserves.

Coal seam in lower horizon which are termed as " Jherruck Seam " and above 0.6 metre cut-off thickness show 2.93 million tonnes of proved reserves of coal, 8.31 million tonnes of indicated reserves and 14.79 million tonnes inferred reserves, thus making a total of 26.06 million tonnes. Jherruck Seam with 0.3 to 0.6 metre thickness has proved reserves of 1.7 million tonnes, 5.18 million tonnes of indicated and 8.6 million tonnes of inferred reserves.

To sum up all the categories of coal reserves in Sonda and north of Sonda area, 280 million tonnes of coal would be available. Hyphothetical reserves are worked out 82 million tonnes for Sonda Seam only.

TABLE - I: DIFFERENT CATEGORIES OF "GEOLOGICAL" COAL RESERVES OF SONDA - THATTA COAL FIELD, SIND, PAKISTAN (IN MILLION TONNES)

COAL SEAM ZONE	0.60 m CUT-OFF THICKNESS OF COAL SEAM					ADDITIONAL RESERVES BETWEEN 0.30–0.60 m THICKNESS OF COAL SEAM					
	PROVED RESERVES	INDICATED RESERVES	INFERRED RESERVES	HYPO-THETICAL RESERVES	TOTAL	PROVED RESERVES	INDICATED RESERVES	INFERRED RESERVES	HYPO-THETICAL RESERVES	TOTAL	
DHADURI COAL SEAM (UPPER)	2.85	8.63	14.36	HYPOTHETICAL RESERVES 82 MILLION TONNES	25.84	4.05	12.34	20.53	—	36.92	RESULTS ARE SHOWN ON DATA OF 23 BORE HOLES DRILLED IN AN AREA OF 100 SQUARE MILES. (250 SQ KM) ALL CATEGORIES OF GEOLOGICAL RESERVES EXCLUDING HYPOTHETICAL RESERVES WORKED OUT AS 250 MILLION TONNES.
INAYATABAD LENSOID COAL SEAM	2.7	8.14	13.54		24.38	—	—	—	—	—	INAYATABAD LENSOID COAL SEAM FOUND IN DH-20 ONLY.
COAL SEAM SONDA	15.58	46.69	77.74		140.00	1.22	3.7	6.14	—	11.06	SONDA COAL SEAM ALONE WORKED OUT AS 140+11 MILLION TONNES. ADDITIONAL 82 MILLION TONNES COAL COULD BE EXPECTED FROM SONDA COAL SEAM ONLY, IN REMAINING 87 SQUARE KILOMETRES.
JHERRUCK COAL SEAM (LOWER)	2.93	8.88	14.79		26.6	1.7	5.18	8.62	—	15.5	
	24.06	72.34	120.43		216.83	6.97	21.22	35.29		63.48	

GRAND TOTAL: 280.31 MILLION TONNES + 82 MILLION TONNES HYPOTHETICAL RESERVES.

TABLE-II: DEPTH, THICKNESS OF COAL SEAM & CHEMICAL ANALYSIS OF COAL, SONDA -JHERRUCK COALFIELD

DRILL HOLE NO.	BOTTOM OF HOLE in metres	DEPTH OF COAL SEAM From	DEPTH OF COAL SEAM To	THICKNESS OF COAL SEAMS. in metre	% of Core Recovery of Coal	Moisture %	Volatile Matters%	Fixed Carbon %	Ash%	Sulphur %	Laboratories performed analysis.
		in metres									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DH-1	233.2	65.73	66.14	0.41		14.73	34.31	33.08	17.88	8.25	G.S.P.
		80.11	80.62	0.50		13.39	26.16	20.42	27.52	4.92	GSP
		84.02	84.81	0.78		8.49	26.16	23.45	41.90	9.21	GSP
		118.34	119.68	1.32		24.75	32.76	31.34	11.15	0.69	GSP
		45.90	46.15	0.36	90%	-	39.9	41.4	18.7	4.5	PMDC
DH-2	224.6	45.90	46.15	0.36	90%	-	39.9	41.4	18.7	4.5	PMDC
						24.68	31.82	39.13	12.77	4.06	GSP
						10.9	38.00	51.30	10.50	4.5	PCSIR
		175.7	176.6	0.9	70%	-	39.3	41.4	18.7	5.2	PMDC
						21.61	34.25	33.17	10.97	5.29	GSP
						9.00	39.40	55.90	13.5	5.1	PCSIR
		215.00	215.11	0.20	90%	-	47.6	45.1	7.3	3.1	PMDC
						7.00	46.6	64.9	7.0	2.54	PMDC
DH-3	244.1	172.4	173.3	0.90	70%	-	41.7	45.4	12.9	3.1	PMDC
						15.55	36.68	36.23	11.51	2.12	GSP
DH-4	183.2	46.2	46.6	0.40	90%	-	32.4	34.3	33.3	4.3	PMDC
						14.86	28.05	28.57	28.57	4.76	GSP
		120.87	121.2	0.3	15%	-	44.2	48.8	7.00	2.00	PMDC
						14.06	40.54	40.20	5.20	1.17	GSP
		124.05	124.38	0.32	87%	-	48.1	44.6	7.3	1.6	PMDC
		-	-	-		25.10	33.17	36.14	5.69	1.5	GSP
DH-5	178.6	97.5	98.1	0.55	56%	18.44	31.20	30.19	20.17	4.6	GSP
DH-6	218.54	139.12	139.47	0.36	62%	-	32.8	47.9	19.3	1.36	PMDC
						-	34.5	36.75	16.19	5.13	GSP
		173.38	173.63	0.25	100%	-	34.5	48.0	17.5	8.3	PMDC
						-	32.21	35.69	13.18	6.05	GSP
DH-7	155.0	131.82	132.0	0.41	48%		Not ana-lysed				
		137.50	137.80	0.30	52%		Not analysed				
		153.3	154.25	0.91	75%	-	35.6	58.8	5.0	1.0	PMDC
						-	33.35	30.21	3.96	0.56	GSP
DH-8	185.0	82.11	82.57	0.46	100%	-	41.3	50.3	8.4	1.0	PMDC

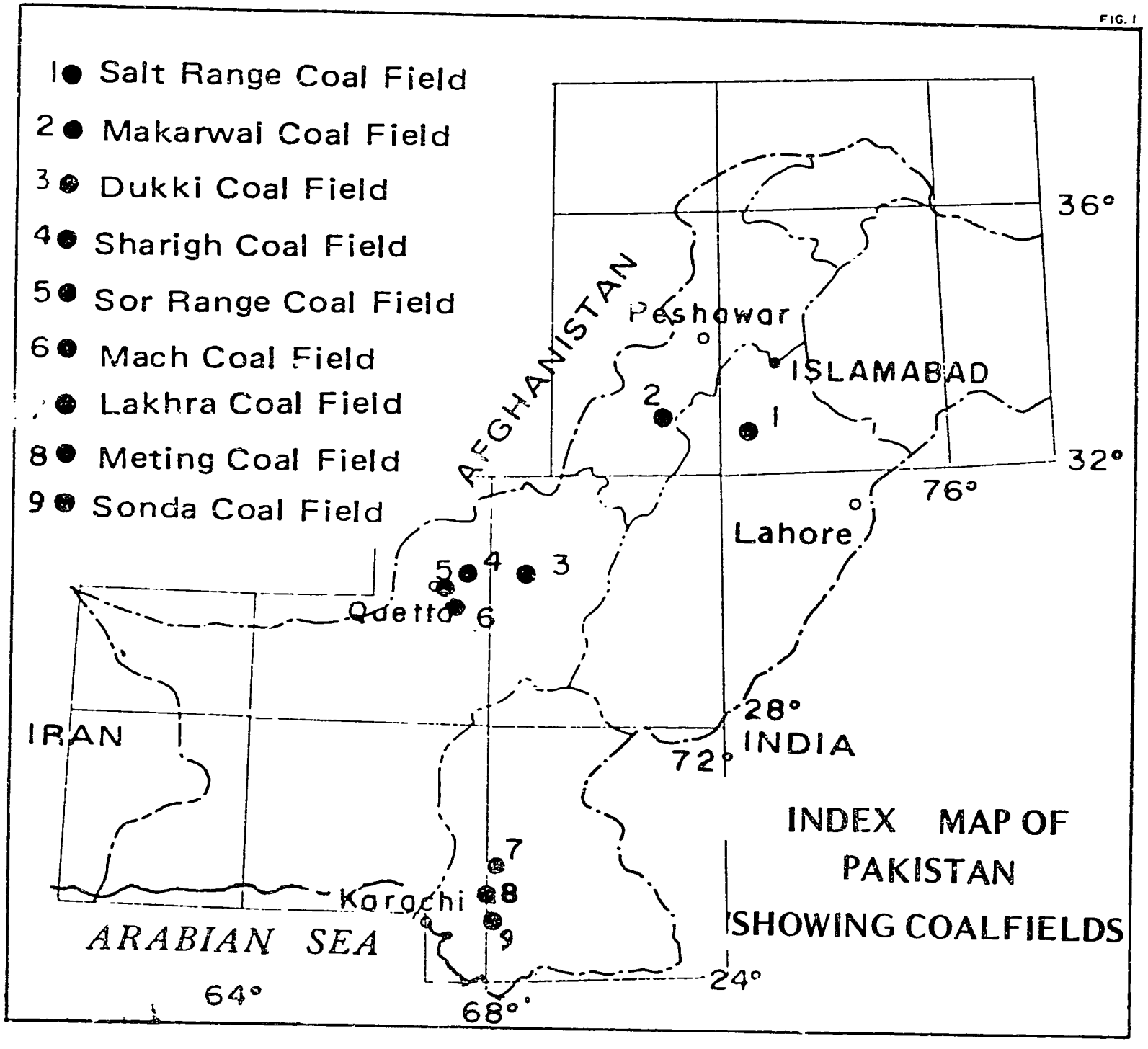
TABLE-II

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DH-8	-	-	-	-	-	-	33.55	34.28	6.44	0.41	GSP
		96.4	96.92	0.53	100%	-	33.7	57.0	9.3	1.5	PMDC
						-	30.95	30.21	3.96	0.56	GSP
DH-9	185.0	67.1	67.31	0.25	75%		Not analysed.				
DH-10	188.0	139.3	139.9	0.61	100%	-	37.1	46.4	17.5	4.8	PMDC
						-	31.25	34.57	12.63	3.02	GSP
		145.1	145.4	0.30	72%	-	Not analysed				
		175.7	176.6	0.91	100%	-	39.5	49.3	11.2	2.9	PMDC
						-	34.74	37.54	8.11	1.96	GSP
		176.9	177.2	0.30	50%						
DH-11	209.0	146.4	146.9	0.48	?	-	15.94	38.17	6.41	3.05	GSP
						-	40.2	45.9	13.9	4.5	PMDC
DH-12	213.3	139.7	140.0	0.33	55%	-	39.2	38.4	22.4	5.1	PMDC
		167.4	167.7	0.33	98%	-	26.35	19.97	32.82	3.63	GSP
		206.8	207.6	0.74	100%	-	33.3	27.5	39.5	1.5	PMDC
						-	19.92	35.99	21.54	4.76	GSP
DH-13	226.1	161.7	162.1	0.36	75%	-	23.58	18.62	32.71	3.90	GSP
							40.1	36.6	43.3	5.2	PMDC
		219.7	220.3	0.67	97%	-	31.87	27.76	26.36	5.95	GSP
							45.1	37.7	17.2	7.1	PMDC
DH-14	192.0	67.4	68.3	0.86	60%	-	17.76	17.06	20.33	5.84	GSP
		136.8	137.0	0.20	71%	-					
		141,0	141.4	0.41	94%	-	30.95	25.97	19.37	2.37	GSP
						-	41.7	34.9	23.4	2.00	PMDC
DH-15	185.0	92.5	93.0	0.46	100%	17.05	32.3	36.9	30.8	4.5	PMDC
							31.55	23.79	27.61	3.96	GSP
		115.0	115.7	0.71	30%	17.29	42.0	41.5	16.5	5.9	PMDC
						-	32.86	23.71	26.15	3.0	GSP
		117.3	118.1	0.79	95%	23.00	38.9	32.0	29.1	4.1	PMDC
						-	33.62	12.58	30.08	4.02	GSP
		148.1	148.7	0.61	17.5%	26.98	44.5	49.5	6.1	1.4	PMDC
					-	-	38.41	15.02	29.15	0.83	GSP
DH-16	228.0	130.0	130.3	0.23	45%		Not analysed				
		171.7	172.0	0.3	96%		33.53	35.32	18.43	4.58	GSP

TABLE-II

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DH-16		172.5	172.8	0.36		-	30.85	31.42	19.21	5.12	GSP
		180.9	181.3	0.40	86%	-		Not analysed			
DH-17	185.0	53.51	53.62	0.10	40%			Not analysed			
DH-18	366.4	45.6	45.90	0.30	95%	10.47	17.97	18.02	53.54	8.69	GSP-Pak Steel
		(Sonhari coal seam)									
		186.8	187.1	0.30	100%	22.10	28.01	35.50	16.39	3.42	-do-
						27.48	30.76	33.36	19.00	3.81	
		225.9	226.2	0.36	90%	11.30	23.52	37.29	27.89	5.48	-do-
						15.03	30.76	29.60	29.14	5.32	
		240.8	242.7	1.9	100%	17.96	27.14	50.14	4.76	1.24	-do-
						20.53	36.41	44.17	5.72	-	-do-
		299.16	299.38	0.39	95%	16.72	13.31	15.64	54.33	0.64	-do-
						8.10	21.63	17.92	53.75	8.63	-do-
		356.6	357.4	0.71	100%	14.48	24.27	44.26	16.99	4.39	-do-
						18.09	35.72	32.98	21.95	3.81	
		359.3	360.6	0.76	70%	17.32	26.69	42.09	13.90	3.54	-do-
						19.25	36.80	36.66	15.69	3.24	
DH-19	305.1	131.7	132.1	0.46	100%	13.42	32.93	41.12	12.53	4.27	GSP
		146.5	147.0	0.43	100%	18.87	31.69	37.81	11.63	3.89	GSP
		184.4	185.2	0.76	100%	14.44	21.81	38.55	25.20	2.18	GSP
		258.6	259.5	0.91	100%	9.81	31.25	43.21	15.73	4.16	GSP
		261.1	261.9	0.76	60%	14.79	27.31	36.88	21.02	3.51	GSP
DH-20	219.8	118.8	119.5	0.61	99%	11.28	33.55	46.42	8.75	2.35	GSP
		124.7	125.6	0.91	95%	12.00	34.61	44.36	9.03	3.55	GSP
		131.7	133.1	1.37	100%	12.50	34.89	45.97	6.64	1.50	GSP
		139.2	141.6	2.43	100%	14.76	26.21	53.05	5.98	0.81	GSP
DH-21		148.7	150.4	1.82	87%	14.32	28.01	46.72	10.95	2.59	GSP
DH-22	259.1	87.4	87.8	0.43	82%		Analysis not yet received				
		153.0	153.3	0.30	65%			-do-			
		179.5	181.1	0.13	100%			-do-			
		184.6	185.4	0.76	100%			-do-			
DH-23	233.8	220.5	221.9	1.37	80% 100%			-do-			

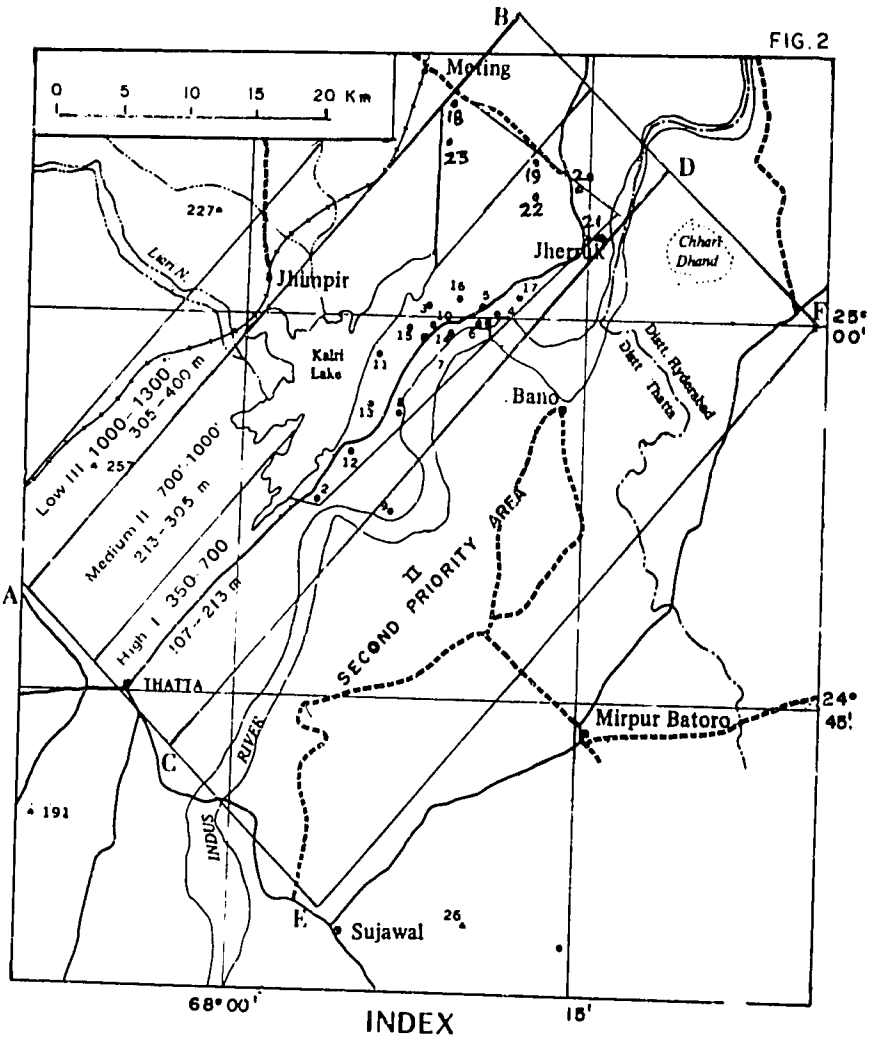
FIG. I



INDEX MAP OF PAKISTAN SHOWING COALFIELDS

MAP SHOWING EXPLORATION AREAS OF PHASE I & II IN SONDA - JHERRUCK COALFIELD

FIG. 2



INDEX

1st Phase Exploration area — 900 sq. km or (350 sq. miles)

Explored area — 250 sq. km or (100 sq. miles)

1. Feasible High area - 400 sq. km or (150 sq. miles) (107–213 m or 350–700 ft.)

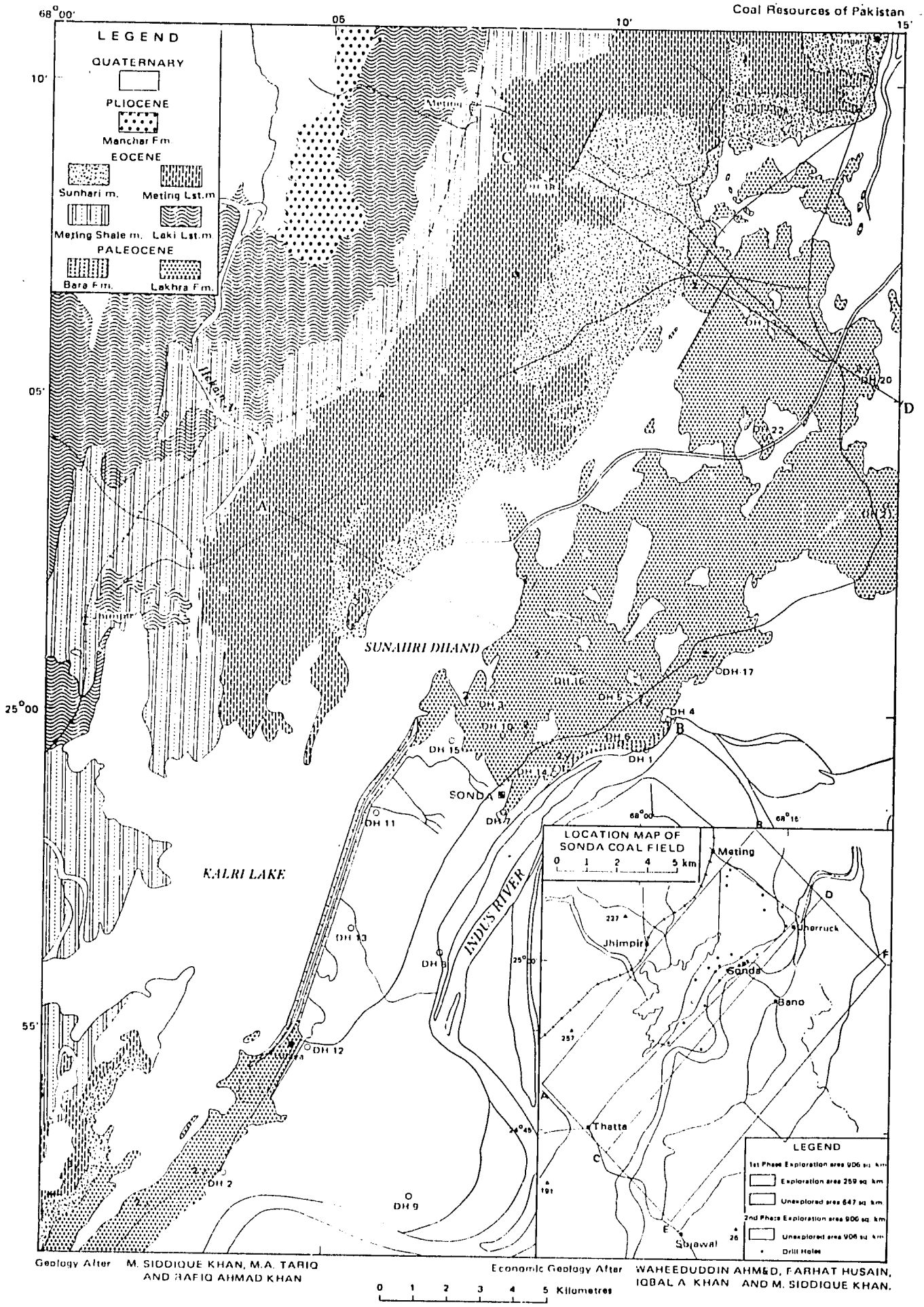
2. Feasible Medium area — 250 sq. km or (100 sq. miles) (213-305 m or 700 1000 ft.)

3. Feasible Low area — 250 sq. km or (100 sq. miles) (305–400 m or 1000–1300 ft.)

2nd Phase Exploration Area — 900 sq. km. (350 sq. miles)

Drill Holes

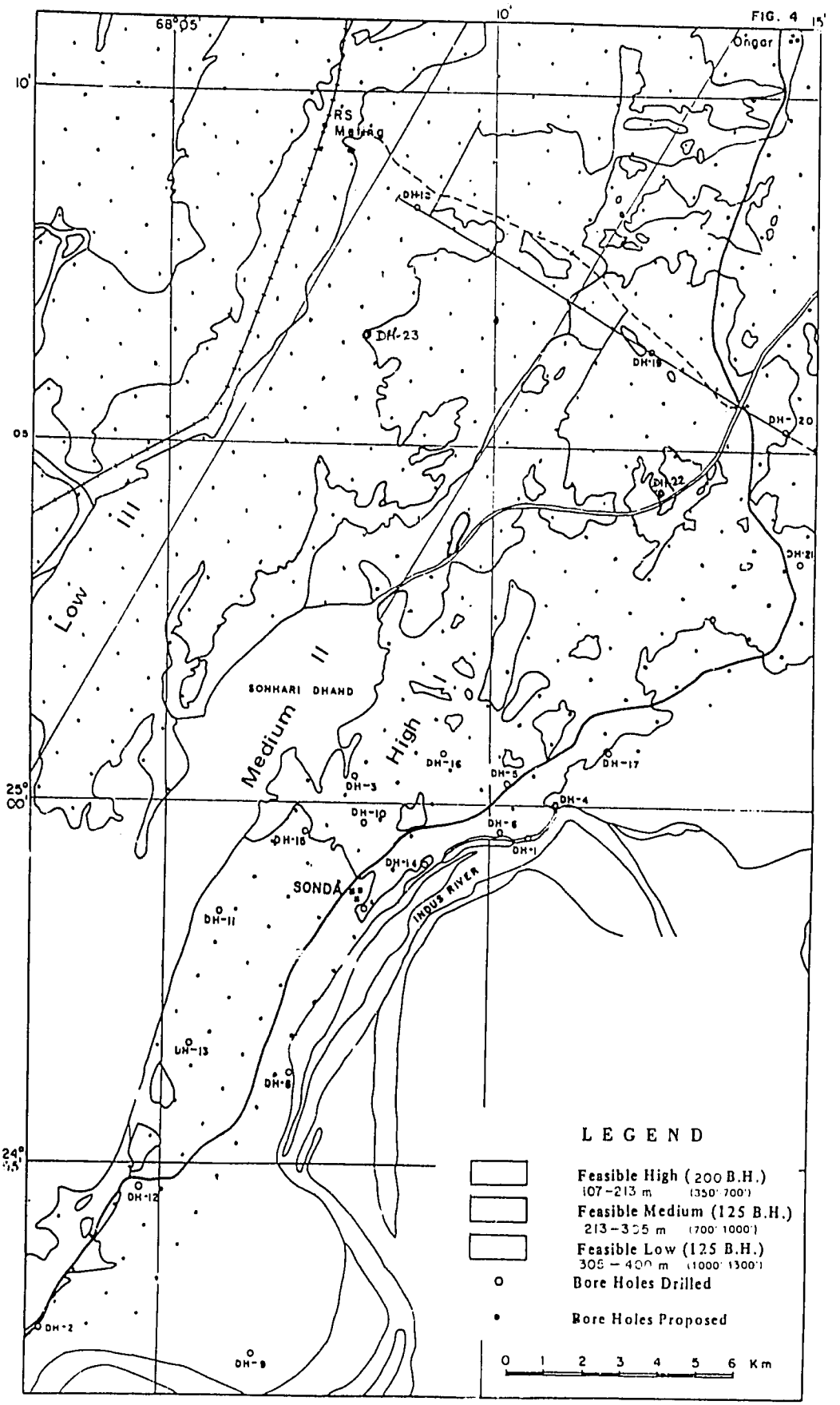
Unexplored



Geology After M. SIDDIQUE KHAN, M.A. TARIQ AND RAFIQ AHMAD KHAN

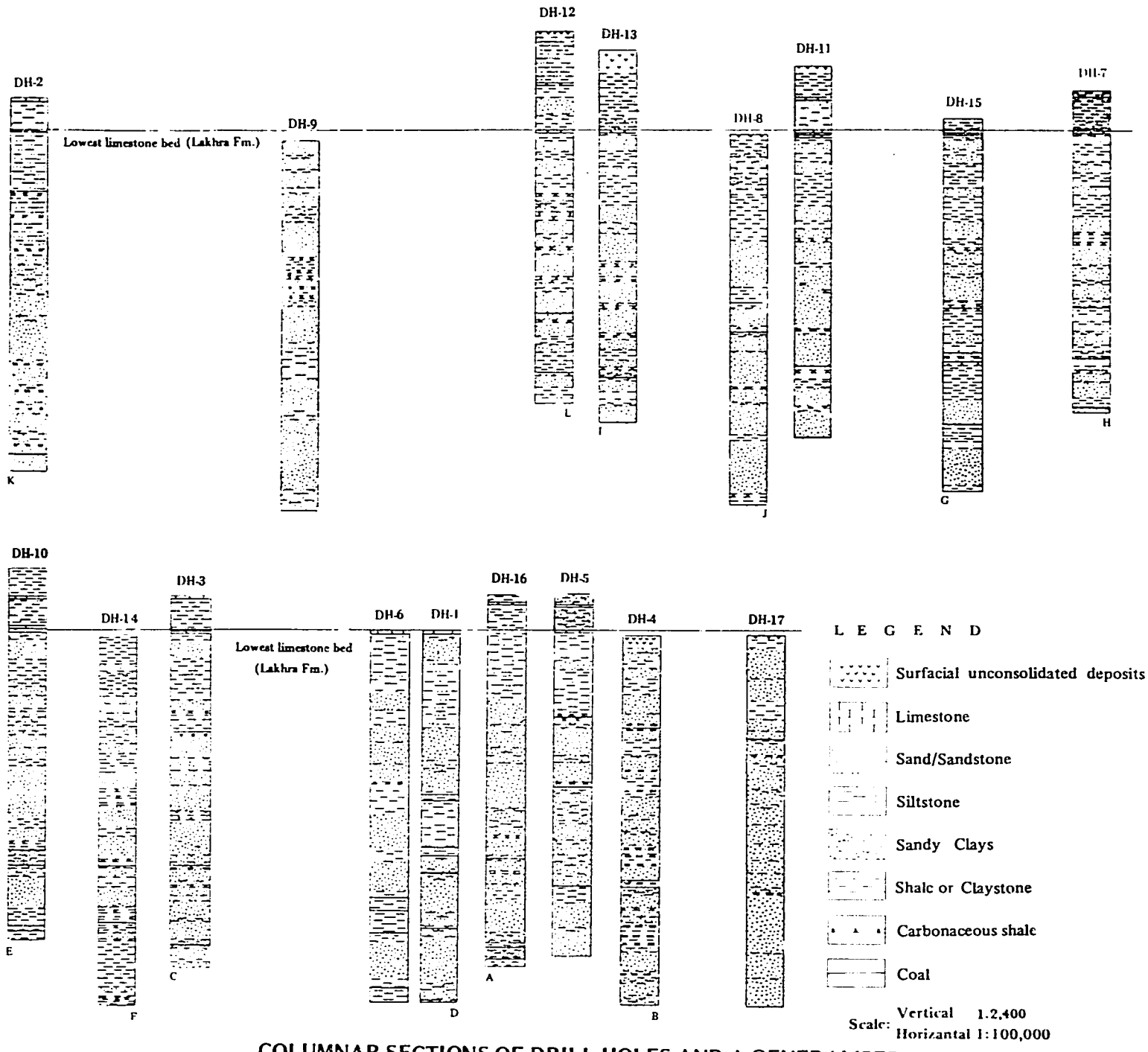
Economic Geology After WAHEEDUDDIN AHMED, FARHAT HUSAIN, IQBAL A KHAN AND M. SIDDIQUE KHAN.

GEOLOGICAL MAP OF SONDA - JHERRUCK COALFIELD AND ADJACENT AREAS

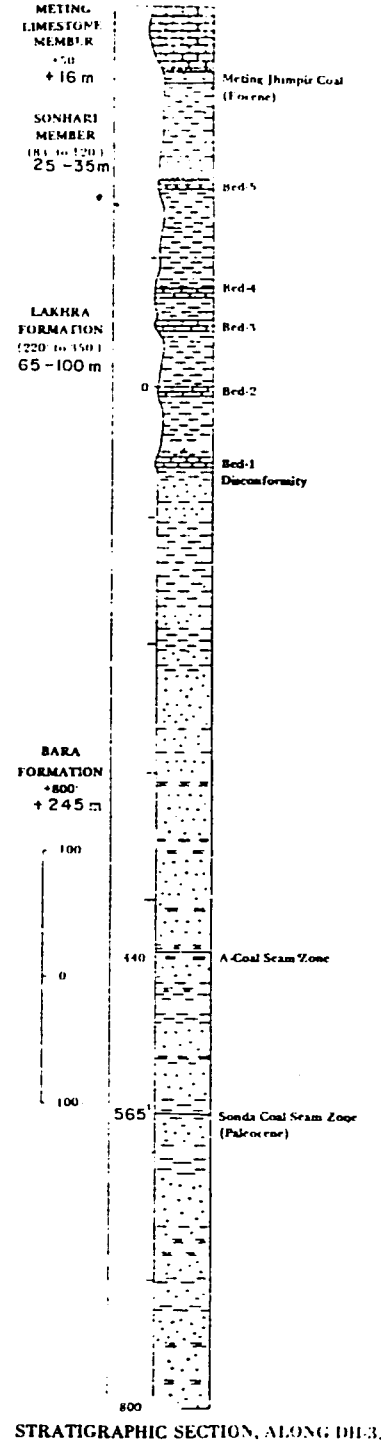


MAP SHOWING FEASIBLE HIGH, FEASIBLE MEDIUM AND FEASIBLE LOW AREAS WITH PROPOSED DRILL HOLE LOCATIONS

FIG. 5



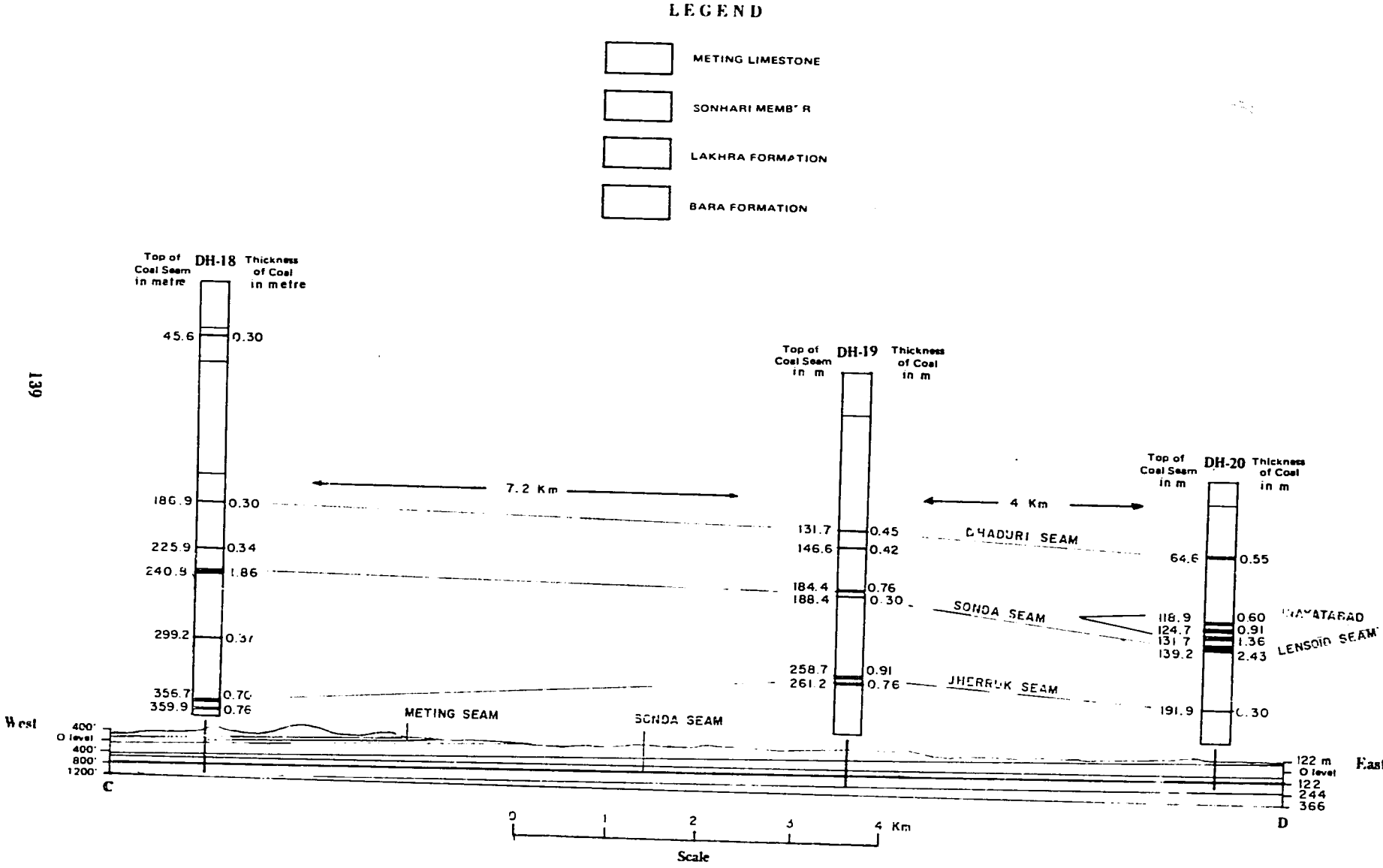
COLUMNAR SECTIONS OF DRILL HOLES AND A GENERALISED GEOLOGIC COLUMN



STRATIGRAPHIC SECTION, ALONG DH-3, SONDA-COAL FIELD

FIG. 6

CROSS SECTION ON THE LINE PASSING THROUGH DH-18, DH-19 AND DH-20



CONTRACT DRILLING FOR MINERAL EXPLORATION AND DEVELOPMENT IN PAKISTAN

Mohammed Istifa, M.D.
Mineral & Engineering Services (Private) Ltd.

Drilling exploration and development in the minerals industry is a vast subject and has over the years evolved into a precise technology in terms of drilling techniques and development of drilling equipment. Diamond bit core drilling is still the most acceptable method of mineral evaluation. The recovery of the rock core enables geologists and engineers to fully evaluate mineral properties in terms of rock types, geochemical analysis, ore grades and thickness, and correlation of rock strata in the subsurface.

Sophisticated methods of mineral exploration have developed over the years as the easily discovered or long known mineral deposits throughout the world have been depleted. Techniques such as remote sensing, geochemical sampling of soils and water and trace mineral analysis of rocks have lead to the initial discovery of many new ore deposits, but it is still the diamond drill that does the bulk of the work and provides the most valuable information about the mineral deposit.

This paper deals with the history, advances, and available technology in the diamond core drilling industry and how it relates to contract drilling in Pakistan.

HISTORY OF DIAMOND DRILLING

The principles of core drilling comes to us from remote antiquity, the ancient Egyptians used tubular drills for boring short holes in the construction of the Pyramids. Examples of early Egyptian cores and drill holes may be examined in the museums today. W.M. Flinders Petrie in "Pyramids and Temples of Gisch" (1885) argues that the tubular drills must have been set with gemstones, but it is more likely that abrasive powders were used. The ancient Egyptian drills were undoubtly hand operated and probably drilled holes of a depth measured in inches rather than in feet.

In 1858, the Mt. Cenis railway tunnel through the Alps between Italy and France was started. Driving a tunnel through solid rock was a formidable undertaking. To advance the phase of the tunnel, men had to drill a pattern of two inch diameter holes six or more feet into solid rock using hand held drill steel and ten pound sledge hammers. It was very time consuming and a hard process. The holes were drilled and then loaded with blasting powder and detonated. The

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Mt. Cenis task was too great for the means available and it became clear that, if the eight mile long project were to be completed, a better way had to be found to drill holes into the hand rock of the tunnel face.

In 1862, Jean Rudophe Leschot, a Swiss Engineer living in Paris, conceived the idea of using diamonds in an annular ring. This revolutionary idea was the forrunner of the modern diamond core drills, which today can bore holes upto a mile or more in depth. Leschot built the first machine in about 1862-63 with the help of a mechanic named Pihet. This first hole drilled by this diamond drilling rig was used for blast hole drilling. The machine had hand rotation and feed and was operated by two men. The bit had an inner diameter of 30 mm and outer diameter of 40 mm.

In 1864, Leschot built a steam driven machine with a speed of 20 rpms, which was used on the Mt. Cenis tunnel. The machine was capable of a penetration rate of 25-30 cm/hour in hard granite. The core was 31 mm and the outer diameter 43 mm. A bit cost from 14 to 21 dollars.

In 1867, M.C. Bullock patented a steam driven diamond drill. The machine operated at 250 rpms. He drilled the first deep hole for coal in 1870, near Pottsville, Penn. The hole was 215 meters deep.

By 1870 drills driven by 5-7 HP steam engines and speeds greater than 360 rpms were available on the market. The steam engine proved an excellent source of power for diamond drilling. It had ideal speed/torque characteristics; the speed of the engine was simply controlled by throttling the steam inlet to the engine by means of a valve. It was necessary to generate steam at the drill site and coal was the common fuel, and was usually available in developing coal mining districts, or anywhere within reach of a railhead. When the search for minerals took the prospector and driller to more remote areas, local sources of wood tapped for use as fuel. With the development of the internal combustion engine, steam as a main power source was replaced.

In 1872, Major Beaumont designed a diamond drill in England and in 1875 drilled a hole 698 meters deep. This hole was 130 mm in diameter. It drilled 2.22 meters in 12 hours and since it only drilled 25 percent of the total time it was not very effective.

In 1886, the Germans had designed a combination diamond drill with cable tool bits for softer rocks and drilled a hole 1748 meters deep.

In the closing decades of the nineteenth century diamond drilling became attractive to prospectors and developers of mineral deposits. The introduction of a swivel head that could be swung out of the way when the drill rods were hoisted or lowered, the inclusion of a hoist with the machine, the adoption of the double tube core barrel, the application of hydraulics, and the introduction of the wire line systems raised the productive rate of drilling. Over the years pronounced improvements in the quality of steel

used in the drilling rods and drilling accessories, and the use of granduiar diamonds (bortz) in mechanically set bits and reaming shells were very marked advances. Developments such as these are continuing to improve the design of drills and drilling accessories.

USE OF DIAMONDS

In theory the principles of drilling rock with diamonds is simple, although, its practical application requires considerable ingenuity, both in the design of equipment, and in its use to achieve acceptable results.

The diamond is pure carbon, the hardest substance found in the earth's crust In the fierce heat and pressure of deep seated, intrusive, igneous pipes, carbon is crystalized into the isometric form of diamonds. Industrial grade diamonds are set into the face of a tubular bit, rotated at proper speed and pushed with the right pressure against the rock. When this happens the diamonds will cut away the rock, allowing a core to enter the interior of the tube.

The earlier diamonds used were the black diamonds obtained from the Brazilian diamond fields, discovered in the first half of the 18th century, almost 130 years before the diamond discoveries in South Africa. The Brazilian diamonds were costly being located in the remote Eastern Brazilian highlands, about 300 miles inland from the Atlantic port of Salvador, 400 miles northeast of the present day city of Brazilia, the deposits were alluvial and the diamonds were scattered over a wide area in stream beds and upland gravel deposits. They did not lend themselves to large scale exploitation, and most of the diamonds were discovered by prospectors and adventurers, working alone or in small groups.

The price of diamonds in 1890 was $20 per carat. By 1900 the price doubled to $40 per carat and subsequently increased at steady rate to a peak of $175 in 1929. After the crash of 1929 the price fell rapidly and by 1935 reached $60 per carat. In the late 1930's diamonds from Africa began to penetrate the world market.

Recently synthetic diamonds have been introduced and are now widely used in diamond drilling tools. Polycrystalline synthetic diamonds are available in the form of triangles that are set in a metal matrix by the drill bit manufacturer. Because the diamonds are thermally stable to 2192 degrees F.(1200 degrees C.) under inert atmospheres they can be adapted to existing high temperature metal bond systems.

Due to the polycrystalline micro structure, the triangles do not have the inherently weak planes of mined diamonds. The tiny diamonds in the polycrystalline triangles have strong carbon to carbon bonds so they resist fracturing in all directions. Individual facets fracture during drilling, which expose fresh, sharp cutting edges. As a result, the polycrystalline diamonds have far less of a tendency to polish or wear smooth as do single crystal natural

diamonds. This results in consistently efficient cutting action throughout the long life of the synthetic diamond bit.

HISTORY OF DIAMOND CORE DRILLING IN PAKISTAN

Diamond core drilling in Pakistan was started at the Warsak Dam site in 1949 for geotechnical studies. Two Swedish core drills were imported by the Central Engineering Authority (CEA) with only one size of drill rods and three different sizes of core barrels The core barrels were single tube core barrels. The drilling rigs and pumps were driven by electric motors through transmission shafts and flat belts. The drill rigs could be easily broken down into parts which could be carried by manual labourers on foot paths to drill hole platforms on sometimes hilly terrain. A water pipe-line was laid from the Kabul River to storage facilities at the project site, then pumped into the hole by the reciprocating pump at the drill.

An investigation for the dam foundations and the underground power house were carried out. The most interesting and challenging job was drilling for bedrock. The drill rig was mounted on a barge made of two boats and anchored at four points by wire cables to the banks of the river. Before reaching bedrock, the overlying alluvium consisting of gravel and boulders had to be penetrated by percussion drilling methods and frequently the large boulders were drilled through and blasted. The progress was slow, and when the casing reached bedrock core drilling began. Warsak was the first project where core drilling was started.

There were two foreign drillers appointed to this project and one Pakistani who had some experience in drilling. The CEA wanted to appoint qualified engineers for this project and Mr. Mohsin Ali, then chairman of CEA had the vision and foresight to see the importance of diamond core drilling to Pakistan. He wanted engineers to come into this profession with a good starting salary, but had problems attracting qualified engineers for this blue collar job. Our engineers in those days did not like "getting their hands dirty". As a result only two engineers were appointed as Assistant Drillers with one leaving after a short period of time, leaving only one, who somehow stayed on because of the Chairman's persuation and advice.

Since the infancy of core drilling in Pakistan the lack of trained personal has always been felt.

At the conclusion of the Warsak project, the core drills were transfered to the Mangla Dam Site. The core drilling was done by the Public sector because there were no Pakistani drilling contracting companies with the equipment and expertise in core drilling. The private sectors experience background was in water well drilling. These private sector companies had no knowledge of core drilling or its future importance to the development of Pakistan. Since they lacked in

the technical know-how they were slow into entering into this field.

A second and equally important factor was the lack of investment capital available to the private sector drilling companies.

When core drilling projects developed in Pakistan foreign drilling companies came to Pakistan and did the work. The private sector attempted to bid on this work, but could not be considered competitive because of the lack of proper drilling equipment and trained personnel. What they did have was old machinery and drillers unfamiliar with the type of drilling required. Once again the lack of trained personnel and proper equipment inbibited the Public sector from taking the private sector seriously.

DRILLING FOR MINERALS

Drilling for mineral exploration differs from drilling for geotechnical site investigations in a number of ways. One, the average overall depth of a drill hole is usually much greater for a mineral exploration hole than that of a geotechnical hole; two, geotechnical/civil engineering projects are usually concerned with the near surface rock materials, whereas in mineral exploration the major concern is usually with rock at depth; three, geotechnical projects are concerned in recovering undisturbed samples for geomechanical testing whereas mineral exploration is concerned with, core recovery and ore grade values.

Diamond core drilling is the most acceptable method for :

(1) Obtaining geological data,
(2) Mineral exploration and development
(3) Blocking out ore reserves,
(4) Designing mine pits and mine development.

The most reliable method of obtaining subsurface geological data is core drilling. The core can be physically examined and analyzed. Coring is also done to help in the interpretation of the stratigraphy and collect data on mineral occurances.

The largest application of diamond core drilling is in the field of mineral exploration and development. Drilling is done to locate mineral deposits, to assess the deposit, that is to gather information on the geometry of an ore body, to identify the geological processes that may have disturbed it , and to evaluate the quantity and quality of the ore.

By core drilling, anomolies such as fault can be identified in advance of mining and potentially save large sums of money that may have been expended by having to do exploratory drifting, cross cutting, or raising or sinking a shaft.

Information secured by drilling enables the workings to be laid out with maximum effeciency from the stand point of haulage and extraction.

When a prospect has been trenched, mapped geologically and by geophysical methods, and properly drilled,

the ore reserves can usually be computed with reasonable accuracy as to tonnage and grade.

Economic minerals deposits occur in varied types of geological environment, flat lying, such as coal deposits; massive ore bodies, such as porphyry copper deposits; vein deposits, such as precious metals. These different type of mineral deposits required varing types of drilling patterns.

The diamond drill, of course, only punctures the ore body and can hardly be said to open it up. In consequence, the estimate of an ore body unless intersected at a large number of points by drill holes, has to be carefully considered. The layout of bore holes will vary depending on the type of mineralization and geological structure incountered. Some minerals require rectangle or square drilling patterns using vertical holes, others parallel sections using inclined holes.

The geologist must decide on the proper spacing from data available. This is very important if the cost per proven ton is to be kept low.

HISTORY OF MINERAL DRILLING IN PAKISTAN

Drilling for minerals was started by the Geological Survey of Pakistan (GSP) in 1957. ICA (International Corporation Administration now known as USAID) provided four diamond Core Drilling Rigs with E size accessories and screw feed drilling heads. ICA also sent a drilling advisor to GSP for starting the drilling programme.

The accessories with the rigs were too small in size. Subsequently larger size accessories were imported and the drilling heads changed from screw feed to hydraulic.

Lack of trained drillers was the main problem. GSP could get only one Drilling Engineer and two Asstt. Drilling Engineers.

Constrains of equipment, personnel and logistic support did not allow for the operation of more than one drilling rig, at a time.

The first mineral drilling was done for Manganese in Lasbela District and then for coal in the Sor Range.

A training programme was started with the help of ICA drilling advisor. The duration of the training was 2 years, including 3 months in GSP workshop, on the repair and maintenance of drilling equipment, a few lectures were also arranged. Most of the training was on the job training at the drill machines. At the end of the 2 year programme an examination was held conducted by ICA drilling advisor and director drilling of GSP. A diploma in diamond core drilling was awarded to the successful apprentice drillers with most of the apprentices being absorbed by GSP. When other Government and Public Sector organisation started buying their own drilling rigs for mineral exploration and development, the GSP trained drillers joined the organisations and are now heading the drilling sections.

The training programme was a success and much of the credit goes to ICA. The drillers produced were very good and the demand for them increased. GSP trained drillers also went abroad and served in the Gulf States, Saudi Arabia, Nigeria, Canada, Libya, Australia, Papua Newguinea. Whereever they served they were successful and there services were appreciated.

At this time GSP imported new drills ranging from 5,00 ft capacity to 5000 ft. capacity, and started operation in East Pakistan (now Bangladesh).

Drillers of GSP drilled the deepest core hole (in Pakistan) at Bahadurkhel District Kohat. The depth of the hole was 1375 meters using "N" size core rods.

The drilling capacity of GSP increased tremendously after the import of drilling equipment and the availability of trained drillers. GSP at one time were operating 7 drills. GSP drillers also had deep drilling experience in coal drilling in former East Pakistan.

After the start of core drilling geologists insisted on examining the core of mineral deposits for correct evaluation. The demands for core drilling increased when organizations dealing with minerals imported their own drilling machinery as they wanted to have the information available as soon as possible. Drilling sections were started in Pakistan Industrial Development Corpn./Pakistan Mineral Development Corpn./Pakistan Atomic Energy Commission/ Punjab Mineral Development Corpn./Sarhad Development Authority.

It was not possible to keep the drilling rigs continuously in operation by the Government/Public Sector but they could afford to keep the drills idle and pay their personnel. It is not possible for a private drilling contractor to keep his staff except key personnel and let the other staff go to work for another contractor on into service with the Government.

CONTRACTING DRILLING FOR MINERALS

Contract drilling for minerals has exhibited slow growth for the following reasons :

1) All the minerals exploration and development drilling was carried out by the Government and Public Sector. They imported the drilling equipment and started their own drilling sections.

2) Private mine owners generally did not go for core drilling as they thought it not necessary for their mine development.

3) Contract drilling company could not afford to buy drilling machinery because of the lack of consistent work.

4) Initial investment and maintenance of drilling equipment is high with tool requirement varying according to the type and depth of drilling.

   a) The capacity of rig depending on the depth of the hole.

b) Type, size and quantity of accessories.
c) Requirement of the diamond tools needed to drill a particular strata.

5) It is difficult for drilling contractor to maintain a large inventory, which would require the backing of large capital since these drilling items are not available in Pakistan and each and every item is to be imported.

6) Payment of Custom duties, and transportation to Pakistan makes the equipment even more expensive.

7) Difficulty in hiring and keeping qualified drillers as the continuity of work is not guaranteed.

8) Cost per meter increases when the drillers are hired for short duration.

9) Reluctance of the banks to arrange financing.

Recently Mineral & Engineering Services Ltd. applied for loan against Pak-U.S. Import Programme. Bank raised querry after querry and demanded almost 250 percent cover before the loan was sanctioned after three and half months.

10) With the increase demand for energy, the hole depths are increasing and the minimum acceptable size of core has also increased which means more investment. The drilling industry has been slow to accept the change and is now in trouble to fully accept the challenge.

Historically, the drilling industry has been a high risk business with a very low return to the contractor. There are few, if any, high risk business ventures that will accept the low return that has been common in core drilling.

For this reason the pay scale for drillers is normally lower than for other positions demanding equal skills. This alongwith the problem of working under less than the ideal conditions and constantly moving from town to town makes it difficult to live and keep qualified and experienced drillers.

Because of the low return, the contractor may find it difficult to purchase new drills or tools and he then finds it impossible to compete with those who have the latest equipment. This can only lead to eventual failure.

The contractor cannot simply raise the prices, since there are optional methods of investigating ore bodies other than core drilling. The biggest advantage for this industry is that core drilling produces a representative sample that proves without doubt the existence of a mineral deposit. No organisation would spend a large sum of money to open a mine without confirmation of the facts.

However, it goes without saying that unless core drilling produces good samples and the cost is kept in line other methods will be used in

its place, if not totally, at least in part.

Contractors are therefore required to increase production and control costs, to achieve this they haveto be uptodate with the latest development of equipment and drilling technology.

The first and most important task is to understand as much as possible about the tools that are available.

New drills can provide features that will greatly improve production but again the Contractor should be totally committed to understanding exactly how the drill is to be operated and maintained or he will not only fail to realise increased production but will have extremely high repair costs.

The hydraulic systems that are mechanically efficient and give the best results operate at very high pressures and are highly vulnerable to contamination damage. Pumps and motors of this type can be totally destroyed in a matter of few seconds if exposed to contamination. To have the advantages of hydraulic system, contractor should be aware of proper operation and servicing of hydraulics.

This is best done by training programmes which should include courses in basic hydraulics, trouble shooting and a complete review of the hydraulic systems used on the drill to be purchased. Unless this is done the cost of operating this type of drill will be extremely high and the benefits lost.

Contractors should have the uptodate knowledge about the diamond tools available for drilling through various formations. Unless the proper bit is used and operated in the correct manner the potential of this may not be fully realised.

They should also be aware of the latest developments in drilling chemicals. The proper use of the chemicals can improve core recovery and progress considerably.

New or modifications to previously developed techniques of exploration are making definite inroads in the exploration field with down hole hammers, reverse circulation drilling and the use of non-coring drilling tools combined with coring tools will play an important role in the future of the core drilling industry.

To be competitive and profitable the contractors must consider the following things :

1) Develope highly qualified and trained operators. An attempt by a good driller to operate a drill or a new set of tools without proper training may result in poor performance and costly down time. New drills and tools are more susceptible to damage than the older models.

2) If contractors want to stay abreast of change they should communicate with other drillers not only locally but should also be done on the national and International levels.

3) Investigate the types of tools and drilling procedures to be used, and when purchasing new drills make certain that they have the flexibility to function effeciently under the expected condition. This is very important to remain competitive.

4) Purchase quality products that will give good results and which are backed up by the supplier. Cheap is not necessarily the best.

5) Establish good line of communication with suppliers and insist on good technical aids or training programmes, on the use and care of equipment.

6) Be prepared to discuss cost saving procedures with customers. Obtaining good samples in smaller sized holes by use of drill chemicals, special core barrels or drilling techniques may result in savings over drilling large holes to achieve good recovery.

Drilling contractors must approach the future with an open mind. If they are rigid in thinking and not prepared to use different tools or techniques, the future may indeed be less than prosperous and bright, as customers will use modern techniques for exploration.

The future of contract core drilling in Pakistan is not bright because of the following factors :

1. The job of core drilling is mainly with the Government/Public Sector and they are reluctant to contract work to private sector as these organisation have or want to have their own drilling section.

2. The job being offered by private mine owners and other private companies are not large enough for the establishment of a core drilling section by drilling companies.

3. The core drilling footage offered for contract drilling does not justify the import of latest machinery.

4. Private contracting companies cannot keep the good drillers continuously on their payrolls, and when employed on job to job basis, the drillers salary is higher thereby increasing the cost per meter with the rate becoming less and less competitive.

5) Lack of support from the Government for the import of latest drilling equipment in the form of :

   a) levy of custom duty on machinery and spares.
   b) non-availability of loans from the bank.

It may be added here that under Pakistan-US Import Programme, USAID has given $10 million to two banks to be given as loan to private sector for the import of machinery and commodities in energy and agriculture sector. With personal experience it can be said that the full amount cannot be utilised because of beaurocratic and procedural delays. What is required is more liberal attitude from the banks, instead of being overly conservative.

What the banks are for ? If they cannot take even small risks.

USAID is helping the Private Sector drilling companies and this is very commendable.

Mineral & Engineering Services Ltd. (MESL) was awarded the first contract for Lakhra Coal Drilling Project by USAID. M.E.S.L. was awarded the next contract for the same project by John T. Boyd Company. The contract was extended for Phase II also. MESL drilled 65 holes with a total meterage of 6800 meters upto Phase I.

SUGGESTIONS FOR ESTABLISHMENT OF PRIVATE DRILLING COMPANIES.

The following suggestions which are offered will help the growth of the core drilling industry in Pakistan.

1. Import duties on complete core drill-machine, accessories and spares be abolished.

2. Banks should open the Letter of Credit against a margin of 15% only. They should hypotheticate the imported machinery for extra cover.

3. The core drilling job which is being done by Government/Public Sector, be offered to private contracting Companies. Contractor will do the job economically, effeciently and quickly. In this way the Public sector will not have to maintain a drilling section even when there is no work. The saving in maintenance of drilling machinery, logistic support and maintaining an establishment will be quite substantial.

4. Core drilling is an industry and should be treated as such it should be given at least five years exemption from all the taxes including incometax.

5. The industry should also be allowed to import new tools for modernisation. The new tools mean the newly developed accessories for improved core drilling. This will not only help to reduce the cost per meter but will also give better results for assessment of a mineral deposit.

6. Executives and employees of private drilling companies should be allowed to travel abroad to attend seminars symposium and drilling courses. They should be given adequate foreign exchange for that period.

7. They should also be allowed to attend International mining shows exhibitions in order to acquaint themselves with the latest development in drilling machinery and technique.

8. Private drilling companies should be encouraged to hold lectures in Pakistan by inviting foreign guests reputed in their field. In this case the fee paid to the lecturers will have to be repartriated.

9. The mining rules should not be applicable to drilling contractors as drilling is not mining and the

contractors drill for other lease holders.

By bringing the private sector into core drilling, Pakistan will be able to appraise its mineral wealth quickly. This will ultimately result in cost saving as this will advance the development of mineral in the country.

THE FUTURE OF CORE DRILLING

It is difficult to envisage any revolutionary change in the mid-future, such as on-line monitoring of the drilling fluid and cuttings, that will replace core drilling for obtaining truly representative samples of metalliferous ores. There will continue to be developments aimed at improving percentage recovery and recovering core more economically. Indication of borehole deviation without withdrawing the drill string, using perhaps a fluid pulsing technique for data transmission, is a possible core barrel development of the future; for in addition to obtaining representative samples it is equally necessary to know in three dimensions from where the samples originated.

The use of open hole drilling down to known horizons, e.g. a well defined, marker bed, followed by core drilling will probably increase but the main increase in open hole drilling will be in those deposits where down-the-hole geophysical logging can provide most of the information required, e.g. coal. The accurate determination of coal horizons, seam thickness, the presence of groundwater or overburden, roof and floor strengths roof caving characteristics etc. may be determined by block neutron-neutron and focussed resistivity logs; in some geological settings ash content may be determined by cross plotting density log traces with other log traces; a sulphur determination log is still some way off but does not look intractable; while analysis of coal cuttings is well established. Some coring is however still necessary for rock strenght calibration purposes; for accurate ash fusion temperature determination; and for swell and caking properties since these can deteriorate for cuttings suspended for sometime in moisture. With the increasing use of mechanised coal mining in the Gondwana coals of India, Southern Africa and Brazil, the problems of the abrasiveness of these coals are becoming apparent. Mineralogical examination of thin sections of the coal backed up by XRD techniques may be necessary to determine whether special measures are necessary to combat abrasion, and core samples are essential for this purpose.

Future mining operations will increasingly be in lower grade minerals in remote locations, where large scale operations to achieve economies of scale will be essential. With the high capital costs involved and the relatively large errors that can occur by imprecise sampling of low grades, the mining industry will be seeking maximum possible recovery of large diameter cores, with excellent surface finish so that fines are not eroded from the periphery of the core, all at an economic price. Undoubtedly there will

be an increase in open hole drilling, but the mid-future will require more and better core drilling and that will provide a challenge for contractors.

TECHNOLOGY AND NEW IDEAS

a. Combination drills capable of rotary drilling to 4000 ft. and then diamond drilling to 6000 ft. are presently being built and used. These drills are equipped with automatic drillers which regulate pressure on the bit, rpm, torque and pump pressures. The drill operator always has the over-riding capability to not only change the variables of the automatic drill units, but to control the drilling operations as required from present instrumentation. Future drills may be powered by diesel electric and/or diesel-electric-hydraulics.

b. High pressure fluids, 1000 to 3000 lb/in^2 and higher should be considered that would assist in creating failure of rock types during the drilling process thereby increasing penetration rates of the bit. These fluids may have to be pulsated or could be continuous and possibly have inclusions of materials and/or chemicals added to them. Pumping capabilities for these pressures are presently available and tool joints should withstand these pressures, but in some cases may have to be modified as well as the plumbing system from the pump to the drill pipe.

c. Polyurethane foams will be one of the new methods of combating lost circulation. One gallon of material will make 10 to 12 gallons which has a compressive strength of 1000 lb/in^2 after setting ½ hour. Nominal setting times vary from 5 to 30 minutes. Downhole tools will be necessary to place these grout materials in the precise location.

d. Polycrystalline Diamonds: Look for changes to come about in design of synthetic diamonds as well as bonding agents which adhere the stone to the bit.

e. Large diameter holes are once again gaining in popularity and wireline tools are being made which will cut a 146mm size hole and 102mm size core. Several manufactures are making tools 101mm diameter capable of drilling to 10,000 ft.

f. Christensen has developed an anti-jam core barrel device that works well in hard broken rock formations. The principle is to vibrate the inner tube of the core barrel until block's is freed or coring is stopped. Care needs to be exercised in coring as the core may be ground away before enough force is created to activate the anti-jam mechanism.

New ideas and techniques are evolving constantly within the core drilling industry. Contractors should be open minded and work with new products and ideas in their development, for that is what will not only create better returns on investments but will also attract the kind of people into the Industry who will be creative, innovative and

interested in their future and the future of the industry.

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COAL MINING OPERATIONS IN THE PUBLIC SECTOR

A.A. Malik, Ex-Chairman
Pakistan Mineral Development Corporation

SYNOPSIS

The coal fields in Punjab and Baluchistan were the first to be discovered in the sub-continent. The railways developed a few mechanized units during 1800-1900. After relinquishing the mines in 1906 the coal mining in these areas relapsed to scattered small scale operations under the private sector and production fluctuated between 55,000 and 300,000 tons. After independence, production gradually rose to 1,400,000 tons in 1968-69, out of which four public sector mines produced about 250,000 tons. Eighty-five percent of the lease holdings were held by the private sector. The current overall production was about 250,000 tons.

The known coal reserves have been tentatively estimated at 1.2 billion tons and more than half of the reserves are located in Sind. There is considerable potential of locating sizeable reserves in the future. The coal is lignitic to sub-bituminous in character with high ash and sulphur content.

Due to lack of a regular market except brick kilns, the industry is stagnant. There is a lack of infrastructure and investment. Except for the public sector operations and a few notable exceptions, the mining methods are primitive and working unsystematic.

The share of coal in the energy mix has come down to 6%. Most of the mines are located in Baluchistan and Sind, whereas the major market is in Punjab and NWFP. There is a glut of coal in the market and stocks at public sector mines have risen to 142,000 tons. Subject to expansion of the coal market and the firming up of coal reserves, the Sixth Five Year Plan envisaged coal production of 5.40 million tons in 1987-88, out of which the public sector will produce 2.07 million tons, including 1.4 million tons required for the first 300MW unit at the Lakhra Power Station.

There is a need to streamline the mining code and make it more investment-oriented and promote joint ventures between private and public sectors and foreign entrepreneurs. In order to promote development of the coal mining industry, Government has to provide infrastructure facilities in mining areas and special assistance to the private sector to explore their properties, rationalize their operations and develop new production facilities to meet the projected demand for coal.

HISTORICAL BACKGROUND

The existence of coal in the North West Regions was known and recorded in the early part of the last century. The North Western Railway had opened several collieries in the Salt Range, Sor Range and Khost-Sarigh areas between 1890 and 1900 to provide fuel for its locomotives. These collieries were well planned and fairly mechanized and on the average produced about 100,000 tons per annum. After the discovery and growing use of high grade bituminous coal from Bengal and Bihar, the railways relinquished most of the leases, and from 1900 onwards the history of coal mining both in Baluchistan and Punjab was that of scattered and small scale operations by private mine owners and petty contractors. The production dropped from 115,283 tons in 1906 to 54,120 tons in

1929. During World War II the coal production steadily increased to about 3,000,000 tons, of which Baluchistan produced nearly half. After independence in 1948, the production dropped to 250,000 tons and again rose to 744,400 tons in 1959. The public sector operations were confined to three units in Baluchistan and one unit in Punjab. These were either inherited as state operations or given over the public sector agencies in later years. In the meantime there was a phenomenal increase in lease holdings, from a few dozen in 1947 to several hundred covering vast acreage of virgin coal field areas. The production increased to 1,428,000 tons in 1968-69 from numerous small operations and again dropped to 1,129,000 tons in 1973-74 because of market restraint. Out of this quantity nearly 250,000 tons were produced from the four collieries under the control of the Pakistan Mineral Development Corporation. According to an estimate, the present coal production in the country is not less than 2,500,000 tons, which includes both reported and unreported production.

RESERVE POTENTIAL AND CHARACTERISTICS OF COAL

The potential coal bearing areas are located in Sind, Baluchistan and Punjab with total reserves estimated at 1,178 million tons (Table I), which in terms of heat value are equivalent to 526.6 million tons of oil. More than half of the total reserves are available in an area of 700 Km^2 in Lakhra and Sonda. Since all the coal fields in the country have not been explored and evaluated, the current estimates are highly conservative and relate to the areas in operation. The estimates are based on projection of geological data and some subsurface drilling. The coal bearing formations extend over large areas in Salt Range, North East of Baluchistan and Sind. The detailed exploration and evaluation of the existing, as well as new coal fields, will make significant additions to the currently estimated reserves.

The coals found in Pakistan are high grade lignite to sub-bituminous with high ash and sulphur. There are marked physical and chemical variations, both within the individual coal seams as well as from one coal field to another. The coal belong to tertiary age have heating value of 10,000 BTU/lb on the average, with high volatiles ranging from 30% to 40%. High sulphur and high volatile content make it particularly amenable to spontaneous combustion, creating specific problems of storage and coal handling. The quality as such does not figure out against its use in heat generation or gasification processes. However, due to high variations in quality the coal fields need to be thoroughly investigated to determine the range of variation and optimum utilization.

PRODUCTION AND PRESENT CONDITION OF COAL MINING INDUSTRY

The production of coal in Pakistan is shown in Table II and coal production under the public sector in Table III. The level of coal production has been fluctuating due to restricted demand and increasing use of natural gas and fuel oil. The industry is stagnant at present.

Over 85% of coal is produced by a large number of small mines under the private sector. Lack of infrastructure, restricted demand, inadequate investment, too wide a dispersal of productive effort and dependence on "fox hole" mining of easily accessible coal has retarded the growth of this basic industry. A large portion of the coal bearing area has been leased out in a number of small sized blocks which makes it unsuitable for systematic planning and rational long term development.

The mining methods are generally primitive and most of the operations are confined to outcrop working and selective mining up to water level. There is a gen-

eral lack of essential mechanization and safety equipment. Often the economical depth of working was not more than 800 feet from the outcrop because of a lack of essential equipment for pumping, mechanical ventilation and haulage facilities. Naked lights and non-flameproof equipment were used in some mines without any consideration for mine safety.

As a result of unsystematic mining, not more than 60% of the coal was recovered. Except for some notable exceptions, mineowners manage to keep the cost of production low by selective mining of easily accessible coal from shallow depths. The mines under the public sector, however, have been planned and developed for systematic mining in depth with essential mechanization, provision for mine safety and optimum recovery of coal reserves. As a consequence, their cost of production was high as compared to the private sector mines. The control of Government agencies over conservation of reserves and planned development of mines was nominal and there was a disconcerting increase in the number of accidents occurring at the mines. The industry as a whole was neither organized for economic production on a long term basis nor geared to meet the more demanding requirements of a particular group of consumers. Essentially because of lack of a regular market for indigenous coal, no organized effort has so far been made by the industry to pool its resources and encourage higher value use of coal for meeting the long term energy needs of the country.

TRANSPORTATION AND MARKETING

The current use of coal was restricted to the brick kiln industry, which consumed over 90% of the production. The remaining quantity was used for power generation and domestic heating. According to a recent survey, the share of coal in the energy mix has declined from 35.1% in 1958 to 7% in 1983-84, whereas the share of natural gas during the same period increased from 8.5% to 34.2% and of hydro power from 0.8% to 18.5%

The marketing of coal, the mode of transportation employed and location of the mines with respect to the main consuming centers had a direct bearing on the prevailing prices and level of production achieved from a particular region. Punjab and NWFP together consumed 85% of the total coal production, whereas their output was hardly 27%. These provinces depended heavily on Baluchistan for their coal requirements, which produced 52% of the coal while itself only consuming 6% of the total production. In recent years there has been a phenomenal increase of production from Sind which has more than offset the increased demand of brick kilns in Punjab and NWFP during the brick burning season.

Nearly 50% of coal was transported by rail and the remaining quantity was cleared by trucks directly from the mine heads to the brick kilns. In spite of the higher cost of transportation through trucks, road transportation was gaining ground because of the chronic shortage of railway wagons in Baluchistan for coal loading during brick burning season. The kiln owners preferred to take delivery by trucks directly from the lines in order to meet their day to day requirements and to keep their inventories low. Baluchistan coal has an edge for its better quality, but with the easy availability of cheaper coals from Sind, Baluchistan coal was gradually losing its attraction and in the foreseeable future its demand will drop unless more industries and power plants are used in Baluchistan on local coal.

The present production in the country is more than sufficient to cater to the current needs of the brick kiln industry. At present there is a glut of coal in the market because of overproduction and restricted demand. This has adversely affected the coal mining industry. The prices have come down by about 40% and the production has decreased. The stocks at

the PMDC mines, as on December 12, 1985 were 141,732 tons - the highest in the history of these mines. The projected annual increase in demand from the brick kilns will not be more than 5% over the next 10 years, provided the brick kilns are restricted to use coal only. PMDC, with its share of less than 15% in the overall market, is not in a position to play any significant role in determining the sale price of coal. The price of PMDC coal is negotiated with Government agencies and it is tendered on behalf of others on an annual basis. At best it can serve as an indicator to the private mine owners to adjust their prices to suit their convenience. Depending on the quality, they tend to regulate their production and sell at the highest price during the peak season.

SIXTH PLAN TARGETS

Subject to the firming up of additional coal utilization avenues, the Sixth Five Year Plan envisaged coal production of 5.40 million tons by the end of the plan period in 1987-88.

	Million Tons
1983-84	2.7
1984-85	3.1
1985-86	3.5
1986-87	4.5
1987-88	5.4

The above requirement is for power generation, cement plants, industrial process and domestic heating and brick kilns. The share of targets fixed for public and private sectors at the end of the plan period was 2.07 million tons and 3.33 million tons respectively. Under the public sector program PMDC is required to produce 1.97 million tons, including 1.4 million tons for the first 300MW unit of the Lakhra Power Station and "PUNJMIN" will produce another 100,000 tons.

The above targets were fixed on the following assumptions:

- Estimate of indicated reserves will be upgraded through detailed geological exploration and evaluation and sizeable capital will be provided for the purpose.
- Development oriented Mining Concession Rules will be framed and smaller leaseholds will be grouped together to form larger economic units.
- The prices of competing fuels will be rationalized.
- Additional market avenues will be firmed up and infrastructure will be improved.
- The efficiency of Pakistan railways will be improved to handle increased coal production.
- Institutional arrangements will be provided to ensure continuous policy attention and to coordinate planning, exploration, research, mechanization and financing.

POLICY CONSTRAINTS AND PROSPECTS

The leasing rights rested with the provincial Governments and each province had its owon set of Mining Concession Rules being administered by the Directorate of Industries and Mineral Development. Similarly, the administration of the Mines Act, regulations, rules and bylaws concerning safety of mines and workers was the responsibility of the provincial Chief Inspector of Mines. Attempts are under way to incorporate a uniform set of Mining Concession Rules and Mines Safety Code and to make the rules more investment oriented and suited for long term planned development of the industry and in order to attract the foreign entrepreneurs to join in equity participation with private sector and public sector agencies in Pakistan. The Mineral Coordination Board, under the aegis of the Federal Ministry of Petroleum and Natural Resources, provides a useful forum to coordinate these efforts between the provincial

and federal agencies, as well as the public and private sectors.

The major part of coal bearing prospects was held by the private sector controlling nearly 85% of the leaseholds. The detailed exploration and evaluation of the properties involving large risk capital was beyond the resources of private mineowners to undertake. A specially equipped agency has to provide these services out of necessity in order to assist the private sector to plan and develop their mines on a long term rational basis.

Too wide a dispersal of production effort needs to be checked and concentration of output from a fewer number of well mechanized larger units employing latest technology should be encouraged through joint ventures between the private and public sector and with foreign partners of repute whenever it was feasible.

The coal market should be expanded as a matter of priority and national policy by setting up coal based power plants in the coal fields. The use of coal in the cement industry and domestic sector should be actively promoted. The price of competing fuels should be rationalized and a uniform sales policy and adequate coal handling facilities be provided to regulate sales throughout the year.

Lack of infrastructure facilities in the mining areas has inhibited the development of the coal mining industry on a sound footing. The majority of mineowners do not have enough resources to provide for the basic facilities. It is imperative for the Government to provide these facilities in mining areas for the benefit of the industry of mine workers.

Paucity of skilled manpower calls for proper deployment and development of available skills through the implementation of a well-conceived and comprehensive program of training of various categories of employees and transfer of technology in different aspects of modern mining practices.

The added value use of coal in the domestic and industrial sectors needs to be promoted through a sustained program of research and development, together with establishing economic processes for large scale commercial utilization of indigenous coal with high ash and sulphur.

The private sector should be encouraged to invest in the development of new production facilities and adequate credit facilities, both in local and foreign currency, should be extended to them on concessional terms and such entrepreneurs should be assisted in putting together bankable mine development plans. They should be allowed liberal import of mining machinery and equipment and tax holiday to rationalize their operations.

TABLE I

COAL RESERVES ESTIMATES

(Million Tons)

	IEDC'S ESTIMATES 1982		
	Proved	Indicated/ Inferred	Total
PUNJAB			
Makerwal/Gullakhel*	1	15	16
Salt Range	6	80	86
BALUCHISTAN			
Sor-Range/Degari-Sinjidi	12	33	45
Khost-Sharigh-Harnai	10	50	60
Mach	6	15	21
Duki	--	40	40
Pir Ismail Ziarat	--	100	100
Abe-Gum	--	--	--
Chamalong	--	--	--
Sor-Range-Kutch	--	30	30
SIND			
Lakhra	62	178	240
Meting-Jhampir	5	35	40
Sonda-Thatta	--	500	500
TOTAL	102	1076	1178

*NWFP

TABLE II

NATIONAL COAL PRODUCTION

YEAR	PRODUCTION IN METRIC TONS
1947	363,488
1948	244,643
1949	337,643
1950	443,763
1951	512,807
1952	609,661
1953	593,100
1954	562,634
1955	537,441
1956	655,104
1957	523,125
1958	606,077
1959	744,398
1959-60	830,319
1960-61	915,324
1961-62	955,022
1962-63	1,242,391
1963-64	1,256,898
1964-65	1,231,506
1965-66	1,291,170
1966-67	1,280,000
1967-68	1,239,000
1968-69	1,428,000
1969-70	1,269,000
1970-71	1,324,000
1971-72	1,255,000
1972-73	1,204,000
1973-74	1,129,000
1974-75	1,314,000
1975-76	1,138,000
1976-77	1,147,000
1977-78	1,279,000
1978-79	1,387,000
1979-80	1,569,000
1980-81	1,577,000
1981-82	1,750,000
1982-83	1,609,000
1983-84	1,870,000

TABLE III

PUBLIC SECTOR COAL PRODUCTION

YEAR	PRODUCTION TONS
1960-61	213,695
1961-62	232,591
1962-63	256,670
1963-64	262,899
1964-65	295,866
1965-66	296,349
1966-67	332,426
1967-68	453,983
1968-69	434,215
1969-70	472,193
1970-71	386,997
1971-72	377,008
1972-73	343,467
1973-74	321,232
1974-75	298,317
1975-76	255,002
1976-77	258,900
1977-78	235,174
1978-79	237,042
1979-80	253,660
1980-81	206,940
1981-82	204,147
1982-83	171,632
1983-84	220,436
1984-85	257,041

PAKISTAN'S EXISTING MINING POLICIES AND REQUIRED CHANGES

Abdul Khaliq
Managing Director
Amin Fabrics Ltd.

I propose today to discuss primarily the need for formulation of new policies and changes in existing policies which are essential for rectification of past mistakes and required to ensure future progress. The subjects discussed in this paper are:

- Background of the Industry;
- Mining Laws;
- Mining Technology and Manpower Training;
- Combustion Equipment and Technology;
- Capital and Resource Mobilization;
- Energy Policy;
- Conclusion.

Background

Except for a short period of three years, during 1959-62 when the Bureau of Mineral Resources was operating, no mining policies have ever been formulated in Pakistan. It is true that production and investment targets were established under all the 5-Year Plans, but these targets were all set up in a vacuum; no efforts were made to assess, much less provide the inputs required to achieve these targets.

In the case of coal mining the position has been further aggravated by the fact that control of mining was vested initially in the Provincial Governments, then transferred to the Central Government, transferred again to the West Pakistan Government and lastly transferred back to the Provincial Government. These changes have not helped in the formulation of long term policies.

It has been rarely appreciated in Government that mineral projects have peculiarities of their own requiring specialized procedures for evaluation and financing. Unlike an industrial venture, a mineral prospect passes through successive stages of unknown to known potential, and the elements of investment risk remain until the potential of the prospect is firmly established. Development loans are not available to the mining industry, partly because the overall effect of mining laws is to render mining assets "non-bankable" for purposes of security, and partly because financial institutions do not have the expertise to evaluate mining properties, and their development potential.

Coal mining in Pakistan is essentially carried out on a small scale. It functions with a low capital base, in relatively small production units, selling against only short term contracts or on the basis of spot sales, and operates with modest levels of technical expertise. Coal is almost entirely consumed by brick kilns, where the level of combustion technology required is minimal.

While coal prices have been based on normal commercial considerations, the price of competing fuels have been subsidized or fixed at artifically low levels. Industrial users have been to a large extent protected from the effects of oil price increases.

Tax and corporate laws favor individual proprietorships, and considerable disincentives exist which prevent the conversion of proprietorships and partnerships to limited companies. The position of mine owners under the Mining Laws is more or less that of tenants-at-will, and this prevents both large scale and entrepreneurial investment as well as the flow of credit.

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Mining Laws

It is unfortunate that mining is viewed in Pakistan only as a potential bonanza, where high profits are achieved providentially and without efforts. As a result Provincial Governments tend to view grant of prospecting licenses and leases as special favors. Peculiar and discriminatory conditions are attached to the grant of each license. In some cases auctions are held, while in the majority of minerals the first right of refusal is given to Government controlled corporations, e.g. PMDC, PUNJMIN, B.D.A. and others.

Examples can be cited where mineowners have been producing minerals for decades, yet mining leases have not been granted; where minerals were discovered by individuals, yet mining rights were conferred on State-owned corporations or to other interests; and where prospecting licenses granted to mine owners were cancelled and the respective mining areas allotted to Government controlled corporations.

As a result exploration activities have come to a virtual standstill and investment in mining has not kept pace with needs.

Mining laws therefore need to be amended to provide a legal framework which is designed to encourage exploration, prospecting, development, and production. The present mining laws and terms of mining leases are extremely defective and one sided in that the mining companies have little or no legal rights and the Provincial Governments are vested with absolute discretion to determine and terminate mining leases, and allot such leases to third parties.

Committees have been set up, from time to time, initially by the West Pakistan Government and subsequently by the Central Government, to review mining laws. This exercise has been going on since 1964. However, because all Committees set up to date have uniformly recommended that the discretionary powers of Provincial Governments need to be circumscribed, and proprietary rights of mineowners reinforced, these recommendations have never been implemented.

There is no provision in the Mining Concession Rules for exploration of large areas, and delineation of prospective areas be followed by intensive drilling to establish reserves, and planning and development of large scale mining operations. To promote large scale and systematic development it is necessary to ensure the enactment of Mineral Concession Rules which provide for the following:

- Grant of Exploration Licenses over large areas on a first come first served basis for three years, during which the concessionaires survey the entire area and delineate prospective areas with the aid of some exploratory drilling. Such licenses would also carry the right of conversion to Prospecting Licenses and Mining Leases;
- Grant of Prospecting Licenses for up to three years over such areas as are considered prospective for purposes of proving and establishing reserves and preparation of schemes for exploitation of reserves;
- Grant of Mining Leases over areas which are large enough, and where reserves are sizeable enough to warrant large scale exploitation for a period of not less than 60 years;
- Security of tenure to mine owners as are necessary to ensure free flow of credit for the exploitation of reserves; with provisions for evaluation of mineral reserves for purposes of compensation in the event of cancellation or withdrawal of leases or nationalization thereof.

Mining Technology and Manpower Training

Current mining methods and techniques are well suited to the present scale of operations. They have the virtue of being simple and cost effective. However, they are wholly unsuitable for large scale coal production.

Large scale mining represents a totally new order. It will require changes in mining methods, techniques and extensive mechanization. New skills will be needed and existing skills in respect of mining methods, operation of sophisticated plant and machinery and its maintenance will have to be improved. Technical manpower capable of acquiring these skills already exists in the country. The basic infrastructure for training mining engineers and geoscientists is in place and functioning. With the creation of job opportunities, mining engineers and geologists will become available in greater numbers. However, the same does not hold true in the case of skilled manpower required at the mine floor level. Here there is a need to supplement existing facilities by an institution specially oriented towards training of overmen, foremen, electricians, and mechanics for coal mines.

The mining industry does not utilize consultants to any significant extent at present. However, this situation must change. Access to credit and to risk capital both require the induction of consultants capable of authoritative evaluation of reserves, and of engineering companies with design and mine development capabilities. The association of Pakistani consulting and engineering firms with expatriate consultants and engineering companies appointed for the Lakhra project would go a long way towards creation of the required expertise and experience.

If the tremendous effort which will be expended in mobilizing for Lakhra mining is not to be allowed to waste itself in subsequent stagnation, it is necessary to postulate plans now for training manpower capable of developing other coal fields in other areas. Notwithstanding pressures which may be brought to bear on Government, Pakistan should insist that engineering companies and contractors employed for Lakhra must do the bulk of design and engineering work in this country. It should further be insisted upon that such engineering companies and contractors who enter into joint ventures with Pakistani engineering contracting companies will be given preferences in the award of contracts.

Considerable criticism has been voiced in the past to the effect that even though vast projects have been set up in the country by WAPDA, all the desig and engineering work was done abroad and all the contractors were foreign. The country has therefore acquired very little capability for design, engineering and execution of similar works. In a neighboring country, all foreign contractors and consultants are required to enter into joint ventures with local counterparts, and are required to do the major part of project design work in that country. As a result, that country has been able to make significant advances, particularly in its engineering capabilities. Pakistan should benefit from this example.

Combustion Equipment and Technology

Over a period of 30 years, as a result of cheap and plentiful natural gas availability, no industrial users of fuel have ever used coal. Therefore apart from the fact that users have been cushioned from the effects of high petroleum prices, total lack of expertise and experience of using coal is a sizeable constraint to its utilization. Coal burning technology is virtually nonexistent in the country. Hence, even in such industries like cement manufacturing, where the cost cushion has been removed, there is considerable hesitation in converting from expensive residual fuel oil to coal. Though the current cost differential betrween coal and residual fuel oil on an equivalent BTU basis is 3:1 in favor of coal, there is little active interest being taken in conversion from fuel oil. The central image associated with coal burning, by and large, remains that of blackfaced stokers shoveling coal into smoking combustion chambers. It is rarely appreciated that coal today is, from the point of the user, a relatively clean fuel which can be fed automatically into combus-

tion chambers under the most controlled conditions.

The mining industry is equally ignorant of the needs of industrial consumers in respect of coal quality. The prevalent attitude appears to be that coal is available, as made by nature, and regardless of quality variations from seam to seam and mine to mine must be accepted by the consumer. Few attempts have been made or have been required to blend or otherwise treat coals so as to provide a coal of more or less uniform characteristics. This is an area to which the industry must devote its immediate attention if it is ever to sell coal, over the long term, to industrial consumers.

To overcome the traditional distaste for coal, it is necessary that industrial users and coal producers be educated in respect of modern methods of coal combustion as well as available equipment and technology; fuel technology be introduced as a discipline in educational and training institutions; financing and loans should be available for conversion of existing equipment to coal, on very soft terms; coal firing equipment and accessories should be exempted from customs duty; and tax credits for BMR should be extended to cover installation of coal firing equipment, boilers, steam turbines, and the like, along with the benefit of accelerated depreciation.

The initiative in this behalf must be taken by Government because they own most of the cement plants and all the power generation facilities in the country. Government institutions alone have the capability to develop training facilities and programs on any significant scale.

Capital and Resource Mobilization

The mining industry is almost entirely self-financed. The most difficult time for any mining venture is the initial period, i.e., the time between the discovery of the mineral and the time when mineral production can be organized. During this period the availability of funds depends solely on the mineowners personal resources. No institutional credit can be obtained because mining assets are not considered "bankable assets."

Risk capital is shy because there is no way of assessing mine potential. Prospecting, developments, and extraction are undertaken contemporaneously, and are almost never undertaken in clearly defined phases. The prime objective is always to obtain saleable product as soon as possible in order to offset capital expenditure. Large scale mining is not feasible in these conditions. There is an obvious need to induct more risk capital in the exploration and prospecting stages; and institutional credit for development and extraction.

In order to induce risk capital, there is a need to make more mining properties available through liberalization of policies for grant of leases and licenses. Owners of mineral concessions, because of the scarcity value of such concessions, are apt to set too high a price on them. This scarcity of mining properties is artificial, considering the need for more exploration. Liberal grants will ensure that sufficient mining properties become available for exploration and development.

Availability of capital is also hindered by Pakistan corporate and taxation laws which do not provide for any participation arrangements other than Partnerships and Joint Stock Companies. These forms are rarely used in exploration and prospecting for minerals. In fact, foreign companies operating in Pakistan have, almost always, set up joint ventures for exploration as well as production under special arrangements with the Government. Such special arrangements are not available to Pakistanis. The virtue of such arrangements is obviously that persons coming together for a mining venture do so only to the extent of providing funds for the work, sharing expenditure, and offtake of the minerals. Each is responsible for his sales and his taxes. These arrangements have become popular on a world-wide basis, because

there is no partnership as such and any one participant in a joint venture is not in any sense accountable for any liability of the other joint venture participants. Amendments in Tax Laws should be made to cater to the special needs of the mining industry.

In addition, the growth of consulting firms of geo-scientists capable of authoritative evaluation of reserves will have to be fostered because risk capital cannot be forthcoming unless mining properties can be properly evaluated. A considerable handicap exists in that there are no contractors and consultants capable of undertaking design, engineering, and execution of mine development works. This limitation is forcefully brought home, particularly to financing institutions, because even if they take over mining properties, they cannot cause them to be converted into productive assets. It is therefore highly desirable that mining contractors be established, with capability of undertaking mine operations and development. This would greatly facilitate attraction of risk capital into mining ventures.

Banks presently provide loans on fairly strict terms, at 14% interest, subject to a debt/equity ratio of 60:40. The criteria for determining debt/equity ratio, debt coverage, and security prescribe that a zero value be assigned to mineral reserves. Only mining machinery and buildings are assigned value, while the principal asset, namely the mine, is considered just a hole in the ground. These criteria cannot be considered as wholly rational. There is an obvious need to create specialized expertise within the banking system to cater to the mining industry.

The same criteria are more or less required to be followed for the valuation of shares if offered for public subscription. In fact, because tax laws permit all expenditure incurred on mining to be written off, the value likely to be put on a mining company's assets by the Controllor of Capital Issues is likely to be even less than the value assigned by banks. Mining companies, therefore, for practical purposes, cannot increase their equity base by converting themselves into public limited companies. Since laws and rules relating to public offering of shares have other and far reaching implications, the only other alternative is to seek a revision of the tax rates applicable to mining companies.

The present tax laws pertaining to mining are based on similar laws pertaining to oil and gas. However, in the case of oil and gas, the depletion allowance is worked out on sales; in the case of coal, it is worked out on profits. The depletion allowance on coal therefore stands substantially reduced. Since a quantum jump is involved in expansion of coal production from existing levels to the projected levels required in the future, the mining companies should be enabled to set aside substantially more funds for future development. It would therefore be appropriate for Government to consider amending the provisions for depletion allowance so as to bring them into conformity with the provisions applicable to oil and gas; and in addition to tax at a reduced rate all funds set aside by mining companies as reserves for future development.

Energy Policy

Coal has particularly suffered because Government absorbed the shock of high petroleum prices and effectively prevented it from taking its due share of the fuel market. Even today, natural gas is substantially under priced, being about one-fourth of the international level. Coal-based power generation, intended to be established at Lakhra, lies 7-8 years ahead. Meanwhile, the coal industry has the problem of surviving these 7-8 years. In this period the coal producers can survive and expand only if they have access to industrial consumers, whose individual requirements lie between 5 tons to 500 tons per day, such as cement plants, textile mills, vegetable oil ghee factories, other

industries still operating on a cost plus basis, and power generating plants operating in the private sector.

Power generation in the private sector, particularly coal based power generation, has not really progressed because the terms on which excess power can be sold to WAPDA apparently cannot be agreed upon. Since coal based power generation will always be more capital intensive, special financing arrangements will have to be provided. The terms under which power may be sold and if offered, must be purchased, need to be laid down by Government. In other countries, experience has shown that inevitably the large utility companies will not buy power unless compelled, and will cheerfully let their consumers suffer.

It is therefore necessary to formulate a well-defined policy, which should provide the following:

Withdrawal of all subsidies on imported fuels over a period not exceeding three years;

An audit of all industries operating on a cost plus basis to ensure that the most competitive and not the most convenient fuels are being used;

Extension of very soft term loans, carrying interest rates of not more than 7% and repayment period of not less than 15 years to private sector entrepeneurs establishing coal based power schemes of 10 Mw and above;

Enactment of laws on the pattern of similar laws pass in the U.S.A., compelling the utility companies to purchase surplus power generated by the private sector at prices equal to the incremental cost of such power generation by the utility companies;

Expansion of coal and other indigenous fuels production;

Amendment of Mining Laws so as to promote exploration for coal and encourage prospecting and production;

Availability of capital resources through joint ventures, creation of reserves and flow of credit from the banking sector;

Developmeng and manufacture of plant and equipment appropriate for use of coal in industry;

Transfer of mining and combustion technology and training of manpower;

Establishment of a National Coal Board to coordinate all activity relating to coal devleopment.

Conclusion

Throughout this paper, I have had to stress the need for Government to take various initiatives. In Pakistan's peculiar situation there is no alternative but to call on Government for help and action. By Government I do not necessarily mean Islamabad and the Provincial capitals. In fact, I include in this term the large industrial and energy producing corporations owned and controlled by Government. We live in an age of Big Government and it is necessary that we should be realistic.

The important point is that there will be other coal fields like Lakhra, and there must be more power stations equal to and bigger than Lakhra. It is essential that we utiize the Lakhra experience to acquire the ability to develop future coal fields and future power stations.

This conference has been a unique opportunity to call attention to the problems faced by the coal mining industry. Institutional, infrastructural, and policy changes will be needed. None of these required changes are new or revolutionary in character. Some of these changes have been considered, reconsidered and agreed by Government and others flow from the successful experience of other countries.

LAKHRA COAL PROJECT MINE DEVELOPMENT PLAN
SIND PROVINCE, PAKISTAN

James D. O'Donovan
Director of Surface Mining, Int'l Projects
John T. Boyd Company
400 Oliver Building
Pittsburgh, PA 15222 U.S.A.

Ronald L. Lewis
Vice President
John T. Boyd Company
400 Oliver Building
Pittsburgh, PA 15222 U.S.A.

ABSTRACT

The successful development of the proposed Lakhra coal mine/power plant project is in the best interest of Pakistan. It creates employment, promotes development of domestic resources, results in the construction of a modern community, and assists in alleviating the current electrical power shortage. The master coal mine plan produces 4.3 million tonnes annually to fuel the proposed 700 MW electrical power generating station. Two modern surface mines, each producing 2.0 million tonnes per year, and one underground mine, producing 0.3 million tonnes per year, are incorporated into the master mine plan. Technically challenging, the Lakhra Coal Project requires a high capital investment and an estimated 5.5 to 6.5 years of development time to achieve design capacity. If the goal of project financing by international donor agencies is to be realized, then the full support of the Government of Pakistan, Province of Sind, and private sectors in both Pakistan and internationally is essential.

INTRODUCTION

Although on-site exploration and numerous technical studies were completed to assess the feasibility of major coal mine development of the Lakhra Coal Project lignite reserves, pre-1984 work was regarded as inadequate by international donor agencies. Under the sponsorship of USAID/Pakistan, WAPDA retained the services of John T. Boyd Company (BOYD) to re-examine available field data and technical reports, and complete an independent coal mine feasibility study. As shown on Figure 2, installation of the proposed Lakhra mines is the final step or culmination of a well organized development plan.

GOAL: Clear definition of the goal must be recognized prior to beginning work. The objective of our assignment was to complete an independent coal mine feasibility study. It, in turn, is to be used as an integral part of the project objective: a new electrical power station fueled by coal produced from Lakhra Coal Project. The goal, however, is somewhat different; it is to obtain necessary financing from the international donor agencies. This difference between objective and goal is much more than terminology. The BOYD organization has the technical expertise and international experience to meet the objective. We have studied the concerns of the donor agencies regarding the status of work completed prior to 1984 and have endeavored to address these issues. Within the guidelines of our objective, we have attempted to be cognizant of the goal. This project is now under review by the various lead donor agencies, and we will soon know if the goal will be achieved.

REVIEW: An examination of available technical information was completed to compile reliable base data for use in he on-going investigation. Adequate time was spent in-country in an effort to overview the existing industry capability. Key issues must be addressed:

* Current mining practices
* Labor availability and capability
* State of technology (including non-mining industries)
* Equipment procurement practices
* Identification of potential operational problems

In addition to underground inspections of 13 coal mines in the Lakhra area, BOYD representatives also visited PMDC's Khewra Salt Mine and Makerwal Coal Mine, Pakistan Steel Mills Corporation, and Pakistan International Airlines. Excluding personnel assigned directly to the field studies (exploration) program, BOYD team members spent an aggregate of 600 mandays in Pakistan researching existing in-country practices.

FIELD STUDIES PROGRAM: Based on our review of previous technical information, a 65 drill hole field studies (exploration) program was developed. By assignment the objective of the initial Phase 1 field studies program was to define a minimum of 42 million tonnes of demonstrated, recoverable lignite reserves. Drilling activity was limited to the Upper Coal-bearing Beds (Seams No. 1 through No. 5, in ascending order) and to select portions of the Lakhra Coal Project property, as identified in the earlier JICA report. In addition to achieving a minimum reserve tonnage objective, Phase 1 program was designed to provide comprehensive data on in situ (raw) and washed lignite quality and to develop additional technical information on hydrology, environmental, geotechnical, etc. During the course of the field studies program, an on-site vertical test shaft was completed to permit bulk sampling of the lignite seams and examine the stratigraphic conditions above No. 1 Seam.

RESERVES: Upon completion of Phase 1 field studies program, a new seam data base was compiled using results of the 137 drill holes available within the study area. [Figure 3] Using our in-house computer facilities and criteria assigned by BOYD to reflect modern mining limitations, estimates of total lignite resources and alternative reserve estimates were completed. As shown on Figure 4, the ability to recover available resources is significantly improved through the use of surface mining methods. Depending on mining method(s) and economic limits, estimated reserves vary from 23 to 122 million recoverable ROM (run-of-mine) tonnes.

QUALITY: Based on analytical test data developed during the Phase 1 field studies program, the estimated average quality of the Lakhra lignite on an as mined ROM basis is: 32% moisture, 5.0% sulfur, 24.7% ash, and 5,120 Btu/lb. (2,840 Kcal/kg). Beneficiation of the ROM product by mechanical washing did not appear warranted and was eliminated from further consideration.

MASTER MINE PLAN: Selection of the master mine plan involved two stages of economic analysis and consideration of non-economic factors. A preliminary assessment of alternative mine designs was completed in June 1985 to select the method(s) of mining for further in-depth investigation. Only direct mine costs were considered (excluding infrastructure, mine management fee, return on investment, etc.); available data was incomplete; and accuracy of the estimates was intended to be within 20 percent. [Figure 5]

As agreed upon by USAID/Pakistan and WAPDA representatives in June 24-25, 1985, review meetings held in Lahore, Pakistan, the master mine plan to produce 1.4 million ROM tonnes per year included: (a) a single surface mine in the West Pit (high grade plan) producing 745,000 tonnes per year using the Case 3 approach (combination dragline and shovel/truck); (b) a series of underground mines in the Central and East areas, producing a total of 655,000 tonnes per year using the Case 4, Lakhra Upgrade approach.

This section of the master mine plan was based on the following rationale: (a) assurance of supply would be maximized by the inclusion of a surface mine component in the overall plan. The combination concept (Case 3) provides reliability of operation by the use of multiple units of diverse excavating equipment; (b) economics, capital, and operating costs clearly favor maximizing underground production; (c) technology required to operate the mine should advance current practices but not require a "quantum jump" which would be unattainable; (d) the overall mine plan should be compatible with the identified demonstrated lignite reserves.

In October 1985, a comparative analysis was made of four alternative mining concepts to aid in the final selection of the master mine plan. All cost estimates are considered preliminary in nature and are intended to reflect an accuracy within 20 percent. The optimum mining methods, as identified in our Alternative Mine Design analysis, were used in all four cases (i.e., surface mining employs a combination dragline/shovel-truck approach and a Lakhra Upgrade mine plan is used in all underground mining scenarios). Annual coal production levels are based on final ROM coal quality estimates. The 1.8 million tonnes per year production capacity represents the revised ROM lignite requirement to fuel one 300 MW unit. Based on our independent reserve estimate for maximizing reserve conservation through an aggressive surface mining concept, the expanded production case (4.3 million tonnes per year) was determined. The larger mine size was also considered prudent relative to projected future Lakhra thermal units (total 1,200 MW capacity) and the need to have an improved order of magnitude to

offset project capital requirements. The 700 MW generating station capacity (two units at 350 MW each) was calculated based on assigned coal mine production capacity. [Figure 6]

During Lakhra Project contractor review meetings held October 3-9, 1985, the objective of the overall project was revised to better address the total power generation needs of the GOP. This expanded approach also achieved a magnitude of scale more consistent with modern international mining project development. Using the current coal reserve estimate of 121.7 million ROM tonnes, recoverable using an aggressive multiple surface mine concept, the master plan was revised to include: (a) two modern surface mines, each producing 2.0 million ROM tonnes annually. Diversity of supply (production) is achieved through the use of two primary large capacity draglines in each mine. Multiple fleets of shovel/truck equipment complete prestripping (removal of upper overburden in deep cover areas) in advance of the draglines; (b) one underground mine, producing approximately 0.32 million ROM tonnes annually, in the southern portion of the Central Area. Overburden depth in this area exceeds the practical limits of surface mining.

An ROM, selectively mined, and hand-picked product will be delivered to the 700 MW Lakhra power station.

The rationale used to support the current master mine plan includes the following: (a) reserve conservation through maximum recovery of the demonstrated lignite reserves; (b) increased capacity to better address the existing critical electrical power generating station construction schedules; (c) development of a mining operation offering improved economics through magnitude of scale to support required investment in equipment, facilities, and project infrastructure; (d) ability to attract qualified international mining companies to manage operations and improve equity participation in the venture.

In addition to the two mining components (surface/underground), the master mine plan study includes a common facilities cost center to account for costs associated with operation of the main office (general administration) and common coal handling/loadout facilities.

Accuracy of capital and operating costs are intended to be within 10 percent. A management fee for services of the expatriate mine manager is subject to future negotiation and is not considered in the report. Three interest rates are applied to initial capital financing and amortization (0, 5, and 10 percent), with a life-of-project (30-year) term of repayment. All monetary values are expressed in constant mid-1985 U.S. dollars (does not consider inflation).

Annual Production

Standard work schedule is 8-hour shifts, Saturday through Thursday; 300 days per year.

The Surface Mine Plan projects contemporaneous development of the East and West Pit reserves throughout the 30-year mine life. Reserves to be mined from each area, together with waste volumes to be moved over the project life, are summarized below:

Pit	Effective* Strip Ratio
East	17.77
West	17.02
Total	17.41

*Total waste volume (overburden, interburden, and rehandle) per recoverable ROM tonne lignite.

Annual surface mine lignite production is scheduled for 4,000,000 ROM product tonnes over a 30-year life with production nearly evenly divided between the two mines (pits). Ability to develop rapidly to a high production mode operation in both pits is constrained by the reserve character, e.g., absence of outcrop (or shallow cover) access, substantial depth of cover (averaging 65 meters of overburden depth to the top of the lowermost No. 1 Seam), and the multiple seam/split seam nature of the lignite reserve. Accordingly, in order to develop the pits to the point where the full annual tonnage requirement can be consistently mined, a significant amount of prestripping is necessary. Access to the deposit by preproduction stripping (utilizing box cuts) in each pit is planned. Overburden depth is fairly uniform and a near steady-state stripping condition is achieved once mine development is completed.

Identified underground reserves are limited to Mine No. 1 (No. 2 Seam) in the southern portion of the Central Area. Estimated underground reserves are adequate to support the assigned production level of approximately 326,000 ROM product tonnes for 14 years at full production, with reserves depleted in year

D+19. Additional reserves would be identified to provide additional underground replacement tonnage as Mine No. 1 is depleted.

Due to spontaneous combustion problems associated with the Lakhra lignite, mine site stockpile inventory will be minimized. The surface mine will carry sufficient in-pit inventory, where approximately 100,000 to 500,000 tonnes will be available for mining, to provide coal supply reliability (over any extended production shortfall from the mines, major electrical outages, and/or other production interruptions). In addition, a long-term dead stockpile ranging from 500,000 to 2,500,000 tonnes is also planned to provide makeup tonnages during emergencies and low production years.

Labor

In all cases, staffing of the mines is based on Western practice and does not overstaff the mine simply to maximize employment.

A reliable source of labor must be secured for the year-round operation of the proposed mines. This is not considered a serious problem for the surface mine since it is less labor intensive and experienced equipment operators should be available. Maintenance personnel should be available but will require specialized training for specific pieces of equipment purchased for the proposed Lakhra mines.

Under present practices, underground workers are migratory workers, returning to their homeland for the summer months.

Any operation will be more efficient with a permanent work force, and we have included several improvements in the overall mining plan to accomplish this, namely: improve underground working conditions; better compensation and fringe benefits; establish a modern colony.

Securing the services of a qualified mine management organization is essential to the success of the Lakhra Coal Mine. We estimate the selection of the expatriate mining company could affect capital and cost estimates by a factor up to 20 percent. That is, exceptional performance by the mine manager could achieve a cost reduction of 20 percent below estimates.

It is common practice for a mining company, having an equity interest or management contract for a foreign mining operation, to have parent company participation in the selection of personnel managing the mine. In addition to senior mine management, the expatriate mine operator will provide key technical staff to supervise engineering, daily production, accounting, training, and maintenance.

A phased reduction in expatriate staff is planned, with Pakistani counterpart staff members assuming these responsibilities as the number of expatriates is reduced.

Capital Estimate

In accordance with WAPDA instructions, capital estimates are limited to initial capital expenditures for equipment and facilities to achieve design mine capacity. Working capital, spare parts, and consumable supplies inventory are included under our capital estimate. Operating costs incurred during the mine development period are expensed on a current basis.

Essentially all equipment and machinery for both surface and underground mines must be imported. A policy of equipment standardization is strongly recommended, as well as grouping of similar types of equipment under a single bid solicitation. This will facilitate training, reduce the number of specialized mechanics, encourage technical support from the manufacturer, and minimize inventory. Equally important with capital cost will be a manufacturer's ability to provide technical support such as on-site training in operation and maintenance and availability of spare parts. Standardization should extend to motors and all common components wherever possible.

The surface mine contemplates using equipment larger than, but similar to, that commonly used in Pakistan in construction of dams, irrigation systems, and roads, as well as in limestone quarries. The system of mining proposed for the underground mine is more mechanized than current manual practices but only marginally so. It is intended to be progressively upgraded as worker proficiency and production demands permit.

Equipment was sized based on projected mining requirements. In surface mine equipment selection, preference was given to demonstrated units and major manufacturers. We have lowered normal equipment availability by 20 to 25 percent as compared with typical U.S. standards. This is considered conservative but appropriate, based on third world experience--operating interruptions, reduced operator efficiency, prolonged repair time, and below average maintenance. This is a key area where superior mine management (maintenance organization) can achieve

significantly higher productivity (performance) levels.

To minimize the fleet size and simplify maintenance, we have selected large capacity surface mine units and assigned them multiple functions. For example, a hydraulic backhoe is used for both selective interburden removal and lignite loading, and a single rock truck model is selected for overburden/interburden and lignite haulage. [Figure 7]

Equipment costs are based on prices supplied by the equipment manufacturers. Quotes were obtained from suppliers in Pakistan who distribute equipment sold in-country and from manufacturers in the U.S. for the large trucks, overburden drills, draglines and shovels. Based on current low market demand and availability of used equipment, attractive prices are being offered by major surface mine equipment manufacturers. We have assumed full on-site training instructions covering operation and maintenance are included in the capital cost estimate. All prices are applicable to the Asian market. The capital costs include estimated shipping from factory of origin to port, heavy lift charges, ocean freight, off-loading charges in Karachi, brokerage and handling fees, transportation costs to Lakhra mine site and, when applicable, erection charges. Fleet discounts are not included in the equipment capital costs. Depending on the expatriate mine management company selected, surplus used equipment may be available. This could reduce total capital cost estimates by a factor of 5 to 15 percent.

Local construction costs for mine buildings were developed in conjunction with Engineering Consultants, Karachi. This was intended to insure compatibility with local construction practices and costing methods. Since the proposed coal handling/loadout facility would be the first such installation in Pakistan, we have assumed this work would be completed by an international material handling contractor on a turnkey basis.

Operating Cash Cost

Included in the operating cash cost estimates are: labor cost (including fringe benefits), parts and supplies (maintenance and rebuild parts, operating supplies, fuels), electrical power equipment replacement expense, production incentive payment, insurance, miscellaneous, and a 10% contingency factor. Provincial severance related charges (royalty at 15 Rupees per long ton and miners' welfare fund at 2 Rupees per long ton), management fee, return on investment, finance costs, etc., are not included.

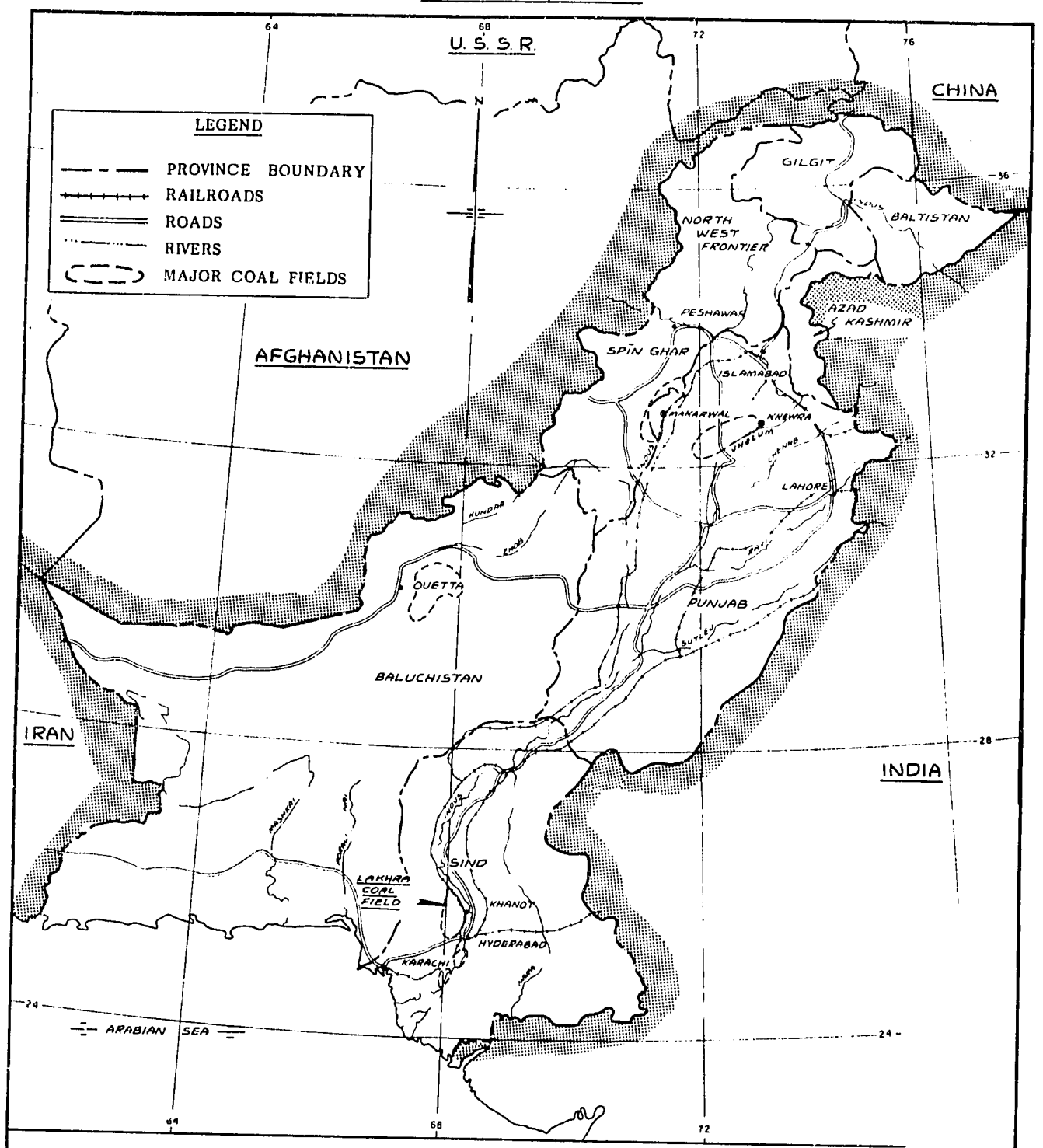
Equity distribution and terms of future financing are not defined at this time. For purposes of this report, we have calculated amortization of initial capital (including development expenses) using three annual interest rates: 0, 5, and 10 percent (real interest, exclusive of inflation) and a 30-year term of repayment. [Figure 8]

Following this page are:

Figure No.	Description
1	General Location
2	Development Plan
3	Drill Hole Data Base
4	Resource/Reserve Estimate
5	Analysis of Alternative Mine Designs
6	Comparison of Alternative Mining Concepts
7	Listing of Major Equipment
8	Estimated Production Cost, Including Amortization

FIGURE 1

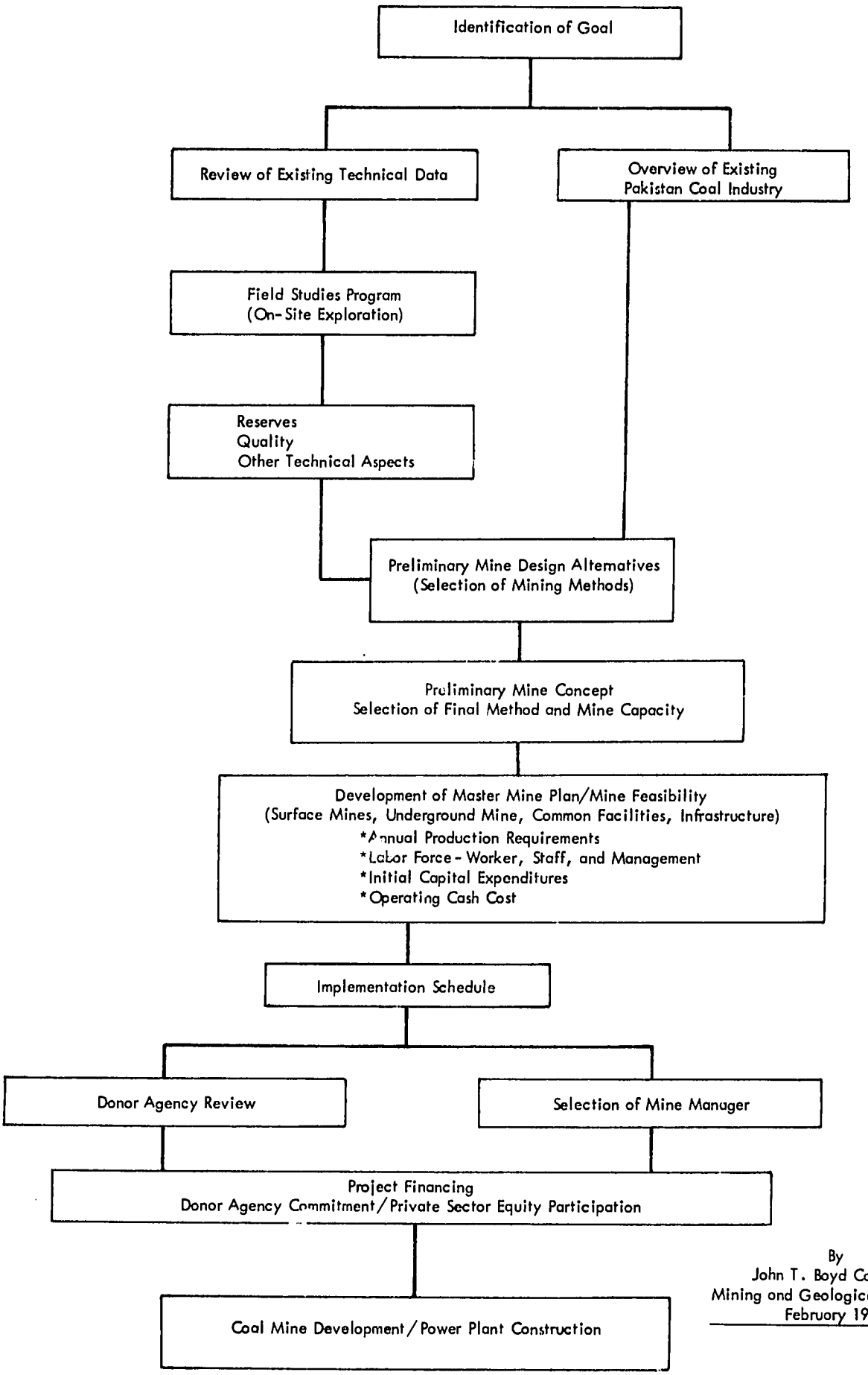
GENERAL LOCATION
LAKHRA COAL PROJECT
SIND PROVINCE, PAKISTAN



By
John T. Boyd Company
Mining and Geological Engineers
February 1986

Figure 2

Lakhra Coal Project Development Plan



By
John T. Boyd Company
Mining and Geological Engineers
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FIGURE 3

EXPLORATION SUMMARY

Source	No. of Drill Holes	Aggregate Meterage Drilled	Date
Geological Survey of Pakistan	3	343	mid-1960's
PMDC	19	1,845	Dec. 1975 - June 1976
JICA	50	5,203	June 1979 - Nov. 1979
USAID Interim	10	1,111	Oct. 1984 - Dec. 1984
USAID/BOYD	55	5,877	Jan. 1985 - May 1985
	137	14,379	

By
John T. Boyd Company
Mining and Geological Engineers
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FIGURE 4

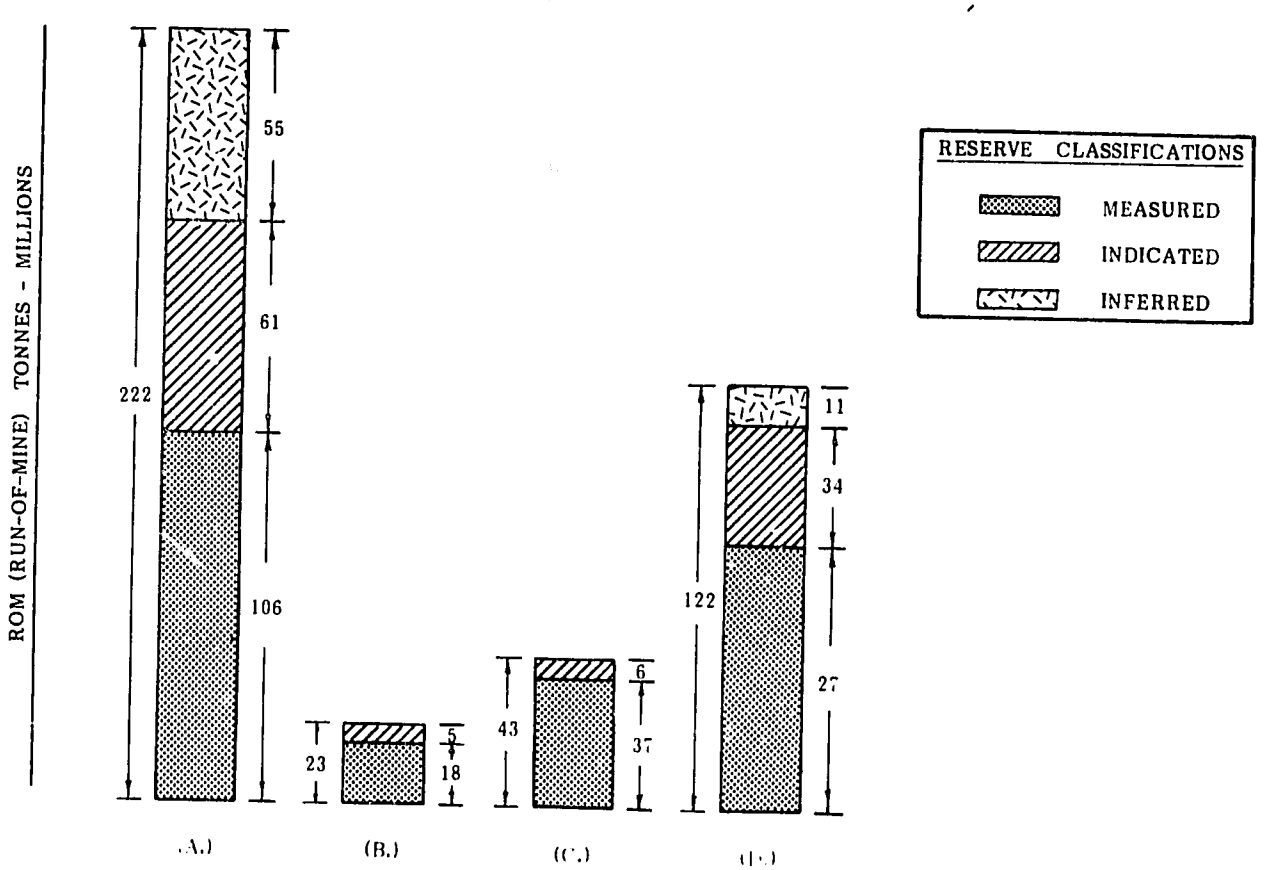
SUMMARY OF ESTIMATED COAL RESOURCES AND RESERVES

(A.) TOTAL RESOURCES

(B.) ALL UNDERGROUND

(C.) WEST PIT SURFACE (HIGHGRADE) CENTRAL/EAST UNDERGROUND (SEPTEMBER 1985 PLAN)

(D.) EXPANDED WEST AND EAST SURFACE UNDERGROUND MINE NO. 1 (OCTOBER 1985 PLAN)



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John T. Boyd Company
Mining and Geological Engineers
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FIGURE 5

PRELIMINARY ANALYSIS OF ALTERNATIVE MINE DESIGNS

	Surface			Underground	
CASE :	1	2	3	4	5
Description :	Dragline	Shovel/Truck	Combination Dragline Shovel/Truck	Lakhra Upgrade	Mechanized Longwall
Annual Production (ROM tonnes - 000) :	745.3	745.3	745.3	354.0	346.7
Effective Strip Ratio (total BCM/tonne):	16.2	11.2	13.8	-	-
Projected Payroll (total no. employees):	305	359	372	555	318
Productivity (avg. tonnes/manshift) :	9.4	8.0	7.8	2.6	4.3
Estimated Costs ($US-000) (excl. import duty and related taxes, royalty)					
Initial Capital					
Direct Mine (incl. development)	108,236	91,714	115,029	19,274	28,106
Interest During Construction*	13,959	7,402	14,007	3,015	2,921
Total	122,195	99,116	129,036	22,289	31,027
Amortization (30-year term)/year*	7,872	6,385	8,312	1,436	1,999
Average Annual Direct Mine Cash Cost/Yr.					
Labor	1,474	1,597	1,624	1,738	1,305
Supplies (excl. Power)	7,962	12,146	8,919	940	1,080
Power	830	507	738	132	16[illegible]
Other	1,258	1,300	1,313	638	558
Contingency	1,152	1,555	1,259	345	311
Subtotal	12,676	17,105	13,853	3,793	3,418
Equipment Replacement	2,832	3,730	3,059	497	1,224
Total	15,508	20,835	16,912	4,290	4,642
Total Direct Mine Annual Cost (incl. Amortization and Interest)	23,380	27,220	25,224	5,726	6,641
$/Tonne	31.37	36.52	33.84	16.18	19.15
Present Value of Estimated Total Direct Mine Costs**	280,679	326,664	303,170	69,390	79,536

*Calculated at 5% annual interest rate

**Calculated at 5% annual discount rate, includes 5-year development period and 30-year mine life.

By
John T. Boyd Company
Mining and Geological Engineers
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FIGURE 6

COMPARISON OF ALTERNATIVE MINING CONCEPTS

Power Station Capacity	300 MW			300 MW	300 MW	700 MW (2 Units @ 350 MW ea.)		
Mining Method	Combination			All	All	Combination		
	Surface	Underground	Total	Underground	Surface	Surface	Underground	Total
No. of Mines	1	5	6	9	1	2	1	3
Annual Coal Production (ROM tonnes-000)	770	1,030	1,800	1,800	1,800	4,000	300	4,300
Estimated 30-year Coal Requirement (ROM tonnes-000)	23.1	30.9	54.0	54.0	54.0	120.0	9.0	129.0
Estimated Identified Coal Reserves (ROM tonnes-000)	23.7[e]	19.3	43.0	23.3	115.8	115.8	5.9	121.7
Estimated Labor Force (No. of Payroll Employees)								
Staff	85[a]	310[a]	395	600	150	190[a]	90[a]	280
Worker	425[a]	1,800[a]	2,225	3,500	800	1,100[a]	520[a]	1,620
Total	510[a]	2,110[a]	2,620	4,100	950	1,290[a]	610[a]	1,910
Avg. Tonnes Produced Per Day Per Payroll Employee(b)	5.0	1.6	2.3	1.5	6.3	10.3	1.6	7.5
Estimated Initial Capital ($US-millions)								
Direct Mine(c)	82	65	147	120	180	325	15	340
Mine Development	38	18	56	30	90	142	1	143
Subtotal - Mine Site	120	83	203	150	270	467	16	483
Infrastructure(d)			54	77	50			57
Development Expense			9	13	9			4
Subtotal			63	90	59			61
Total Investment			266	240	329			544
$/Annual Tonne of Production			148	133	183			127
Operating Cash Cost ($/tonne)								
Direct Mine								
Labor	1.85	6.90	4.73	7.70	1.25	1.10	5.35	1.40
Supplies	13.35	4.50	8.30	4.50	14.00	14.00	4.20	13.30
Power	0.80	0.45	0.60	0.50	1.00	1.10	0.45	1.05
Other	0.55	0.40	0.46	0.40	0.60	0.60	0.25	0.55
Contingency	1.65	1.25	1.42	1.30	1.70	1.70	1.05	1.66
Equipment Replacement	4.05	3.90	3.95	3.90	3.70	2.65	2.75	2.65
Subtotal	22.25	17.40	19.46	18.30	22.25	21.15	14.05	20.61
Common Facilities	1.00	0.50	0.72	0.70	0.75	0.50	0.50	0.50
Subtotal - Mine Site	23.25	17.90	20.18	19.00	23.00	21.65	14.55	21.11
Infrastructure(d)			0.85	1.00	0.65			0.55
Total			21.03	20.00	23.65			21.66
Amortization (Capital + Development Expense @ 30-year term)								
0% Annual Interest			4.93	4.44	6.09			4.25
5% Annual Interest			10.33	8.80	13.07			9.15
10% Annual Interest			23.67	15.80	18.20			16.76
Total Mining Cost (incl. Amortization)								
0% Annual Interest			25.97	24.44	29.44			25.91
5% Annual Interest			31.37	28.80	36.42			30.81
10% Annual Interest			44.71	35.80	41.55			38.42
Relative Ratings*								
Reserve (Quantity) Position	Adq.	Inadq.	Inadq.	Poor	Excs.	Adq.	Inadq.	Adq.
Reserve Conservation	Good	Poor	Poor	Poor	Good	Good	Poor	Good
Mining Risk	Low	High	Mod.	High	Low	Low	High	Low
Capital Investment	High	Mod.	High	Mod.	High	Mod.	Low	Mod.
Operating Cost	High	Mod.	Mod.	Mod.	High	Mod.	Low	Mod.
Labor Requirement	Mod.	High	Mod.	High	Mod.	Low	High	Low

Notes: (a) Includes allocation of common facilities and infrastructure labor force.
(b) Estimated using 300 days per year operating schedule.
(c) Includes allocation of common mine site facilities (i.e., coal handling/loadout facility).
(d) Infrastructure estimate based on Khanot power station site.
(e) West Pit high grade (lowest strip ratio) reserve estimate.
* Adq. = Adequate; Inadq. = Inadequate; Excs. = Excess; Mod. = Moderate

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FIGURE 7

SUMMARY OF MAJOR EQUIPMENT
LAKHRA COAL PROJECT

EAST PIT / WEST PIT SURFACE MINES

Major Stripping Machinery

6 - Overburden Drills (BE 55R, or equivalent)
2 - Interburden Drills (BE 355R, or equivalent)
4 - Rubber-tired Loaders (Cat. 980 C, or equivalent)
4 - Powder Trucks
4 - Supply Trucks
4 - Electric Walking Draglines - 58 cubic meters each
4 - Bulldozers (Cat. D-10, or equivalent)
4 - Bulldozers (Cat. D-8, or equivalent)
2 - Electric Shovels - 27 cubic meters
45 - End-dump Trucks - 136-tonne capacity
9 - Bulldozers (Cat. D-9, or equivalent)
6 - Graders (Cat. G-16, or equivalent)
5 - Water Trucks
14 - Scrapers (Cat. 657-E, or equivalent)
3 - Backhoes (O&K RH120, or equivalent)
3 - Front-end Loaders (Cat. 922, or equivalent)
2 - Scrapers (Cat. 631-D, or equivalent)
2 - Front-end Loaders (Cat. 988, or equivalent)
4 - Scrapers (Cat. 632-D, or equivalent)

UNDERGROUND MINE NO. 1

Underground Machinery

3 - Diesel Tractors for Supply Transport
6 - Diesel Scooptrams, 2.5 cubic meter capacity
1 - Road Maintenance Machine
6 - Diesel Personnel Vehicles - 6 passenger
5 - Diesel Personnel Carriers - 24 passenger
6 - Belt Conveyors, 914 mm width, 37 KW
4 - Belt Conveyors, 914 mm width, 75 KW
6 - Air Compressors, Electric, 37 KW
4 - Air Compressors, Electric, 56 KW
4 - Pan Conveyors, 11 KW
700 - Hydraulic Roof Supports
1 - Set Bulk Rock Dusting Equipment

Surface Machinery - Underground Mine

1 - Portable Crushing Plant, 400 TPH
1 - Radial Stacker
1 - Lignite Hauling Truck, 30-tonne
1 - Front-end Loader

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FIGURE 8

ESTIMATED PRODUCTION COST
(INCLUDING AMORTIZATION)

Component	($US - Millions) Initial Capital	Development Expenses	Interest During Development Period	Total Amount Amortized	$US/Tonne Average Operating Cash Cost	Amortization (Principal + Interest)	Total (incl. Amort.)
0% Annual Interest Rate							
Surface Mines	315.4	136.0	-	451.4	21.15	3.76	24.91
Underground Mine	13.7	0.0	-	13.7	14.05	2.33	16.38
Common Facilities	11.0	6.8	-	17.8	0.50	0.14	0.64
Subtotal	340.1	142.8	-	482.9	21.11	3.78	24.89
5% Annual Interest Rate							
Surface Mines	315.4	136.0	49.9	501.3	21.15	8.07	29.22
Underground Mine	13.7	0.0	1.4	15.1	14.05	3.91	17.96
Common Facilities	11.0	6.8	1.8	19.6	0.50	0.29	0.79
Subtotal	340.1	142.8	53.1	536.0	21.11	8.03	29.14
10% Annual Interest Rate							
Surface Mines	315.4	136.0	105.6	557.0	21.15	14.67	35.82
Underground Mine	13.7	0.0	2.9	16.6	14.05	6.11	20.16
Common Facilities	11.0	6.8	3.8	21.6	0.50	0.52	1.02
Subtotal	340.1	142.8	112.3	595.2	21.11	14.51	35.62

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CONSIDERATIONS IN MECHANIZATION

Morgan J. Barber
Managing Director
British Mining Consultants

INTRODUCTION

As a result of recent droughts in Pakistan, the electricity produced from hydroelectric power stations has been low, with a large shortfall from the industrial demand. This presents a severe obstacle to development in Pakistan. To overcome this potential shortage in the future, the Government is planning over 15,000 MW of new generation capacity by the turn of the century.

In the Sixth Five Year Plan, which began in 1983, the Government was committed to the mining and use of indigenous fuel to fire large scale power generation plants, of which the first of 300 MW is to be built near Hyderabad. The Lakhra lignite field close by is to be developed for this purpose.

The total annual lignite production from Lakhra is currently all from private mines and is reported to be about 500,000 tonnes per year.

The lignite area is divided into a checkerboard of concessions held by private mining companies and by the Pakistan Mineral Development Corporation (PMDC). Private leases make up most of the total number and these have still to be explored fully to establish proven reserves.

The Government of Pakistan is firmly committed to a policy of giving the maximum private participation in the Lakhra mining project, which would ensure that long-term contracts are awarded to private mine owners for the supply of fuel to the power plants.

The fuel required for a 300 MW power station would be of the order of 1.4 million tonnes. This would require a threefold increase in the amount currently being produced. As the projected generating capacity in the Lakhra area is increased to 2,000 MW, then the lignite required would be 20 times the current output.

How can this challenge be met? Mechanization fo the mines could be the answer. The following thoughts attempt to list some of the aspects for consideration before mechanization is undertaken, so that the development of the Lakhra area can be soundly planned on a firm economic base, without having to undergo the mistakes made elsewhere, and ensure a secure supply of tonnage of a different order from that presently available.

OBJECTIVES OF MECHANIZATION

The objectives of mechanization are profitability, concentration of operations, and safety.

Profitability

In assessing the effect of coalface mechanization upon profitability, the following adverse, as well as beneficial, factors must be considered:

Advantages:

- Decreased face labor cost.
- Increased output leading to a higher recovery of the fixed expense of operation.
- Less hard manual labor.
- More regular output per hour which reduced output fluctuations.
- Increased safety.

Disadvantages:

- More capital expenditure required.
- Increased cost of maintenance.
- Increased power cost.
- Increased likelihood of output loss due to machinery breakdown.

Concentration of Operations

To be fully beneficial, mechanization requires large tracts of coal, free of washouts and faults and with uniform gradients and coal thickness. This is desirable to ensure the uninterrupted use of equipment without downtime and delays. An ideal, perhaps; nevertheless, this has to be aimed for in a mine design.

With mechanization comes the concentration of men and equipment with the need for close supervision and control, if the completion of the tasks and operations is to be assured. If disruption of mining activity due to geological problems arises, then major organization problems ensue. Unlike the winning of coal from the traditional pillar and stall system, mechanization longwall mining cannot readily be transferred to areas of improved geology without the cessation of output and the organization of a major movement of equipment elsewhere.

In order to avoid precipitate or unexpected transfers of equipment, it is necessary to plan the mine with as much geological data as possible, with boreholes to internationally accepted standards both in number and quality of rock data obtained.

Safety

The concentration of mining activities allows close monitoring and control, and substantial moves have been made in remote monitoring of environment and also equipment "health". Safe methods of working are paramount in running an efficient industry if the days lost due to accidents to workmen are to be a minimum. In the UK, safety legislation has grown with the advent of mechanization. The implementation of this legislation by mutual cooperation of the mine managers of the National Coal Board and the mines inspectorate has been successful. in a period when there has been a widespread increase in the use of mechanical equipment, coal production has increased enormously, while the accident rate per 100,000 manshifts worked has decreased to the lowest ever.

In taking the step from manual methods to mechanized mining, safe methods have to be designed in from the start and call for judgment and experience.

THE CHANGES IN PHILOSOPHY

Management Style

In all disciplines, engineers welcome a challenge, especially one which involves new methods, new ideas and a learning process where new problems have to be solved and few case histories from which to draw on for a solution. Mechanization in Pakistan could be such a challenge.

To begin at the root of the matter, the style of management must change from that where a mine manager is obsessed with the fine detail of the enterprise to one who heads a number of engineering departments, each with a senior engineer with freedom to make decisions and who is held accountable to the mine manager for the financial and technical contribution of that department to the whole undertaking.

The duties of each senior engineer need to be clearly defined so that the long-term planning of the business is the function of the mine manager, while that for the short-term is the function of the senior engineers.

The long-term planning would include establishing market demands and preparing and evaluating alternative production plans.

The short-term planning would be to implement the plan most suited to the applied constraints of manpower, machines and money.

THE REQUIREMENTS OF MECHANIZATION

Size and Shape of Reserves

Where the reserves are comprised of small irregular shaped areas of coal, it is often uneconomic to establish short life mechanized longwall faces where the effort of assembling the equipment outweighs the financial return. Although mechanization is possible by the introduction of heading machines in these cases working a modified pillar and stall method, only modest outputs can be achieved, unlike the mechanized longwall systems which are geared to producing bulk output. The flexibility of the systems used is dependent upon the degree of geological and physical data available and the skilled use of this by the mining engineer.

Variable Seam Section

In the organic mass of debris which formed the coal seams initially, the regular stratification and thickness of the seam is more the exception than the rule. After millenia of sedimentary deposition and increasing cover load, the coal forming debris has been squeezed into varying thicknesses, interspersed in some cases by sediments of sand or shale, or often eroded by water courses which meandered through the partially compacted plant debris. Mechanized longwall methods, with very little flexibility to vary the workable seam section, may not always be as useful for total coal extraction as traditional pillar and stall methods. In some cases, a decision has to be made for coal to be left behind where the immediate thickness is beyond the range of the supports used.

Customer Satisfaction

Size of Products - Whether or not the market demands influence the size of coal produced is a factor to be considered. Although there are machines on the market which auger the coal and produce a larger product, it is true to say that coal produced generally by shearer loaders is below 25 mm diameter. Therefore, if coal size is a governing factor then provision must be made for a machine to be used which will give the requisite size, possibly the need to prepare the coal by screening and dirt extraction in order to satisfy the customers' requirements.

Consequently, mechanized coal mining may not be as flexible as the conventional manual method in producing large coal, if this is a market consideration.

Reduction of Sulphur or Dirt Content - In cases where the market demands that the coal is washed to reduce the ash or sulphur content, because of the high percentage of small coal produced by mechanization, care must be taken in the plant design to avoid overloading the fines circuit.

Compatibility of Equipment

To contemplate uprating a mine from conventional manual methods to mechanized mining, it is essential that the output required from each production face is assessed realistically.

The face design must ensure that the equipment proposed is capable of producing the amount of coal in the available shift time, with due allowance for ancillary work being carried out on the face which is non-coal productive.

The equipment must be such that it is able to pass coal at the rated output and that the infrastructure is compatible with it, so that coal is brought to the surface without delay on conveyor belts or in mine cars. Adequate bunkerage must be provided to smooth out production peaks and store buffer stocks for dispatch to the customer, as required.

In the transition from manual to mechanized longwall, the existing underground supply roads must be checked to ensure that there is sufficient clearance for the trains of supplies to pass safely.

The capacity of a supplies system must be such that the requisite amount of materials and equipment can be taken into the mines as required and that the most bulky or heaviest piece of equipment in use can be hauled on purposely built rolling stock to the point of use with a minimum of delay and human effort. Only in this way will underground development roadways progress at the rate required to prepare new working faces and explore further areas and the mechanized longwall faces will produce coal continuously at the rated output.

Engineering Services

An adequate power and water supply must be available for a mechanzied mine to function, 2 to 4 MVa being the power rating for a mine producing 1,000 to 2,000 tonnes/day. With a fully mecnanized face and, say, five development roadways, the water requirement per day is approximately 200 cubic meters. Therefore the control and distribution of these two essential items is costly and requires much care and attention in the design.

Repair and Maintenance

Repair and maintenance of equipment requires well equipped workshops, skilled personnel and a system of planned maintenance. Routine maintenance is carried out to fixed schedules which record the extent and frequency of the work, so that replacement of work or damaged parts takes place before failure occurs, which might otherwise result in a major breakdown with loss of output.

Stocks of the most frequently consumed spare parts should be readily available at the mine to enable expensive equipment to be kept running. This requires a degree of forward planning and ordering of stores to agreed working levels. Consequently an effective purchasing and stores department is essential to a mechanized mine.

Similarly the rate of, say, roadway supports will change dramatically in a mechanized mine in contrast to one using manual methods. The increased output from the mechanized face will necessitate the quicker replacement fo working faces and, as a result, a faster rate of development roadway drivage will be required. Consequently, the stores administration is a key one in mechanized mining.

Transportation

To supply a fixed daily output from the mine to a power station, for instance, requires a critical examination of the existing transport system to verify that it is capable of a sustained workload at minimum cost. The transportation of small loads by private companies is one thing; to convey 4,000 tonnes/day to a power station by the same means could be totally inefficient. Rail or belt conveyor could be a much more economic alternative.

Manpower Requirements for Mechanization

Labor/Supervisory Capabilities - When moving from manual methods to some form of mechanization, management must recognize the existing skills fo the workforce and build on these resources to create a nucleus of competent workmen to staff the new systems.

The differing skills of operatives required on a mechanized longwall face necessitate the selection of persons who have an interest in mechanical matters and a keen awareness to detail, as the operatives required to work a mechanized longwall face successfully must be readily able to absorb technology and use it to maximum effect. With the use of mechanical and electrical equipment there is a shift from a preponderance of manual to skilled workers for the daily operation, maintenance and repair of equipment. In addition, the number and skills of supervisory staff are increased, as the success of all aspects of

mechanized mining depend upon the competency of junior management and the willingness of senior management to delegate responsibility to that level so that it functions smoothly. Consequently, there should be no responsibility without authority.

Training and Operational Assistance - Pakistan is anxious to expand its industrial base and superstructure. This requires further expansion of the power industry. In that process, the transfer of appropriate technology from the developed countries to the developing ones has an important part to play. Education and training are as important in successful transfers as the provision of machinery or other equipment.

To turn the Pakistani workforce from the traditional manual methods to more productive mechanized methods will require all aspects of training:

- classroom training at home and abroad;
- on the job training at home and abroad; or
- the use of expatriate labor and supervisor to carry out the work of winning coal and the development of the mine while training the Pakistani workforce on a one to one basis.

The mining company must call for assistance to determine the following requirements so that the transition from hand to mechanized methods can be orderly and planned:

- Assess the training needs;
- Specify the training objectives;
- Design the training program;
- Select the training methods;
- Conduct the training;
- Evaluate the training given.

Any real increase in productivity of a mine due to mechanziation is dependent, almost exclusively, upon the degree of confidence that exists between management and men, particularly regarding the future, and this means training in its many aspects. The appreciation, understanding and guidance of its people in this matter is management's most urgent problem.

The Learning Period

To train and obtain the necessary experience as a mine worker requires time: time to see the operations carried out by an expert, time to develop the confidence and skill to carry out the work safely.

Training by example is the best means of teaching. With the innate willingness of the Pakistani worker to learn, "on site" training with a large teacher to pupil ratio can yield good results quickly.

The development of the Kakul Phosphorite Mine in Abbotabad in the NWFP Pakistan is such a case. On site training has been given to the workforce, together with UK based experience for the management. Within two years the mine is operational, albeit at a modest output.

INTERIM STEPS IN MECHANIZATION

Mechanization of mining operations can be carried out in stages so that there is a gradual evolution from manual methods to full mechanization with the latest design in powered supports to hold up the roof supports.

To convey the mineral from the working place by belt conveyors can be the first significant step in improving output. It, in addition, the distribution of supplies to all parts of the mine can be done quickly on modern rope or locomotive systems, then the development headings of the mine can be driven reasonably quickly by hand methods which can be fully mechanized at a later stage.

With the need for bulk output, longwall coal faces are required of 100 to 200 meters in length, equipped with machines which can cut and fill the coal at a rate of several hundred tonnes per hour. As the coal is cut and conveyed out of the mine, the ground exposed is supported temporarily in one of a number of ways to allow men free access along the coal face.

These operations can be carried out by equipment varying in cost and sophistication and it is in this area of mechanization that much debate has taken place as to how a mine can best maximize profits from bulk output as the conversion is made from handgot methods to fully mechanized mining.

Very often the criterion is cost and varying degrees of mechanization are embarked upon for this reason.

EXAMPLES OF FAILURE OF MECHANIZATION PROJECTS

Evidence is available which shows that mechanization projects have failed as a result of one or more of the following essentials having been ignored. They are:

- Lack of exploration of the geological structure.
- Lack of adequate planning of the mine: the rates of development required to ensure continuity of output with the provision of men and equipment; and the detailed design of face mechanization.
- Decisions made without technical or financial justification.
- Unsuitable training of the management or workforce.
- A lack of experienced fitters and electricians.
- A lack of spare parts for equipment repair.
- Inadequate funds to pay for these requirements.

BENEFITS OF DEVELOPING THE LAKHRA AREA

In conclusion, the rewards of careful planning are high if the visionary is far seeing.

When the Lakhra area is developed to a unified plan it will result in the employment of an additional 1900 Pakistanis and begin the development of a modern large scale coal industry.

Generating electricity with Lakhra fuel would cost 30% less than that obtainable using imported oil. The cost of generation using imported coal is the same as that when using Lakhra fuel, with the exception that an additional $38 million/year of foreign exchange would be needed, which the country cannot afford.

With the model design of the Lakhra area, other coalfields in Pakistan would be developed which would make available low cost coal for other energy applications. A cumulative effect of harnessing the resources and capabilities of Pakistan's private sector would be rapid growth and prosperity.

CHEMICAL, PHYSICAL, MINERALOGICAL, AND PETROLOGIC CHARACTERIZATION OF COAL AND THEIR ECONOMIC AND ENVIRONMENTAL SIGNIFICANCE

Dr. Nisar Ahmad
Fuel Research Centre
Pakistan Council of Scientific
and Industrial Research
Karachi 39, Pakistan

Dr. Frederick O. Simon
U.S. Geological Survey
Mail Stop 956
Reston, Virginia 22092
U.S.A.

ABSTRACT

Coal is a sedimentary rock which contains more than 50 percent by weight and 70 percent by volume of carbonaceous material. Differences in plant material, depositional conditions, degree of metamorphism, and concentration of mineral matter are the basis for methods of the classification of coal by type, rank, and grade. Laboratory tests to determine the chemical and petrological composition and physical characteristics of coal have been devised by national and international organizations to assure buyers of coal a fair value for their money and the sellers a fair price for their product. The three most commonly applied coal-classification systems require that the coal be tested differently and determinations used in one may not be used in others. The similarities and differences of test methods required for a large number of tests have been developed for the purpose of determining the chemical composition (ultimate and ash analyses) and physical characteristics of coal. The suite of chemical and physical tests used to evaluate a coal resource can have a significant economic and environmental impact on the power, cement, steel, and synfuel industries. Coal-quality studies are important in plant design and in reduction of plant-downtime due to fouling, slagging, erosion, and corrosion.

INTRODUCTION

Coal is defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal." (1) The classification of coal by rank (ASTM D388) is the most commonly used system in the U.S. as well as in many industrialized nations (2). The position of a coal in a progressive series starting with peat (least coalified) and ending with graphite (most coalified) is dependent on the temperature and time of burial and, to a lesser extent, the pressure which the coal has been subjected. The chemical, biological, and physical changes that occur prior to and during coalification will affect economic factors such as calorific value and ash yield of a coal which can be readily determined in the coal-testing laboratory.

Partially decomposed plant remains were buried for millions of years and altered to petrographic constituents of coal (macerals) which can be examined microscopically in both transmitted and reflected light. Major differences in the composition of coals results from the differences

in the types of original plants, the mineral matter added by hydrologic and l processes and inherent in the plants, the depositional environment in the peat swamp (factors such as pH and Eh), and factors such as time and temperature of burial. The quantities of various macerals, the moisture, volatile matter, and carbon contents, and the type and quantities of the various minerals present in a coal are the characteristics or attributes that differentiate one coal from another. Inorganic elements can be present as discrete minerals or bonded to organic functional groups, commonly as salts of organic acids. Mineral phases can be present as cleat fillings or intimately mixed with the organic material (inherent ash).

Coal has traditionally been used as a source of heat, a feedstock for the chemical or synfuel industries, and a raw material for the production of coke. The various uses of coal have varied somewhat over time and regionally. As a source of thermal energy, it is used for electric power generation, in cement plants, as process heat in various industries including brick kilns (which currently is the major use of coal in Pakistan), and for domestic home heat. More than 50 percent of the coal produced in the world is used for the generation of electricity (3). During the last decade, the production of synthetic gaseous and liquid fuels from coal became increasingly important, but recent economic developments indicate that, except for captive economies, synfuels will not be a major consumer of coal for the remainer of this century.

The use of coal to produce coke and fertilizer and as feedstock for the chemical industry has been known for a long time. In 1982, approximately 12 percent of the world's urea-based fertilizers were produced from coal, and coke manufacturing accounted for 15 percent of the world coal production (4).

The utilization of coal requires technological, economic, and environmental evaluations of data such as the coal type, rank, grade, and elemental contents which are potential environmental contaminants of both air and water. The economic evaluation depends on the end-use of the coal but generally requires data from the determination of calorific value, ash yield, and moisture, and constitutents that cause slagging, erosion and corrosion. Some end-uses require coal with specific compositions--for example, coke strength can be predicted from maceral composition and other parameters--and, therefore, coal contracts commonly specify compositional ranges for some constitutents. Contamination of the air and water have caused concern in countries where coal is utilized and in neighboring countries which are downstream from the source of the air and/or water pollution. The major environmental concerns are the contamination of the air by sulfur and nitrogen oxides (precursors of acid precipitation) and volatile toxic elements such as mercury, and the contamination of surface and ground water by compounds such as sulfuric and nitric acids and toxic elements such as arsenic, selenium, and mercury. Properly equipped laboratories can determine the chemical, physical, mineralogical, and petrologic

parameters necessary for the economic and environmentally safe utilization of coal resources. Therefore, it is essential to analyze and classify coal samples as part of any coal resource evaluation.

CHARACTERIZATION OF COAL

Sampling. Coal is a complex and heterogeneous material for which there is a wide variety of tests and methods for evaluation. In order that different laboratories (usually commissioned by the buyer and seller) obtain the same analytical result (within prescribed limits of error) for a given constituent or parameter, various organizations such as the American Society for Testing and Materials (ASTM) and the International Standards Organization (ISO) have established standardized procedures for the analysis of coal.

A representative portion of the coal being analyzed must be obtained carefully by following prescribed sampling and sample preparation. For a given determination, one gram or less may represent the coal in an entire unit train, the production of a coal mine, or millions of tonnes of resources. Sampling must be carried out pr[illegible]d with extreme care because it will a[illegible]ignificance of all additional work. Procedures for some sampling methods have been est[illegible]hed by ASTM (ASTM D2234) and ISO (ISO 1988). Samples used for resource studies are generally collected as channels in coal mines, as cores from drilling, or, less commonly, as channels in an outcrop. How the sample is collected will greatly affect the interpretation of subsequent petrographic, mineralogical, chemical, and physical tests. Factors such as whether the sample represents the entire thickness of the coal bed or the thickness of a single bench and whether the sample includes or excludes partings will affect most subsequent determinations, but especially ash and sulfur contents and calorific value. The preservation of the sample after collection is also important. Loss of moisture and contamination by foreign material are the most common threats to the integrity of the sample; double-wrapping samples in polyethylene in combination with storage in metal or heavy plastic containers or drums will generally protect the samples.

To utilize the analysis of a coal sample, it is necessary to know the basis upon which the results are being reported. The most common bases are:

i) as received,
ii) air-dried,
iii) dry or moisture-free (mf),
iv) dry, ash-free (daf),
v) dry, mineral-matter-free (dmmf),
vi) moist, mineral-matter-free (m,mmf).

The determination of the true (total bed) moisture content of a coal bed by heating is difficult because of several factors: 1) the loss of moisture during sample preparation, 2) the temperatures at which surface, inherent, and chemically combined moisture and water of hydration are liberated, and 3) oxidation (which offsets moisture loss).

Classification. The two most generally used systems for classifying coal (fig. 1) are the ASTM classification of coal by rank and the ISO system; the National Coal Board (United Kingdom) coal classification system is similar to the ISO system. Most classification systems used throughout the world use calorific value, fixed carbon or volatile matter, and the agglomerating properties of the coal. In some systems, additional tests further classify the coal by utilizing free (crucible) swelling index, dilatometer, and less commonly, carbon and hydrogen contents. The ASTM system utilizes calorific value (moist, mineral-matter free) and fixed carbon (dry, mineral-matter free); the agglomerating character (free-swelling index) is necessary to differentiate between subbituminous A and high-volatile C bituminous coals.

Recently the Economic Commission for Europe adopted a new codification system for classifying coals which is based upon vitrinite reflectance, the crucible swelling index, volatile matter, inertinite content, and gross calorific value (5).

Chemical composition. On a moisture-free basis, coal consists of an organic fraction and an inorganic (or mineral) fraction and the proper characterization of coal requires the analysis of both fractions (fig. 2). The ultimate analysis consists of the determination of the carbon, hydrogen, nitrogen, oxygen, and sulfur and is generally thought of as referring to the organic fraction, although all of the elements listed above also occur in minerals found in coal. The calorific value of a coal is generally determined directly with a calorimeter and can be estimated from the proximate and ultimate analyses. There is an inverse relationship between the calorific value and the ash and moisture contents; the calorific value (CV) can be calculated from the Mott-Spooner formula (6):

$$CV(mj/Kg) = 0.336C + 1.42H - 0.1450 + 0.094S$$

where C, H, O, and S are the carbon, hydrogen, oxygen, and sulfur contents, respectively.

Coal ash is the inorganic residue remaining after the combustion of the organic matter and should not be confused with mineral matter. There are several formulas which relate the ash content to the mineral matter content; the Parr formula used in the ASTM system or some modification of it is the most common (7): Mineral matter = 1.08 x ash + 0.55 x sulfur. The as-received-basis results are generally used by consumers to evaluate coal for end use. The dry, ash-free; dry, mineral-matter-free; and moist, mineral-matter-free bases are used for classification and chemical comparisons.

Sulfur in coal exists primarily in two forms--pyritic and organic; a third form, sulfate sulfur, occurs in minor concentrations. In some coal fields in Pakistan (including the Lakhra coal field), weathering of the coal has increased the amount of sulfate sulfur even at overburden depths greater than 100 meters. Knowledge of the forms-of-sulfur is particularly important for predicting the efficiency of coal beneficiation plants. Organic sulfur, which is chemically combined with the organic matter, cannot be

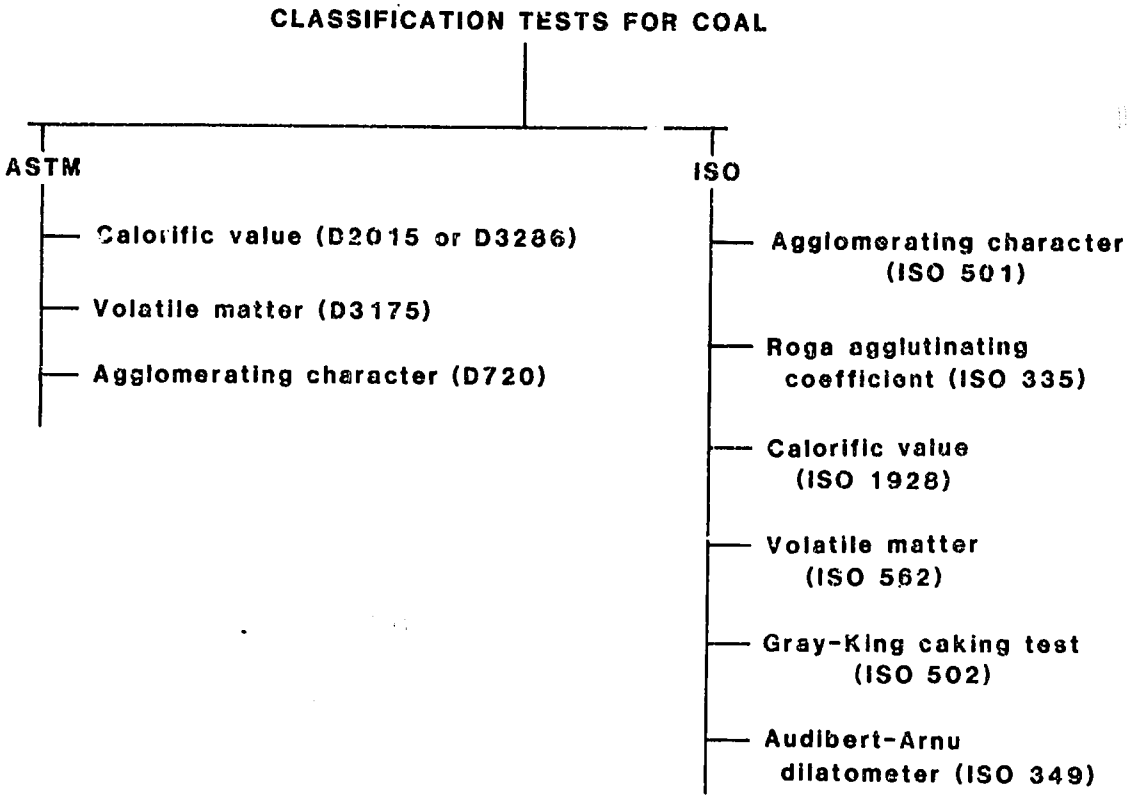

Figure 1. Classification parameters of ASTM and ISO.

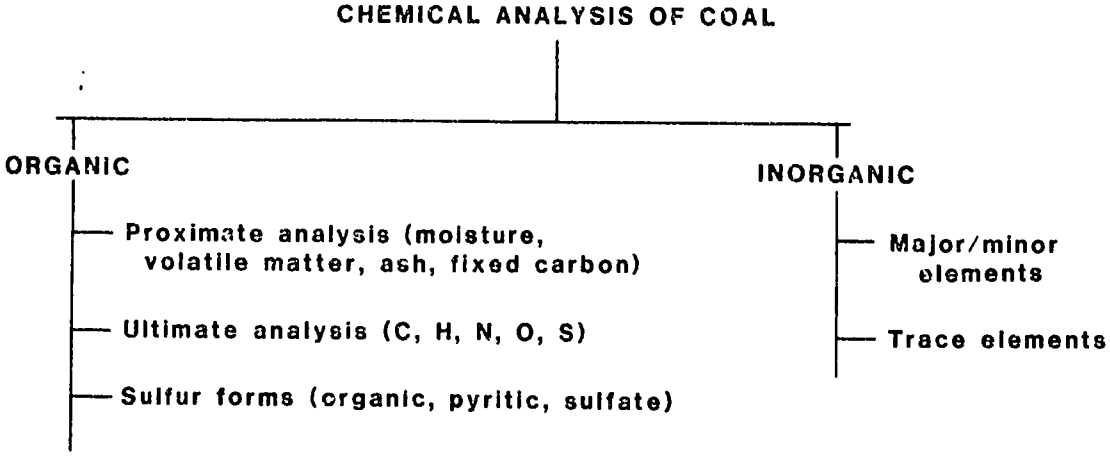

Figure 2. Chemical analysis of coal.

removed by the physical methods used in most beneficiation plants. Some chemical cleaning methods will partially remove organic sulfur but they result in a degradation of the heating value and are presently too expensive for most coal applications. Pyritic sulfur can be removed by physical cleaning, but only if it is not too intimately mixed with the organic matter. Framboidal pyrite is an example of a form that is commonly too finely disseminated to be removed by most physical methods.

Elements determined on coal ash and generally thought to be associated with the mineral matter in the coal includes silicon, aluminum, iron, calcium, magnesium, sodium, potassium, and approximately 70 additional trace elements. Many, if not all, of these elements can also occur as part of the organic fraction. Most chemical analyses of coal do not attempt to separate the elements associated with the organic fraction from those associated with the minerals.

The major constituents in coal ash are classified as to whether their oxides are acidic or basic in nature:

Acidic oxides	Basic oxides
Silicon dioxide-SiO_2	Calcium oxide-CaO
Aluminum oxide-Al_2O_3	Magnesium oxide-MgO
Ferric oxide-Fe_2O_3	Ferrous oxide-FeO
Titanium dioxide-TiO_2	Sodium oxide-Na_2O
	Potassium oxide-K_2O

The ash fusibility of a coal is substantially affected by the relative amounts of the acidic and basic oxides: Fe_2O_3, CaO, MgO, Na_2O, and K_2O lower the viscosity of the silicate melt formed from the heating of coal ash. During combustion, pyrite (and marcasite) are oxidized to ferric oxide and contribute to the lowering of the ash viscosity, but these elements also cause serious corrosion problems through the production of acidic gases and by direct attack of internal furnace surfaces by molten iron sulfides prior to oxidation. The presence of shale partings in a coal, which consist of mainly silica and alumina, will raise the ash fusion temperature, whereas calcite and dolomite serve as fluxes and lower the ash fusion temperature. Acid/base ratios, total acidic oxides, and total basic oxides, are used to predict ash-fusion temperatures, slag viscosity, corrosion, and high- and low-temperature fouling (8, 9). Most fouling indexes in the literature are limited in application; an index that is applicable to eastern U.S. coals may not be applicable to lignites or even similar coals from another region (10).

Sodium and potassium are the major contributors to the fouling of large boilers. The high vapor pressure of the alkalis at the operating temperatures of a power plant causes the vaporization of these elements, which then condense on boiler surfaces and cause the reduction of heat transfer. Anions that increase the vapor pressure of the alkalis (for example, chloride) can increase the fouling rates or cause a fouling problem where the alkali contents are too low to be a problem separately. The alkaline-rich condensates on boiler tubes and superheater elements serve as a sticky surface to trap particles (fly ash) being transported by the flue gas (10).

Laboratory tests to determine the major element composition, the ash fusion temperature(s), and the temperature at which the ash attains a viscosity of 250 poi· (T_{250} test) assist in the design of boilers with minimum fouling problems.

Mineralogy. For practical purposes, most users classify the mineral matter in coal as "inherent" or "adventitious" (11). Inherent mineral matter is the inorganic minerals too closely associated with the organic matter to be readily separated and usually applies to mineral matter interpreted as part of the plant precursers; adventitious mineral matter is the material less intimately associated and interpreted as having been transported into the peat (detrital) or formed from solution (authigenic, syngenetic, or epigenetic). Some researchers have classified minerals in coal according to their origin (12):

--detrital	deposited by wind or water;
--authigenic	formed in place;
--syngenetic	formed simultaneously with coal;
--epigenetic	formed after initial coalification.

Table 1 lists some of the more common minerals found in coal; the table should not be considered inclusive because more than 100 minerals have been identified in coals.

Low-temperature ashing of coal (13), combined with x-ray diffraction and infrared spectroscopy techniques have been used to determine the gross mineralogy of coal. These techniques generally do not detect minerals present in c ncentrations

Table 1
Selected minerals in coal
[Modified from references 12 and 14]

Mineral group	Mineral
Clay minerals	Kaolinite
	Illite
	Chlorite
	Montmorillonite
	Mixed-layer clays
Carbonates	Calcite
	Dolomite
	Siderite
	Ankerite
Sulfides	Pyrite
	Marcasite
	Sphalerite
	Galena
	Chalcopyrite
	Arsenopyrite
Oxides	Quartz
	Hematite
	Magnetite
	Goethite
	Rutile
Sulfates	Gypsum
	Anhydrite
	Barite
	Jarosite
	Szomolnokite
Phosphates	Apatite
Chlorides	Halite
	Sylvanite
	Bischofite
Other minerals	Zircon
	Garnet
	Sanidine
	Orthoclase
	Albite
	Epidote
	Kyanite
	Augite
	Biotite

less than 5 percent. Scanning electron microscopy, combined with energy-dispersive x-ray spectroscopy, has been effectively used to study minerals present in coal in minor or trace concentrations (14).

The inorganic elements present in coal as discrete minerals are a major cause of problems in using coal as a source of energy. Performance, reliability, and efficiency of coal burning power plants are limited by the slagging and fouling characteristics of the coal; corrosion and abrasion of the heat-receiving surfaces are a function of the type and amount of mineral matter in coal. The efficient operation of slagging gasifiers are also dependent on the slagging, fouling, and abrasive nature of the feedstock and filtration and catalysis steps in liquifaction or solvent-refined-coal processes also require coal characterization for efficient operation. The identification and quantification of elements and minerals in the ash are major steps in dealing with the slagging, fouling, abrasion, filtration, and catalysis problems encountered in coal utilization and in minimizing the operating costs of a power plant.

Coal benefication can change the mineral and chemical composition of coal ash by selectively removing some mineral constituents. Inherent ash is generally not affected by coal benefication; adventitious mineral matter, which commonly occurs in coal as cleat fillings or other discrete entities which are sufficiently large, can be partially separated by conventional gravity separation methods. Previous coal benefication studies have concentrated on the removal of sulfide minerals to reduce the SO_x emissions and on the removal of moisture and ash to reduce transportation costs.

Petrography. Coal consists of two basic classes of materials (see fig. 3): 1) inorganic, crystalline minerals, and 2) organic, phytogenic, non-crystalline macerals. The macerals form the carbonaceous, combustible fraction of the coal and must form 50 or more weight percent. The more common maceral types are listed in table 2; the usefulness of this type of data is widespread, from pure scientific investigations such as characterizing sedimentary environments of the coal-forming peat swamp to the more practical uses such as predicting various aspects of coke quality or liquefaction yields. In the conversion of coal into metallurgical coke, coke strength, coke yield, coke reactivity, coke size, and coking pressures can be predicted from the maceral and mineral compositions. In the conversion of coal into liquids, the conversion yield is proportional to the amount of "reactive" macerals (vitrinite + exinite) present (15).

Physical properties. The uses of physical properties and their measurements include not only basic studies of the chemical composition and structure of coal, but also to mechanical and plastic properties which are important to the power and steel industries. Some of the tests devised to evaluate the mechanical and plastic properties are briefly described in table 3.

Table 2
Partial list of coal macerals
[Modified from ref. 16]

Vitrinite	An oxygen-rich, medium reflecting maceral that comprises the humic fraction of coal and is produced by the gelification and alteration of plant cell walls.
Fusinite	Highly reflecting maceral consisting of carbonized woody material and produced by the rapid charring or chemical alteration of plant cell walls.
Micrinite	Highly reflecting, granular maceral which shows no plant-cell structure and is commonly found in the attrital fraction of coal; it is produced by the fragmentation or granulation and subsequent coalification of plant substances.
Exinite	A hydrogen-rich, medium reflecting maceral that comprises the attrital fraction of coal and are derived from the waxy cell secretions such as plant cuticles and spore and pollen exines.
Resinite	A hydrogen-rich, medium reflecting maceral that are derived from the resinous secretions of plant cells.
Macrinite	Highly reflecting particles derived from humic material and which do not display cell wall organization.

Table 3
Physical tests for coal

Calorific value	This is the single most important test for coal. Methods to measure this parameter usually employ an oxygen calorimeter which measures the gross calorific value (water exists as a liquid at the completion of the process); the net calorific value is obtained by correcting for the heat of vaporization of water.
Grindability	The most common approach to determine the grindability of a coal is to supply a fixed energy input and evaluate the fraction of the sample reduced to a suitable fineness (Hardgrove grindability). An alternative approach is to measure the energy required to grind the sample to the specified fineness.
Plasticity	Determining the plasticity characteristics of coal is difficult because of the heterogeneous nature of coal. As the coal is heated, chemical and physical changes occur both concurrently and sequentially, making attempts to describe and characterize the changes difficult at best. A number of tests, mostly related to the coking characteristics of a coal, have been devised and are described briefly in the next section.
Density	Three categories of density are determined for coal: 1) bulk density is the weight per unit volume, measured by weighing a box of known volume full of crushed coal; 2) true density (sometimes referred to as helium density) uses a fluid, usually helium, to determine the volume by penetrating the pore spaces of a weighed amount of coal; and 3) apparent density uses a fluid such as mercury that does not penetrate the pore spaces to determine the volume.

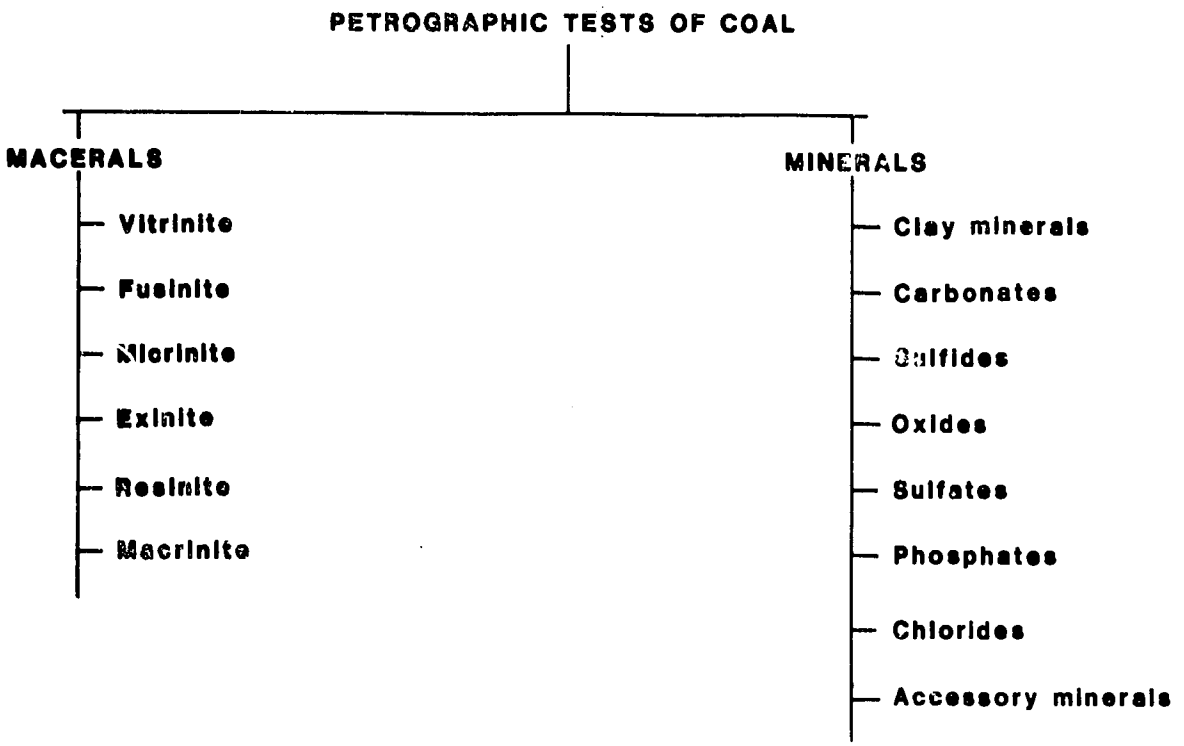

Figure 3. Petrographic tests of coal.

Carbonization (coking) tests. The formation of coke from coal involves the interaction of a wide range of chemical and physical processes at elevated temperatures. The properties of the coke formed--reactivity, yield, and strength--are dependent on the plastic (surface flow caused by the pressure of gases at elevated temperatures), agglutinating (binding quality), agglomerating (tendency to form coke), and swelling (volume change at elevated temperatures) properties (3) of the coal used and on the carbonizing conditions. The tests used to ascertain these properties are summarized in table 4.

Table 4
Carbonization Tests

Test	Property measured
1. Crucible swelling No. (Free-swelling index)	agglomeration
2. Gray-King test	changes in volume
3. Audibert-Arnu dilatometer	changes in volume
4. Gieseler plastometer	plasticity
5. Roga coefficient	agglutination
6. Jenkner retort	quantity of coke, tar, gases, and water.

DISCUSSION

Economic aspects of coal analysis. The impurities in coal (grade) have a substantial impact on the economic value of the coal. For power plants, sulfur in flue gases, the ash yield, and boiler-tube corrosion and slagging caused by contaminants are the major deleterious factors. In a few instances, trace contaminants in coal ash can be economically recovered. In coal-conversion processes, some contaminants have a catalytic effect and are beneficial. Therefore, in addition to the analyses needed to

classify coal according to rank (calorific value and proximate analysis), many different analyses are required for coal commerce (e.g., calorific value, ash yield, sodium and chloride contents, and ash-fusion temperatures) and for determining the environmental effects of coal use (contents of sulfur, nitrogen, and toxic trace elements such as mercury, arsenic, and selenium). Improper boiler design can lead to excessive down-time because of fouling caused by burning coal with high ash yields or with an improper ash-fusion temperature. The amount of sulfur removed from a coal by a coal-cleaning plant depends on 1) the relative amounts of organic and inorganic sulfur, and 2) the particle size and distribution of the inorganic (pyritic) sulfur. The removal of ash-forming elements and minerals also depends on particle size as well as whether or not the minerals are present as cleat-fillings, discrete layers, or nodules, or whether they are intimately mixed with the vegetal matter (inherent ash). Coal testing laboratories can provide data needed to answer questions concerning the economic use of a particular coal and insure that the buyers and sellers agree to a fair and equitable exchange.

Environmental aspects of coal analysis. Coal production will increase in the world and particularily in Pakistan at an accelerated rate with the major portion of the increase being used to provide fuel to generate electricity. Therefore, trace element occurrences and distributuions must be evaluated geologically, geochemically, geographically, and environmentally in order to minimize the impacts of mining, benefication, use, and disposal of coal wastes, on human health.

Contamination of the air and water by sulfur and nitrogen compounds and toxic trace elements can be reduced or evaluated by knowledge of the contaminants in coal and the utilization of adequate safeguards during mining, beneficiation, and use. During exploration and mine planning, failure to prove the environmental safety of a proposed fuel can jeopardize funding by international lending institutions such as the World Bank and the Asian Development Bank. In some areas, coal ash may be beneficial to crop growth because it serves as a source of trace-elements essential to plants. Examples of these essential trace elements are sulfur, calcium, boron, and zinc (17).

The chemical composition of coal is specific according to site, coal bed, and location within the coal bed. Boron, mercury, lead, molybdenum, arsenic, cadmium, antimony, and selenium are more abundant in coal than in the earth's crust (17). However, because large quantities of coal are used to generate electricity, large quantities of certain trace-elements can be mobilized in wastes and by-products to potentially contaminate the air and water. Volatile elements such as sulfur, nitrogen, arsenic, fluorine, mercury, and selenium are of particular environmental concern because of their ability to be transported in the atmosphere and move across national and continental boundries. For a 300-MW power plant using lignite containing one part per million (0.0001%) contaminant, more than one tonne of

that contaminant will be mobilized annually. The amounts of selected trace elements being liberated annually in the world and for a single power plant have been estimated (18). This estimate is based on the distribution of these elements in U.S. coals which were deposited under a variety of conditions and include all coal ranks. Table 5 lists the estimates of the amounts of selected trace elements mobilized for a single 300 MW power plant and for the world in the years 1978 and 2000. The coal quality of the Lakhra and Sonda-Thatta coal fields in Pakistan is currently being evaluated by the Geological Survey of Pakistan and the U.S. Geological Survey, and although these data are not yet available, both toxic and beneficial trace elements will be present.

Table 5
Quantities of trace elements mobilized as a result of coal production
[Modified from ref. 17; data are in short tons.]

Element	300 MW power plant	World (1978)	World (2000)
As	5.1	19,000	47,000
Be	1.4	5,100	13,000
Cd	0.14	510	1,300
F	65.	230,000	590,000
Hg	0.09	328	843
Pb	7.1	25,000	65,000
Se	1.7	6,200	16,000

The U.S. National Committee for Geochemistry convened a panel on the "Trace Element Geochemistry of Coal Resource Development Related to Health" which concluded (16) that besides the troublesome compounds of carbon, sulfur, and nitrogen, the elements of greatest concern are arsenic, boron, cadmium, lead, mercury, molybdenum, and selenium. Elements of moderate concern are fluorine, vanadium, chromium, nickle, copper, and zinc; elements of minor concern are lithium, sodium, manganese, cobalt, germanium, chlorine, bromine, strontium, and barium. Their recommendations are applicable to all nations:

-- chemical and mineralogical form of trace-elements related to health should be determined:

-- a trace-elements-in-coal data bank should be maintained;

-- more data are needed on the trace-element mobility in topsoil, overburden, and underclay;

-- more and better data are needed on trace-element mass balance and migration pathways;

-- standard reference materials certified for critical trace-elements are needed.

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A SYSTEMS APPROACH TO COAL HANDLING AND TRANSPORTATION

J. PHILIPP
VICE PRESIDENT POWER TECHNOLOGY

S. MCPHERSON
MANAGER OF FOSSIL SERVICES

BURNS AND ROE COMPANY
NEW JERSEY USA

ABSTRACT

This paper discusses the various alternatives for transporting coal from the mine to the power plant, i.e., road, overland conveyor, and rail; also the systems generally employed for unloading, stackout, and reclaiming coal at the power plant. Capital-intensive and labor-intensive systems are reviewed. System reliability and maintainability considerations are discussed. Silo design features and safety considerations in storing and handling fuels prone to spontaneous combustion are identified.

COAL DELIVERY

Coal deliveries overland to the plant site receiving station may be by way of truck, overland belt conveyor, unit train, or any combination. The delivery mode used depends on such factors as plant location, distance from the mine to plant, daily "burn rate" under full-load conditions, available coal-yard acreage, and the relative costs of the competing transportation modes.

Trucks are generally used in short haul applications and are particularly suited where the power plant is located at the mine mouth. Compared to railroads, trucks use about four times as much energy per ton mile. In situations where a good road highway system exists, trucks represent the minimum short-term capital expenditure. In the USA, about 10% of the coal is transported by truck.

Overland belt conveyor systems are also ideally suited for mine-mouth plants. Overland belt conveyors have been used to transport coal up to 32 kilometers (20 miles); beyond this distance their advantage fades sharply. In special situations where the terrain may necessitate circuitous road or rail routes, an overland belt conveyor system that could follow an "as-the-crow flies" path may have an advantage. Single flight conveyors as long as 8500 meters (28,000 ft) have been used in 16 kilometer (10 mile) systems. Overland conveyors can be regarded as a capital intensive, low energy, low labor use system.

On highway systems, trucks are limited to around 40 tons. In situations where private roads can be constructed specifically for the transportation of coal from the mine to the power plant, "Off Highway" trucks capable of hauling loads up to 136 tonnes (150 tons) can be utilized. As stated earlier, trucks are energy intensive and the fuel costs are very sensitive to the length of the haul. In areas where low labor rates prevail this can offset the impact of the fuel costs.

It should be mentioned that coal slurry pipelines are also used to transport coal. In addition to the pipeline, a slurry preparation plant at the mine and a slurry storage facility at the power plant is required. The product is dewatered and stored dry. Economics favor slurry pipelines when coal has to be transported over significant distances. The 437 kilometer (273 mile) long Black Mesa pipeline runs from northeastern Arizona to southern Nevada. Coal is reputed to be delivered for about half the cost of shipping by rail.

Experience has shown in the USA and elsewhere that unit trains, more than any other transport mode, are the most efficient way to haul large volumes of coal over distances.

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A typical modern unit coal train comprises about 100 cars, plus three to five locomotives, with each car carrying 89.3 tonnes (100 tons) of coal. This 8930 tonnes (10,000 tons) train continually operates back and forth between the source of coal and the generating plant remaining as a unit and operated as a shuttle.

The average unit coal train is over a mile long. Therefore, enough track must be provided at the plant site to allow both loaded and empty trains to remain clear of the main rail line, or such other interferences as grade crossings, access roads, shunt rail lines, etc.

Generally, a loop track is used to get the longest possible track layout in the least space. Often, the coal storage and reclaim system and a locomotive and car maintenance and repair facility are located inside the loop. In some cases, straight track may be used for both loaded and empty trains where the right of way is available parallel to the railroad line.

Length of track around the plant's unloading loop establishes the maximum length of the unit train that can be handled since the most economical operation requires that the train be handled as a unit, not separated into sections.

A train of a hundred 89.3 tonnes (100-ton) cars each about 16 metres (53 ft) long plus three locomotives will extent a total of about 1700 metres (5,600 ft) head to tail.

Such a unit train has a gross weight of about 13,000 tonnes (15,000 tons). Loops can also be designed which require the train to go around the loop twice, once to conduct the string of loaded cars clear of the main line and bring the first coal car into the unloading station, and the second loop to unload the cars in sequence and store the empty cars clear of the main line. This can sometimes save a considerable amount of track, as well as space, but has the disadvantage of increasing track wear and train turnaround time.

System Design

The main objectives in the design of a coal-handling system are to provide a system which will be reliable and maintainable with as simple a design as possible, based on a thorough understanding of the characteristics of the coal to be handled. In addition to these general considerations there are other factors to be evaluated. Systems may be designed to be labor intensive as opposed to capital intensive where low cost labor is available. To the greatest extent possible the country's natural resources and manufacturing capabilities should be utilized to minimize the expenditure of foreign exchange. The systems provided must be capable of being maintained consistent with the level of craft skill available locally.

In planning a new coal-fired power plant, it is recommended that the coal-handling facility layout should be developed in the early stages of the total power plant planning and closely coordinated with the location and orientation of the balance of the plant. For example, in the case of a plant having multiple units, it could be advantageous to arrange the entry of plant feed conveyors in the center of the plant, rather than at the end of the plant. This approach will enable silo feed in both directions simultaneously with less conveying equipment and will improve system availability. Coal handling layouts should be developed with a minimum number of transfer points. Coal receiving, stockpiling, reclaiming, and plant feed sub-systems should preferably be arranged for "one-way" coal flow pattern to minimize conveying distances.

A coal-handling system must also feature a broad redundancy of equipment: in-plant coal-handling facilities; facilities for direct feed; emergency temporary storage; active and inactive storage; coal-storage reclaim. A coal-handling system can be broken down into five functional sub-systems: (1) receiving/unloading; (2) crushing/screening; (3) direct (live) feeding; (4) storing; (5) stacking, reclaiming.

Such ancillary operations as coal sampling and analysis, dust suppression and collection, fire and explosion prevention, and manual and automatic controls, are generally superimposed across all these basic subsystems.

The authors' company has designed coal handling systems to cover a wide range of fuels such as bituminous, subtuminous and lignite.

Presented here today are four basic systems, shown on Figures 1, 4, 6 and 8, which have been used for plants in the USA and overseas. It is not implied or construed that these are the only solutions available in the design of a coal handling system.

Figure 1 - Coal-Handling System 1

Unit train cars arriving at the plant site proceed to the rail car unloading building. When a rotary dump system is employed, the rail cars are of the top-dump gondolar type. Alternatively, bottom dump cars which empty directly over the receiving hoppers can be of the saw-tooth configuration or the rapid discharge bottom-dump type, where virtually the entire coal supporting area is opened for quick unloading. For purposes of this discussion, the latter type of bottom dump car is assumed. Whereas we have mentioned 89.3 tonnes (100 ton) rail cars, cars of lesser capacity, say 63.5 tonnes (70 tons), are available.

Figure 2 shows a rotary car dumper. A rotary-dump gondola car has no bottom hoppers or side gates for unloading; it is simply a box on wheels. To discharge its load at the unloading facility, the car is literally turned upside down. To permit this, a rotary-swivel coupling, rather than a conventional interlocking coupling, is used.

For rotary-dump unloading, the unloading station must have equipment that precisely positions each car, holding it locked in position on the rails and then rotating it nearly upside-down.

Dumpers are rotated by an electromechanical drive. The mechanical portion consists of a gear-reduction drive through either a rack and pinion, wire rope on a drum or capstan, or a chain. One or both end rings may be driven.

A rotation of 140 to 160 degrees usually will empty cars of free-flowing material. Normally a dumper is designed to rotate over and back in 30 to 35 sec.

A variety of factors can distort the time required for any of these functions. Under ideal conditions, mild temperatures and dry free-flowing coal, a 100-car-unit train can be unloaded in less than 3-1/2 hours.

If conventional interlocking couplings and manual positioning of the car are employed, then the overall time to unload the unit train would be in the order of 6 hours. Factors to be considered in establishing a unit train size will be influenced by the round trip time, unloading time, plant burn rate, and the investment required to purchase rail cars.

For bottom-dump unloading, the hatches of the hoppers are opened as the car moves over the unloading facility. The hatches can be trip-opened manually or automatically. When the hatches are opened, the coal falls through a metal grating (grizzly) between the track rails into large coal hoppers.

The newest quick-dump, 89.3 tonnes (100-ton), hopper car can empty its load in about 15 sec. These cars have steep interior slopes with clean lines to minimize areas for coal hangups. Transverse hatches--up to 12 per car, two on each of six hoppers--form the major portion of the bottom of the car. When these hatches are automatically thrown open, most of the bottom of the car disappears, in effect, and the coal drops out smoothly and quickly.

When provided with the necessary capacity in the receiving hoppers and coal take-away conveyors, the entire 89.3 tonnes (100 ton) car unit train can be unloaded automatically in about 3 hours. If the car bottom dump hatches are manually tripped, the time required would be greater.

The receiving hopper design for bottom dumping is similar to that for a rotary car dumper. The total depth of pit required is around 18 metres (60 feet); subsoil conditions and water table elevation can significantly affect costs of these underground structures. Bottom dump cars cost more and require more maintenance than rotary dump cars. During the life of the plant, the rail cars may have to be replaced once and this fact should be considered in any evaluation. However, the immediate offshore capital expenditure would appear to be minimized by the use of a bottom dump pit subsystem.

As shown on Figure 1, the coal is conveyed from the receiving hoppers under the railroad track to the crusher tower. In the event that the crusher tower and the conveyors downstream leading to the plant silos cannot receive the coal, provision is made to stackout the capacity of a unit train. A separate conveyor may be used for emergency stack out purposes. Under normal circumstances, coal from the receiving hoppers is sent via the crusher tower to replenish the in-plant coal silos. The function of the equipment in the crusher tower is to remove tramp-iron via magnetic separators before entering the surge bins feeding the hammer mills where the coal is crushed to a maximum of 1.9 cm x 0 (3/4" x 0) lump size. Samples of the "as fired" coal for laboratory analyses are obtained at this location. Analyses are performed to determine the heating value and the chemical constituents of the coal to assure the quality of the coal and to optimize the furnace operation. The coal is then conveyed via dual belt conveyors to the plant. Provisions are made to transfer from one belt to another in the event that one of the conveyor belts is unavailable. For all four systems discussed herein, the arrangement from the crusher tower to the coal plant silos is essentially the same.

When the plant silos are full, the coal is discharged to the active pile utilizing a rail mounted stacker reclaimer conveyor located on concrete beams at grade.

The active pile usually contains 72 hours of storage and is stacked out on both sides of the track. It is available for immediate use by the plant and can be reclaimed by remote control without the use of mobile equipment.

Reclaiming is achieved by a boom-mounted bucket wheel which contains a series of scoop-shaped baskets which dig into the pile, scooping up loads of coal. The coal then falls from the wheel into a surge bin and on to the conveyor belt. The machine is capable of stacking out and reclaiming over the length of the pile. Coal can be moved to and from the active and inactive pile by mobile machinery, as required.

The coal-handling system for the Cross Generating Unit, South Carolina, USA, which is based on System 1, is shown in Figure 3.

Figure 4 - Coal Handling System 2

System 2 is similar to System 1 except for the method of stackout and reclaim. As shown on Figure 5, the coal is stacked out by travelling tripper mounted on an overhead conveyor. Coal from the active pile falls by gravity into the slots in the bunker and is then scraped onto conveyor belts by rotary plow feeders which travel the length of the active pile. In a multi-unit plant, the slot bunker and travelling tripper length can be installed to suit the needs of the initial units then extended to meet the needs of the subsequent units. This allows the plant construction costs to be tailored to the need of the units actually in operation. Construction costs of the slot-bunker can be adversely affected by subsoil conditions and high water table elevations. Extensive dust and fire protection services, sump pumps, etc. are required in all underground structures particularly when handling fuels prone to spontaneous combustion.

The machinery equipment is simple in design and is considered maintainable by even inexperienced craft labor. The offshore capital expenditure for System 2 should be less than System 1. Since dual rotary plow feeders are provided, an emergency reclaim system is typically not required. The elevated covering is intended to keep rain off

the active pile and is only necessary in areas which have abundant rainfalls.

Figure 6 - Coal-Handling System 3

System 3 is based upon bottom dump cars unloading over a trestle as shown on Figure 7. The trestle is about 15 metres (50 feet) high and the length is dictated by the size of active pile. On an 8 unit 2100 MW plant in Venezuela, designed by the authors' company, the trestle was 500 metres (1640 feet)long.

Two significant advantages of this system are:

1) Reclaim is above ground, and

2) The unit train can be dumped without the trencher reclaimer or yard conveyors being in operation.

Above-ground reclaim as opposed to underground reclaim does not require sump pumps, ventilation systems, fire protection, and exit points for personnel safety.

The trencher reclaimer requires a skilled operator but is easier to operate than the stacker/reclaimer in System 1. It also requires less maintenance since no reversing belts are employed and the controls are simpler. The system is not manpower intensive and will require some expenditure of capital offshore. However, an above ground reclaim system has significant safety advantages over below ground systems, particularly when handling fuels with a propensity for dusting and prone to spontaneous combustion. The additional transfer towers will add capital and maintenance costs to the system. The long drop of coal can create dust problems which may necessitate the use of sprayed wetting agents. An emergency reclaim facility is provided to supply coal when the trencher reclaimer is unavailable.

Figure 8 - Coal-Handling System 4

System 4 also employs trestle unloading and stackout as shown on Figure 9. Reclaim is underground via rotary plows. Both plows feed onto conveyors which, in turn, discharge to a centrally located conveyor taking coal the crusher tower. This system probably has the lowest machinery cost of all systems. It has low offshore capital expenditure when compared to the systems requiring either a stacker/reclaimer or trencher reclaimer.

Subsoil and high water table elevation can significantly impact the cost of underground structures. The underground structure will require all the previously mentioned services.

Silo Design

All of the systems described are designed to deliver coal to the in-plant silos. The plant silos normally hold enough coal to keep the plant operating at 100% load for at least twelve hours. The system used to deliver coal to the pulverizer is shown on Figure 10.

The coal leaves the silo primarily under gravity flow, usually through a coal valve and downspout and into a belt type feeder. The feeder controls the rate of flow of coal into the pulverizer, and thereby is the key element in controlling the firing rate of the boiler. Coal leaving the feeder passes through a transition to the pulverizer via the inlet pipe.

One of the major considerations when dealing with low-grade fuels which tend to have a disproportionate quantity of fines is the design of the silo.

In the U.S., the National Fire Protection Association (NFPA) has mandated that coal silos will be designed on the mass flow principle. Mass flow means that the coal which enters the silo first will leave the silo first.

In the past, little attention was paid to the flowability of material, and the slope for bunker and silo walls was around 55 to 60 degrees.

Storing low-grade fuels with high surface moisture and clay content in these silos has resulted in "funnel flow" as opposed to "mass flow" as shown in Figure 11.

In essence, coal stuck to the sides of the silos, and the last coal in was the first coal out. Since the usable content of the silos was reduced, coal had to be fed to the silos more frequently. Coal supply to the feeders was often interrupted due to the intermittent nature of the flow, causing operational problems. The most serious problem of all was that the static coal ignited.

For these reasons it is important for any new fuels, particularly lignite, that flowability tests be carried out to determine proper silo angle and optimum size of the silo outlet.

On a recent project burning lignite, with 33% average moisture, in which the authors were involved, a 78 degree angle and a 91.4 cm (36 inch) opening were required to ensure mass flow in the silo. The silo hopper sections were lined with stainless steel and all corners were curved and smoothed.

All silos should be provided with connections that allow the coal to be emptied via temporary chutes to trucks in an emergency situation. In operation, it may be necessary to store less than the silo design capacity to lessen the possibility of fire. All hoppers and bins used in the coal-handling system should be designed to ensure mass flow.

COAL STORAGE SAFETY CONSIDERATION

Normally, inactive storage requirements are governed by the reliability of the coal supply and transportation system.

Provision to store from 60 to 120 day supply of coal is generally made in the plant design. In recent years, due to the large capital investment in maintaining such huge reserves, many utilities in the USA have been endeavoring to reduce these quantities to around 45 days.

Minimizing the inactive storage could be a significant safety consideration when storing fuels prone to spontaneous combustion. Inactive storage piles are generally formed in layers around 12 inches deep up to a height of about 40 feet. The packed density is carefully controlled to preclude voids. By reducing the supply of oxygen, the potential for spontaneous combustion and the resultant fires is reduced. Generally, crusting agents are applied to the pile to minimize dusting and weathering of the coal. Weathering of the coal, particularly lignitic fuels, can degrade the heating value of the fuels. Coal piles are generally inspected for "hot-spots" on a daily basis. Hot coals are removed by mobile equipment and spread on the ground to cool.

It is important in the design of the coal handling system that every effort should be made to detect fires and prevent the generation of dust. Fire protection and dust control measures must be provided as necessary, particularly in underground reclaim facilities and other enclosed structures, and maintained in working order throughout the life of the plant. All measures to facilitate good housekeeping, such as washdown systems and heavy-duty systems should be provided.

In spite of all the provisions made in the design, successful and safe operation will depend on the vigilance, discipline, and training of the operating personnel.

We trust that the views offered in this paper will be of value in the successful and safe operation of the coal-handling system chosen for the Lahkra project.

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COAL TRANSPORT MODES

- SHIP (COLLIER)
- BARGE
- RAIL
- PIPELINE
- TRUCK
- CONVEYOR

FIGURE 0

COAL HANDLING SYSTEM I

UNLOADING - ROTARY DUMPER/BOTTOM DUMP PIT
STACKOUT - STACKER RECLAIMER
RECLAIM - STACKER RECLAIMER

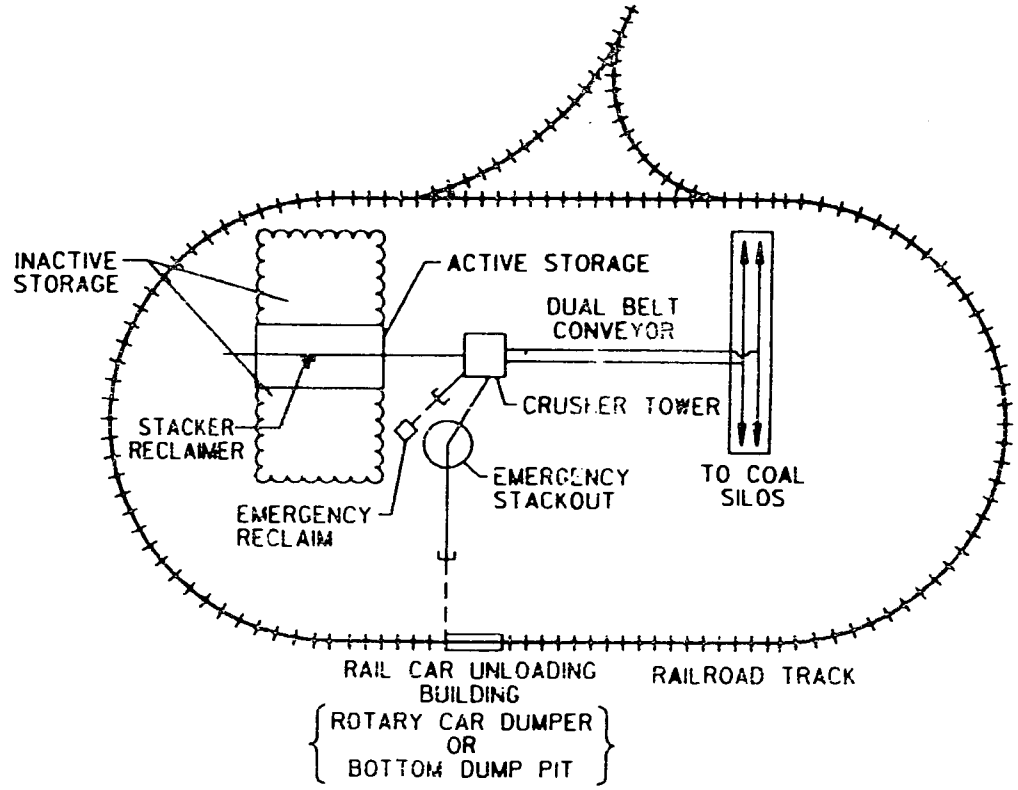


FIGURE I

ROTARY CAR DUMPER

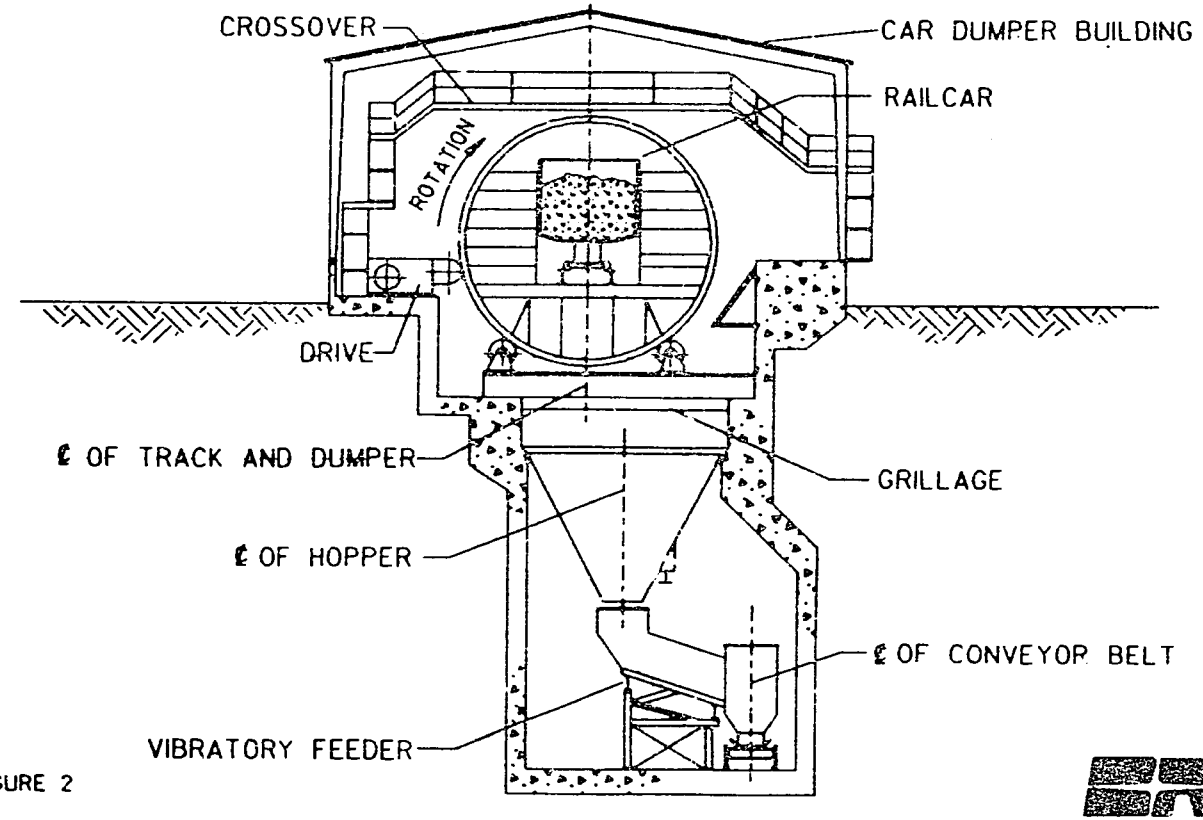


FIGURE 2

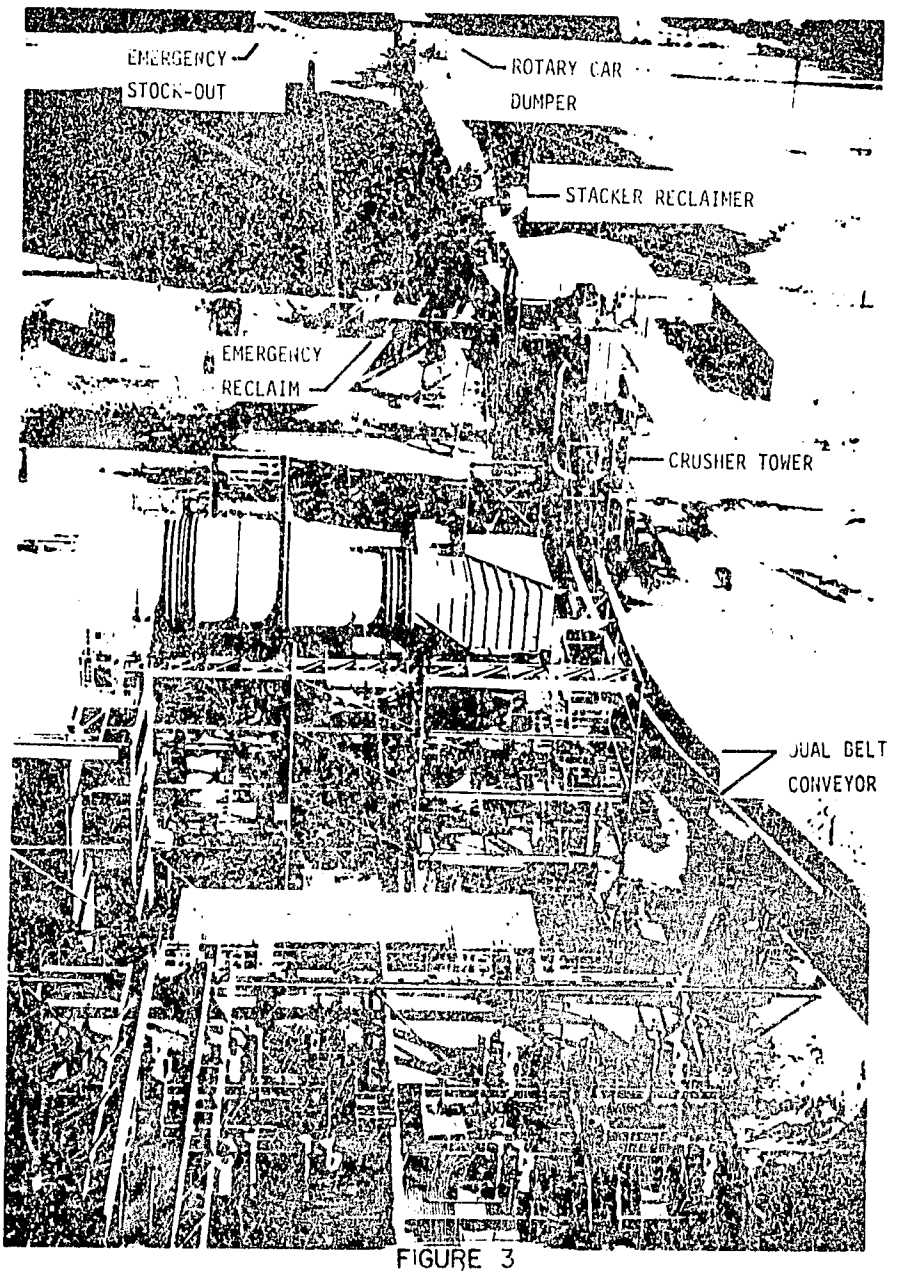


FIGURE 3

COAL HANDLING SYSTEM CROSS GENERATING UNIT SOUTH CAROLINA USA

COAL HANDLING SYSTEM 2

UNLOADING - ROTARY DUMPER/BOTTOM DUMP PIT
STACKOUT - CONVEYER -TRAVELLING TRIPPER
RECLAIM - ROTARY PLOW FEEDER

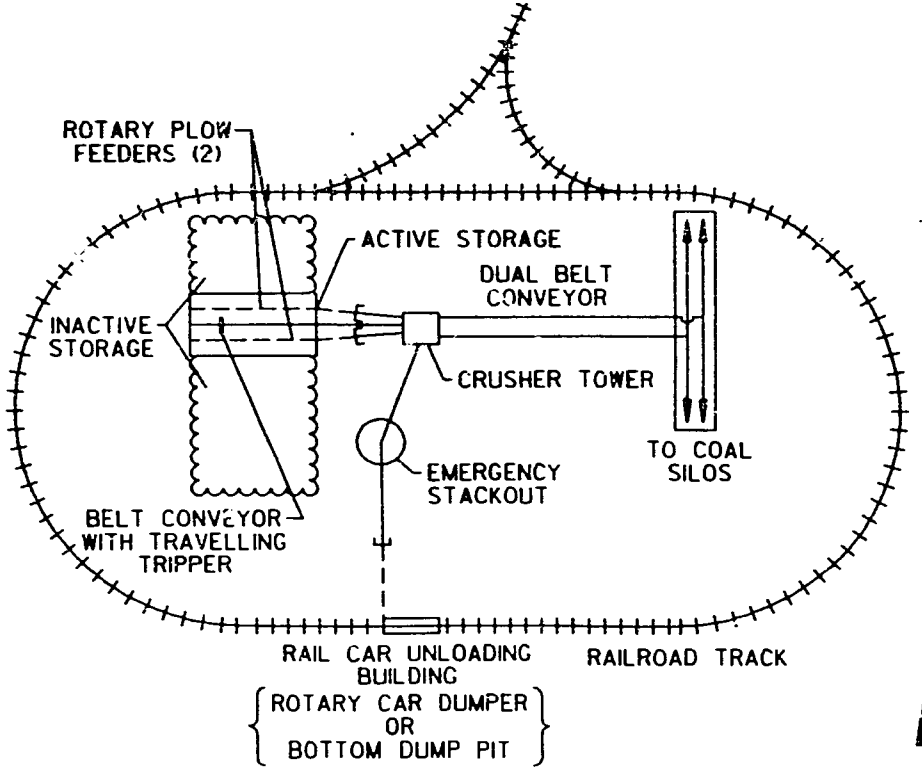


FIGURE 4

SLOT BUNKER-ROTARY PLOW FEEDER

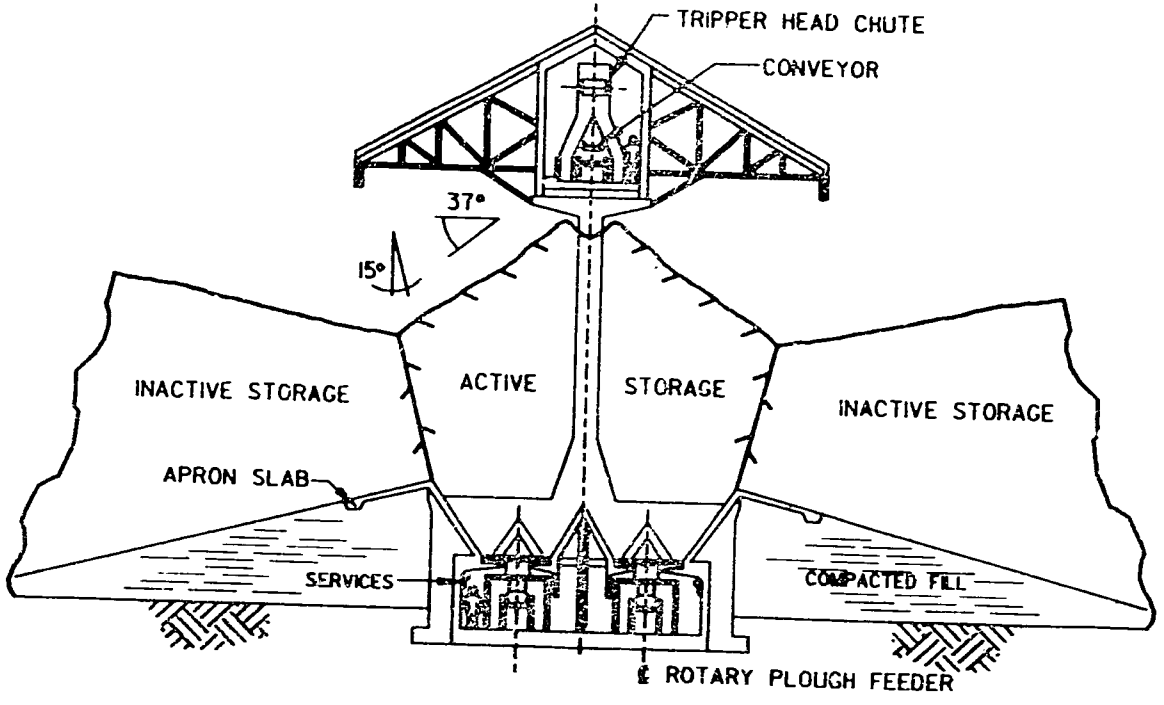


FIGURE 5

COAL HANDLING SYSTEM 3

UNLOADING - TRESTLE
STACKOUT - TRESTLE
RECLAIM - TRENCHER RECLAIMER

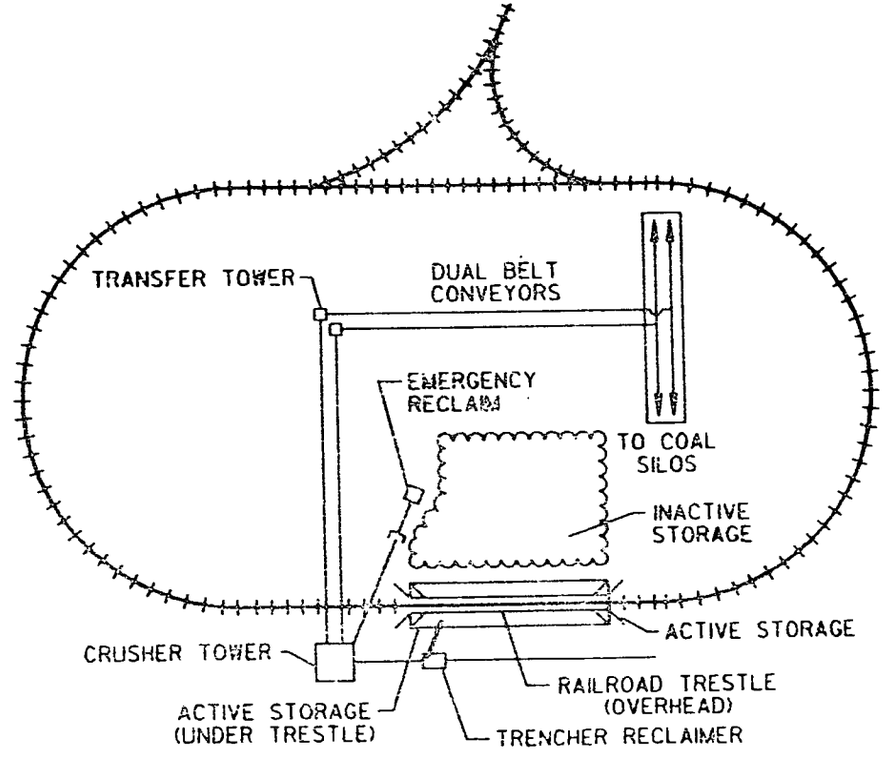


FIGURE 6

TRESTLE UNLOADING-ABOVEGROUND RECLAIM

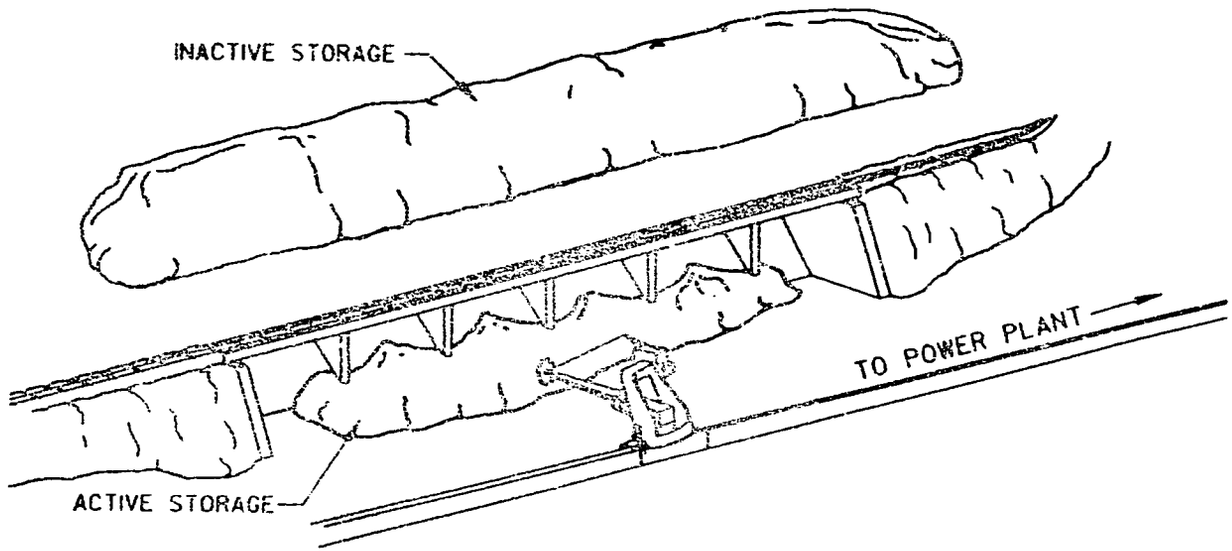


FIGURE 7

COAL HANDLING SYSTEM 4

UNLOADING - TRESTLE
STACKOUT - TRESTLE
RECLAIM - ROTARY PLOW FEEDER

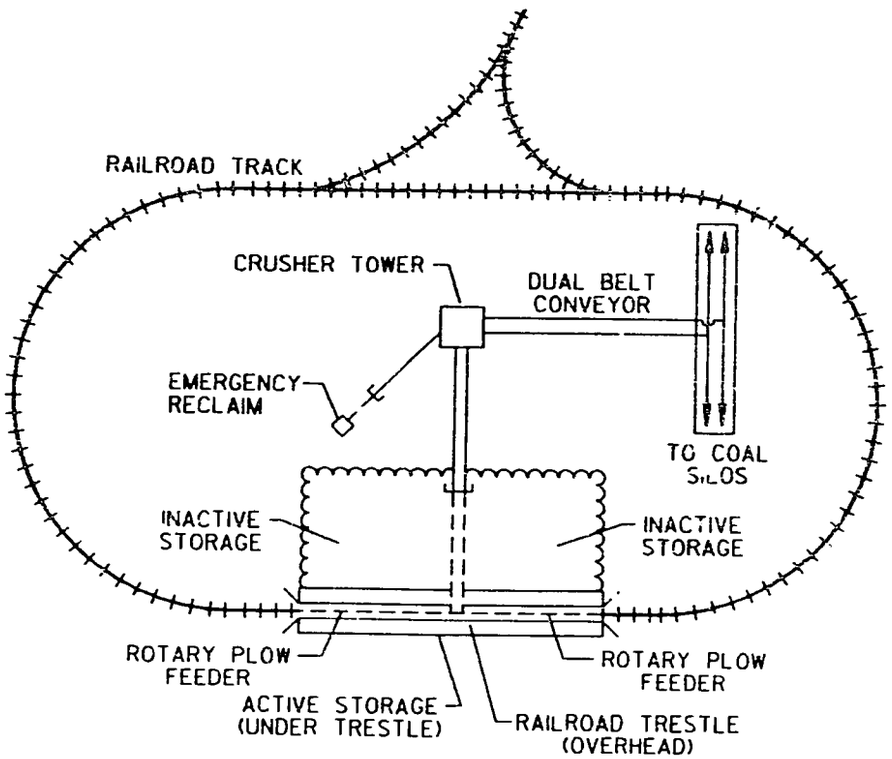


FIGURE 8

TRESTLE UNLOADING-UNDERGROUND RECLAIM

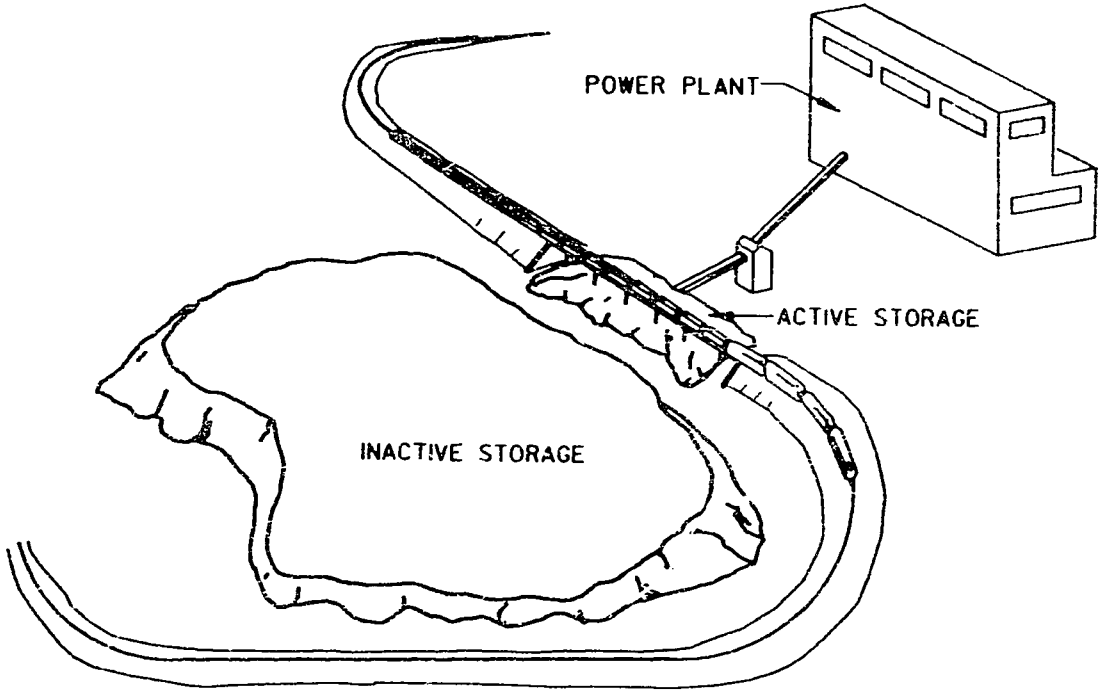


FIGURE 9

COAL SILO PULVERIZER EQUIPMENT

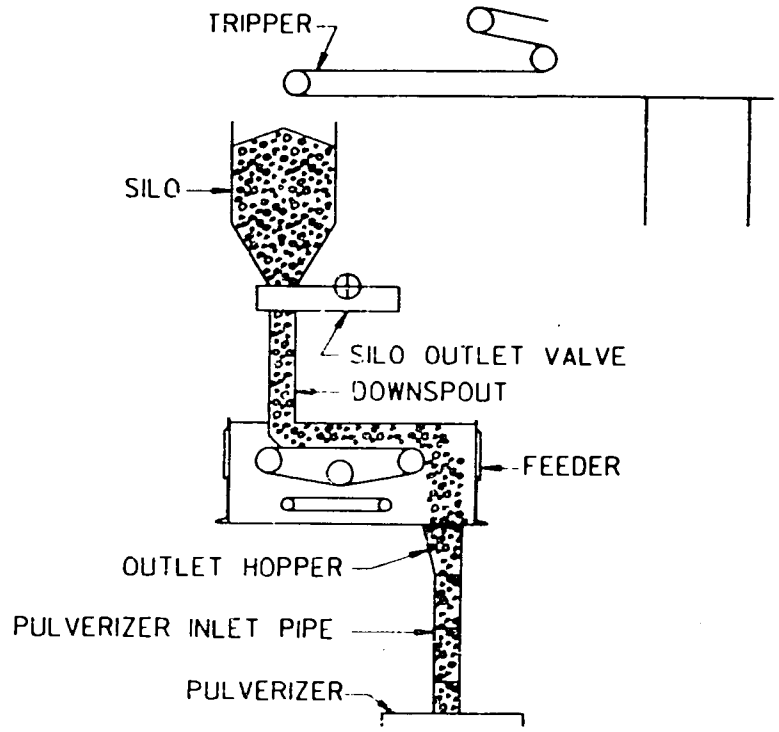
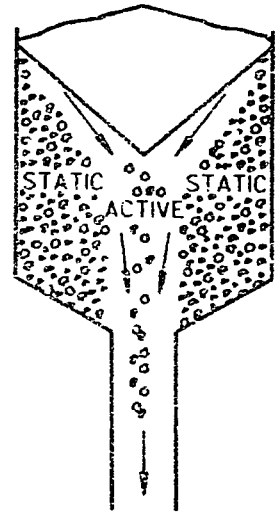
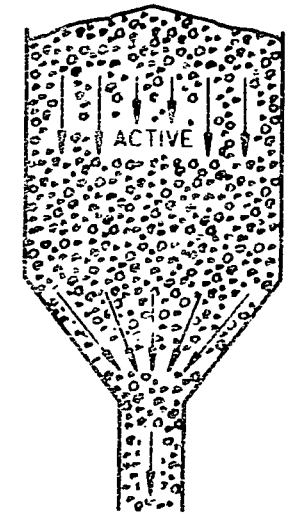


FIGURE 10

COAL SILO DESIGNS



FUNNEL FLOW COAL SILO



MASS FLOW COAL SILO

FIGURE II

BENEFICIATION AND BLENDING TO IMPROVE THE COMBUSTION CHARACTERISTICS OF LAKHRA COAL

G. Fred Moore
Stone & Webster Engineering Corporation
245 Summer Street
Boston, MA 02108

ABSTRACT

Lakhra coal is a lignite mined in Pakistan that is characterized by a high ash, high moisture, and high sulfur content. This lignite is unique because of its unusually high iron pyrite content. Most lignites in the United States are not especially amenable to conventional methods of coal cleaning, such as heavy media washing, because the specific gravity of their ash is not much higher than that of the lignite itself. The coal particles are normally so large that much of the ash and iron pyrites are still attached to the coal. It has been suggested that heavy media washing of the Lakhra coal, using a specific gravity of 1.6-1.8, will remove part of the sulfur and ash. However, this process probably would not be cost effective.

One alternative would be to blend the lignite with an imported bituminous coal as a means of lowering the ash and sulfur content. If a bituminous coal with 1-percent sulfur were blended with an equal amount of a 6-percent sulfur lignite, the sulfur content of the mixture would still be 3.5 percent. This would raise the heating value of the mixture by 42 percent as well as lowering the ash content by 30 percent. The imported coal would cost about $60/mt. In addition, the two coals would have to be blended very well because improperly mixing the lignite with bituminous coal would increase the probability of spontaneous combustion.

One of the new cleaning technologies provides another alternative. Electrostatic cleaning has been used to clean high sulfur bituminous coal. It is a dry method and will clean coal with a top particle size of 400 mesh. Because of the high sulfur in the Lakhra lignite, it is thought that this method can be used with good results. Advanced Energy Dynamics, Inc. has improved the method so that the small particles can be handled without an appreciable loss in combustibles.

INTRODUCTION

Lakhra coal is the indigenous coal resource of Pakistan. It is a lignite bordering on a sub-bituminous C coal[1] Lignites are geologically the youngest coal. They are characterized by a high moisture content and a low heating value. They are a very reactive coal. It takes less energy to release their volatile content than for higher rank coals. The volatiles that are released have lower boiling points and therefore are more volatile. The high moisture content and volatiles are released very rapidly when introduced into the high temperature of a flame. This causes the coal particles to burst into many pieces, increasing the surface area and the reactivity of the lignite.

Because of Lakhra lignite's high ash and high sulfur content, it would be most helpful to beneficiate Lakhra lignite to reduce maintenance and reduce emissions. The sulfur and ash in Lakhra coal should be reduced. If the ash can be reduced by one-half by cleaning, the impact on the boiler and auxiliaries will be much less. Sulfur is the major cause of boiler corrosion, and both sulfur and ash cause serious slagging problems. Sulfur emissions are also a severe threat to the environment.

Lignites are not easily beneficiated by conventional ways. The following is an excerpt from a University of North Dakota Energy Research Center (UNDERC) report on the washability data of western coals[2]:

"Washability curves produced from coal washing data suggest that float yields are related to rank of the samples. All samples produced minimal amounts of float fraction at 1.3 specific gravity. Differences in float yields, however, became obvious at 1.4 specific gravity. The Hagel and Beulah-Zap lignites produce only 17 and 34 cumulative weight percent of float, respectively, at this density, the sub-bituminous coals produced 74 to 86-percent float, and the bituminous coals

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produced from 91- to 92-percent float. Approximately 90 cumulative weight percent of the lignites floated at 1.6 specific gravity, whereas nearly 100-percent (by weight) of the higher-rank coals floated at 1.6 specific gravity."

Figure 1 and Tables 1 and 2 show the washability data for the coals mentioned above, derived from samples ground to a 65 mesh (0.21mm) top size. Conventional coal washing, even for level 4 or 5 cleaning, uses coal sizes of 3-inch x 1/4-inch and 1/4-inch x 28 mesh (0.59mm)[3]. This size does not allow as good ash and sulfur removal and carbon recovery as the smaller particle size.

LAKHRA LIGNITE

Low rank coals are more susceptible to spontaneous combustion than higher ranked coals. Lakhra lignite in particular is vunerable to spontaneous combustion because of its high iron pyrite content. Extreme care should be taken when storing Lakhra lignite.

Float-sink studies to determine washability characteristics were done in a 1981 study by Japan International Cooperation Agency (JICA).[1] Results of that study (Table 3) show the difference between 1.6 and 1.8 specific gravity for ash removal, calorific value, and percent yield. Table 4 shows sulfur content and removal rate at 1.8 specific gravity. In the JICA tests 10 samples were taken from the core samples. Float and sink tests were carried out on the 10 samples at 1.30, 1.35, 1.40, 1.50, 1.60, and 1.80 specific gravity. The raw coal ash content for the washability tests fluctuated from 9.41 to 33.69 percent. After the review of the specific gravity of the coal portion, it was clear in general that the intermediate fractions between 1.3 and 1.6 were more common in the raw coal. It would be difficult to beneficiate the raw coal with a medium having a specific gravity lower than 1.6. This float-sink test was made with 10mm top size coal. A commercial washing plant would use larger coal and the recovery rate and ash removal rate would not be as good as shown in this study.

Conventional coal washing, being a wet method, requires the coal to be dried. The cost of drying would have to be accounted for. This cost would depend on the cost of fuel for the drier. In review of the JICA data others have conducted their own washability studies; they concluded that conventional coal washing would not produce enough benefits to offset the carbon loss.

COAL BLENDING

An alternate way to reduce the ash and sulfur in Lakhra lignite is to blend it with a low sulfur, low ash, bituminous coal. This coal would have to be imported. For example, blending an Australian coal[4] with 11,500 Btu/lb (6389 k Cal/kg) and 1.0 percent sulfur with Lakhra lignite with 6830 Btu/lb (3794 k Cal/kg) and 5.88-percent sulfur, 3.88-pounds of Australian coal would be needed per 1.0 pound of Lakhra lignite to reduce the sulfur to 2.0 percent. This would cost approximately $41.61/ton of blended product*. It would increase the heat content of the mixture to 10,543 Btu/lb (5857 k Cal/kg) and decrease the ash percentage to 15 percent. The blended product will cost $1.79/mm Btu and the Australian coal will cost $1.68/mm Btu.

ADVANCED COAL CLEANING METHOD - ELECTROSTATIC PROCESS

Advanced Energy Dynamics, Inc. (AED) has developed an ultrafine coal (UFC) dry electrostatic cleaning process that could be used to beneficiate Lakhra lignite. The UFC process, a dry cleaning method, would eliminate the cost of drying the coal that would be necessary for a heavy media washing method. It can be used to beneficiate pulverized coal where 20- to 40-percent of the fuel is smaller than 400 mesh (37 microns). AED has extensive test data on a 1-ton/hr (1-TPH) single unit and will be demonstrating a 1-TPH multistage unit as part of a U.S. Department of Energy advanced coal cleaning project. To provide a 3- to 5-percent ash product from a 10- to 20- percent ash coal, AED has data for several coals that show 95-percent carbon recovery.

The AED UFC process was used to beneficiate a ROM pulverized Lakhra lignite with the results shown in Table 5.

The sulfur data and Btu recovery data is not as good as expected. The sample was not ideal, it was pulverized and contained in a barrel in a wet condition so there was probably considerable

*The price of Australian coal is probably higher than the figures I have shown here. The infrastructure from Quasim to Jamshoro is not in place to handle the amount of coal that would be needed.

oxidation of the coal and sulfur. The amount of oxidation was not determined. In view of the amount of ash reduction and Btu enhancement of this sample, further testing should be done on a much larger and better prepared sample. This sample was only recycled twice. It was projected that with five recycles, 87- to 92-percent ash reduction could be achieved. One attractive feature of this cleaning method is that it can be placed between the pulverizer and the burners. This would eliminate a separate coal washing plant.

CONCLUSIONS

Lignite is difficult to clean by conventional heavy media washing. Lakhra lignite is more susceptible to spontaneous combustion than lower sulfur lignites.

Coal blending is one way of reducing ash and sulfur, but imported coal would have to be used.

The advanced cleaning method using an electrostatic process looks promising, but additional tests should be run on a better and much larger sample.

If 72 percent of the combustible product was recovered which had a higher heating value of 10,903 Btu/lb (6057 k Cal/kg) the total heat content recovered would be 7850 Btu/lb (4361 k Cal/kg). The feed had a heat content of 7789 Btu/lb (4327 k Cal/kg). This could probably be improved if a fresh sample was used. The reduction in ash alone would be reason enough for further investigation. Thus, the cleaned product has a slightly higher HHV, 7850 Btu/lb (4361 k Cal/kg), and a significantly lower ash (12.64 percent vs 31.53 percent) than the run of mine coal.

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ACKNOWLEDGEMENTS

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Mr. Stanley R. Rich and D. E. Heyburn of Advanced Energy Dynamics, Inc. for beneficiating the Pakistan lignite.

TABLE 1

RAW COAL DATA
(65 MESH x 0 TOP SIZE)

Coal	Rank	Ash (%)	Total Sulfur (%)	Pyritic Sulfur (%)	Btu/lb
Hagel Bed, McLean Co., ND	Lignite	6.8	0.6	0.01	9,907
Beulah-Zap Bed Lignite, Oliver Co., ND	Lignite	8.5	1.0	0.11	10,031
Wyodak-Anderson Seam, Campbell Co., WY	Subbit.	5.1	0.4	0.01	11,058
Lower Deadman Seam, Sweetwater Co., WY	Subbit.	8.5	0.7	0.07	11,810
Bed 78, Bottom, Carbon Co., WY	High Vol. C Bit.	4.5	0.9	0.10	11,895
FF Bed, RioBlanco Co., CO	High Vol. B Bit.	3.7	0.3	0.05	12,178

TABLE 2

WASHABILITY DATA OF SELECTED WESTERN COALS
(65 MESH X 0 TOP SIZE)

Coal	Product	Direct Wt. %	Direct Ash %	Direct Total Sulfur %	Direct Btu/lb	Cumulative Wt.%	Cumulative Ash %	Cumulative Total Sulfur %	Cumulative Btu/lb
Hagel Bed, McLean Co., ND	F - 1.30	2.6	3.8	0.6	11,349	2.6	3.8	0.6	11,349
	1.30 - 1.40	14.6	4.8	0.8	10,620	17.2	4.7	0.8	10,730
	1.40 - 1.60	79.3	6.8	0.6	9,533	96.5	5.8	0.6	9,746
	S - 1.60	3.6	53.5	4.6	4,213	100.0	7.5	0.8	9,557
Beulah-Zap Bed, Oliver Co., ND	F - 1.30	3.4	5.3	0.8	10,848	3.4	5.3	0.8	10,848
	1.30 - 1.40	30.2	7.0	0.8	10,396	33.6	6.8	0.8	10,442
	1.40 - 1.60	58.2	9.8	0.9	9,782	91.7	8.5	0.9	10,034
	S - 1.60	8.3	62.2	4.6	3,236	100.0	13.1	1.2	9,470
Wyodak-Anderson Seam, Campbell Co., WY	F - 1.30	0.5	4.0	0.4	X	0.5	4.0	0.4	X
	1.30 - 1.40	85.4	4.4	0.4	10,942	85.9	4.4	0.4	10,878
	1.40 - 1.60	12.5	7.6	0.5	10,374	98.4	4.8	0.4	10,814
	S - 1.60	1.6	57.8	3.2	3,313	100.0	5.6	0.5	10,694
Bed 78 Bottom, Carbon Co., WY	F - 1.30	4.0	2.5	0.6	12,946	4.0	2.5	0.6	12,946
	1.30 - 1.40	86.9	3.1	0.7	12,230	90.9	3.1	0.7	12,262
	1.40 - 1.60	6.9	20.1	1.2	9,676	97.8	4.3	0.7	12,079
	S - 1.60	2.1	47.6	9.4	5,096	100.0	5.2	0.9	11,920
Lower Deadman Seam, Sweetwater Co., WY	F - 1.30	1.6	3.8	0.5	12,951	1.6	3.8	0.5	12,951
	1.30 - 1.40	72.8	4.3	0.6	12,022	74.4	4.3	0.5	12,042
	1.40 - 1.60	15.3	14.1	0.5	10,651	89.7	6.0	0.6	11,805
	S - 1.60	10.3	65.1	2.6	3,394	100.0	12.1	0.8	10,938
FF Bed, RioBlanco Co., CO	F - 1.30	0.3	1.6	0.4	X	0.3	1.6	0.4	X
	1.30 - 1.40	91.7	2.7	0.3	11,769	92.0	2.7	0.3	11,734
	1.40 - 1.60	6.8	11.8	0.5	11,117	98.8	3.3	0.3	11,692
	S - 1.60	1.2	65.0	10.7	3,427	100.0	4.1	0.4	11,591

X = Insufficient sample for analysis.

TABLE 3

COMPARISON OF SEPARATION

Specific gravity of separation medium	1.6	1.8*
Raw coal ash	19.7	19.7
Clean coal ash	9.2	12.0
Calorific value (Clean) kcal/kg	6,556 (dry basis)	6,293 (dry basis)
Yield	73.2	82.2
±0.1 near gravity	12.3	7.5

*estimated from washability curves

TABLE 4

SULFUR CONTENT AND REMOVAL RATE

Sample	Total Sulphur % Raw Coal	Total Sulphur % Clean Coal*	Removal Rate %
JT 5-1	6.70	3.88	42.1
JT 7-5	9.50	7.31	23.1
JT24-1	13.21	7.30	44.7
JT29-7	14.43	8.10	43.9
JT10-4	8.02	5.72	28.8
JT34-7	10.00	5.86	41.4
JT45-1	5.10	3.27	35.9
Average	9.57	5.92	38.1

*Separation medium with less than 1.8 specific gravity

TABLE 5

UFC LIST OF CLEANING OF UNWASHED PRE-PULVERIZED PAKISTAN LAKHRA LIGNITE

	Sulfur Wt%	Sulfur $lb/10^6$ Btu	Ash wt%	Ash $lb/10^6$ Btu	Btu/lb	Kcal/Kg	% Combustible Recovery
Feed (Start)	4.35	5.58	31.53	40.48	7,789	4,327	
Cleaned Product	4.02	3.69	12.64	11.59	10,903	6,057	71-72%
% Reduction or Increase	-7.59	-33.9	-59.9	-71.4	+40	+40	

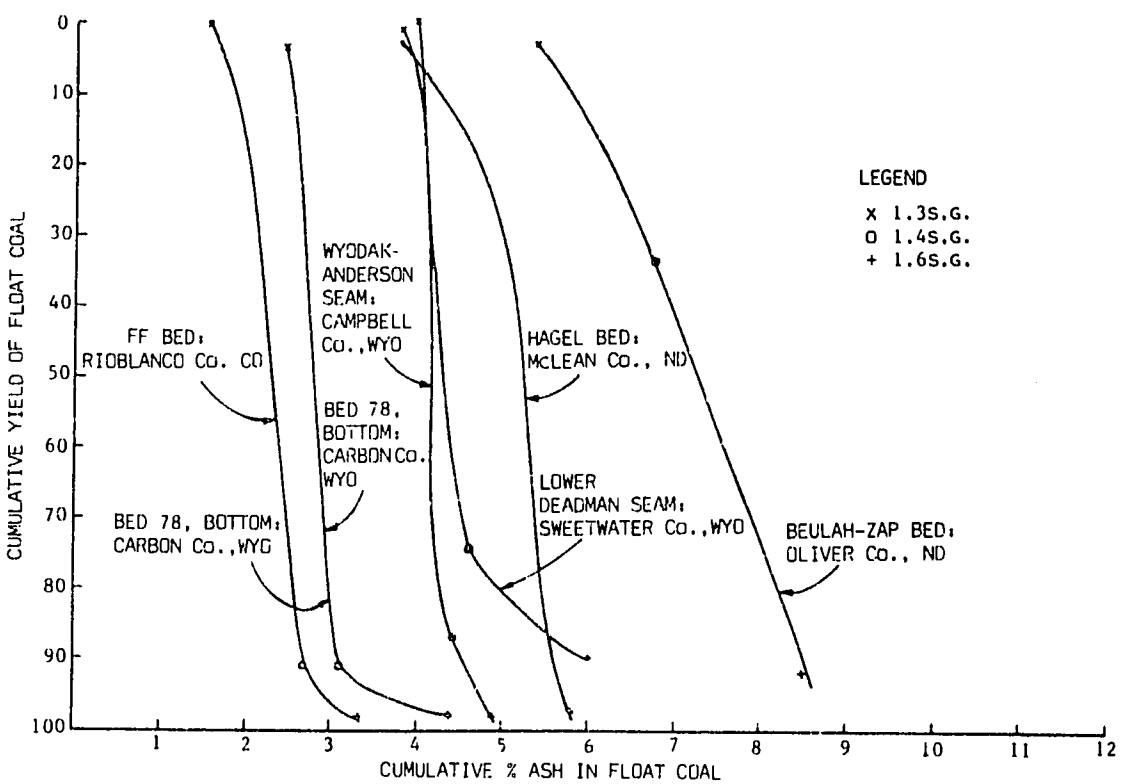

FIGURE 1 PLOT OF FLOAT YIELD VS FLOAT ASH

PLANNING FOR ECONOMICAL DISPOSAL OF COAL WASTE PRODUCTS IN PAKISTAN

L.E. Wilson, P.E., President - Engineering, Design & Geosciences Group, Inc. (EDGe) Nashville, Tennessee

Michael R. Stomer, Engineering Geologist - Geologic Associates, Inc. (a subsidiary of the EDGe Group), Knoxville, Tennessee

Barry K. Thacker, Senior Geotechnical Engineer - Geologic Associates, Inc. (a subsidiary of the EDGe Group), Knoxville, Tennessee

ABSTRACT

Large volumes of solid wastes will be generated by modern coal preparation plants and coal-fired power plants in Pakistan. Well-planned and managed disposal areas and systems for coal rejects and ash are critical to the economic and efficient operation of mining and power generating facilities. This paper focuses on innovative methods, which have been used for economically disposing of wastes generated during the preparation and/or burning of coal, and discusses how these methods apply to the coal production and power generating operations in Pakistan. Methods of assessing the capital and operating costs associated with these operations are also presented for a variety of potential disposal methods. Two existing disposal sites located in geologic and topographic settings similar to those found in Lakhra are described to show how an initial economic assessment was used to select the disposal mode, how the actual disposal operation has progressed and how the economics of coal production and power generation were affected over the short- and long-term.

INTRODUCTION

Data developed from the exploration of coal in Pakistan indicate that the raw coal has a relatively high ash content on the order of about thirty percent. This high ash content results from impurities in the coal, such as shale, sand, silt, clay and gypsum. When the raw coal is burned in a modern power plant, the large quantities of ash can result in rapid degradation of the plant equipment and costly handling of the ash throughout the plant system. Consequently, the construction of a coal preparation plant will likely be cost-effective in removing a large percentage of the impurities before the coal is burned at the power plant.

Typically, the rejects from a coal preparation plant consist of coarse refuse (rejects larger than a Tyler No. 28 mesh). Because of their relatively high specific gravity, these rejects can be removed from the lower specific gravity coal by using water in a heavy media separation system. The removal of a significant quantity of the impurities in the coal preparation plant will reduce the ash content of the "clean" coal to about five to ten percent.

Utilization of the wastes generated at coal preparation plants and power plants is well-documented and includes the use of these wastes as road base, engineered fill for embankment construction and additives for concrete[1]. Unfortunately, because of the relatively large quantities of wastes that will be generated, only about ten to twenty percent of the coal wastes are typically utilized. The remainder of the wastes must be disposed.

Worldwide, there are numerous cases where poorly designed disposal facilities at coal preparation plants and power plants hinder the efficient and economic operations of the facilities. For instance, wastes disposed at random and at relatively short

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distances from the plant during the early phases of its operation may be cost-effective only in the short-term. Photograph 1 shows a small, deep mining operation in Lakhra where spoil has been disposed a short distance from the mine shaft opening. This photograph exemplifies on a small scale how such random placement may impede access to other disposal areas, which may be required during later phases of the plant and mining operation. As described in the following sections, a key aspect of the design of a disposal facility is the selection of the optimum method for efficiently and economically handling these wastes.

POTENTIAL MODES OF COAL WASTE DISPOSAL

The potential modes of transportation of coal wastes from a plant to a disposal area can be divided into wet handling syscems and dry handling systems. Wet handling systems consist of pumping a waste and water (slurry) mixture from the plant to the disposal site. These slurried wastes can be disposed within an impoundment created by a dam or a dike constructed across a narrow valley or canyon. Alternatively, a portion of the coarse wastes can be separated at the plant or at the disposal site to serve as borrow in the construction of additional stages of the dike or dam. Clarified water from a wet handling system can be returned to the plant as process water after being decanted from the slurry which has been placed in the slurry impoundment.

Dry handling systems consist of dewatering the waste at the preparation plant and then trucking or conveying the wastes to the disposal site. Water removed from the wastes at the plant can be recycled as process water. After being transported to the site, the wastes can be spread and compacted into a non-impounding fill.

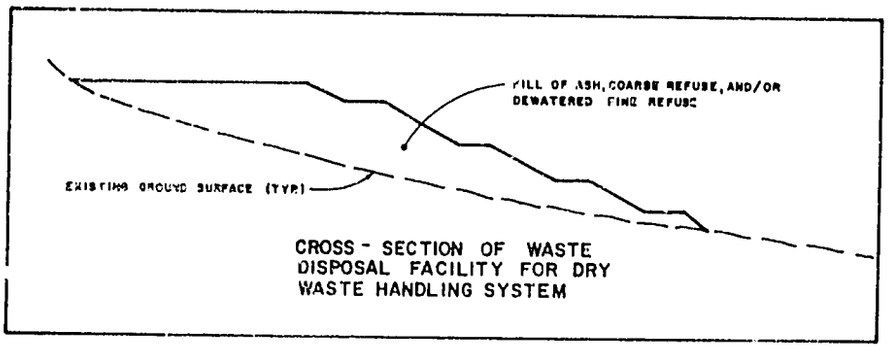
Figure 1 shows an example of the waste disposal facilities typically constructed for wet handling and dry handling systems.

CASE HISTORIES OF COAL WASTE DISPOSAL SITES IN THE UNITED STATES

Highsplint Site; Harlan County, KY

From 1977 to 1982, the Highsplint Coal Preparation Plant operated a dry handling system for coal refuse produced at the plant. Specifically, fine refuse was dewatered in the plant and mixed with the coarse refuse. The combined refuse was then conveyed to a fill where it was spread and compacted with bulldozers. Because the capacity in the existing fill was nearly depleted, plans were initiated in 1981 to design and build a new disposal facility.

SMALL, DEEP MINING OPERATION IN LAKHRA



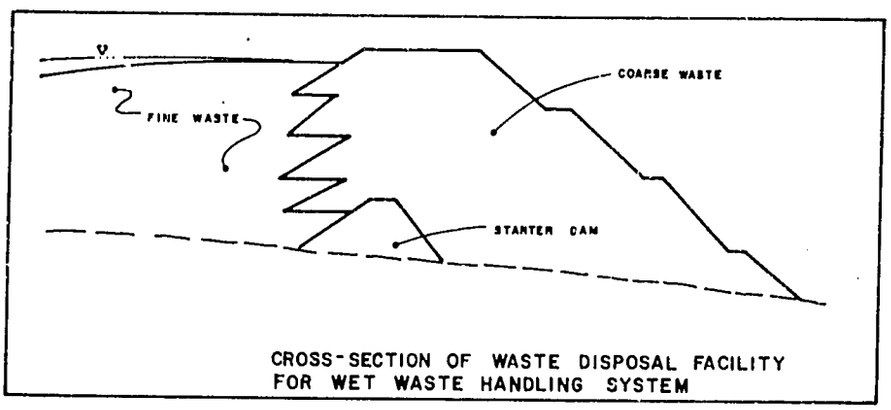


FIGURE I
TYPICAL DISPOSAL FACILITIES FOR WASTES GENERATED DURING THE PROCESSING AND BURNING OF COAL

A cost study was performed for both a new dry handling facility and a new wet handling system. Generally, the cost study indicated that the capital costs associated with a wet handling system were nearly identical to those of a dry handling system. However, the study showed that based on operating costs, approximately $1.00 (U.S.) for every ton of clean coal produced at the plant (i.e., the plant produces approximately 1,000,000 tons [907,029 metric tons] of clean coal per year) could be saved with a wet handling system as compared to the dry handling system. Such a cost savings could be realized due to:

- elimination of the dewatering system in the plant,
- reduced maintenance cost on the refuse conveyor including belting, machinery and cleanup costs,
- less maintenance of the road around the plant and of the road from the refuse conveyor to the refuse area,
- substantial reduction of the equipment required to spread and compact the refuse,
- reduced cleanup costs at the plant.

Based on the results of the cost study, the facility was converted to a wet handling system. A starter dam was constructed and the fine refuse slurry was pumped to the new impoundment for disposal. The coarse refuse was used to build additional stages of the dam. Since the wet handling system became operational in 1982, the coal company has actually saved an estimated $1.50 (U.S.) per ton of clean coal as compared to the

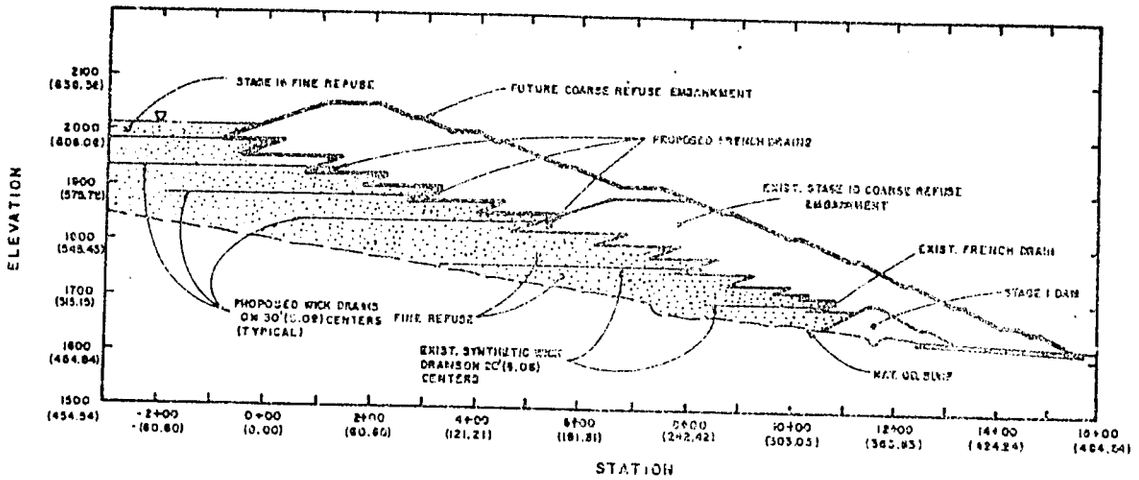


FIGURE 2
CROSS-SECTION OF HIGHSPLINT COAL WASTE IMPOUNDMENT

NOTE: NUMBERS IN PARENTHESIS ARE MEASUREMENTS IN METERS.

previous costs associated with operating a dry handling system.

A key to the safe construction of the Highsplint Refuse Impoundment is the use of synthetic wick drains for dewatering the fine refuse. Because of the terrain in the area of the plant, the facility had to be built by the upstream method. As shown on Figure 2, during upstream construction, the later stages of the facility are constructed using coarse refuse, which is placed upstream of the previous stage. Consequently, the hydraulically placed fine refuse becomes a part of the foundation for the dam. The synthetic wick drains allow dissipation of excess pore pressures (dewatering) of the fine refuse as the coarse refuse is placed over the fine refuse throughout the construction of the dam[2].

Marion Site; Marion County, West Virginia

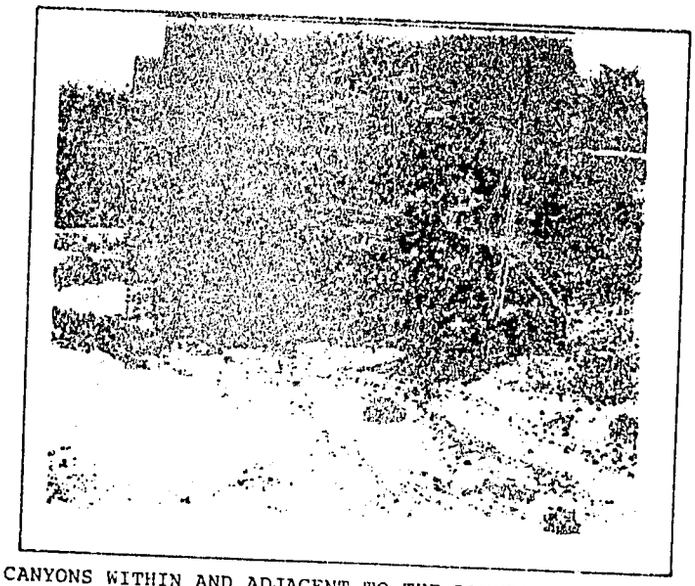
The Marion Preparation Plant has operated as a dry handling system for several years. In 1984, plans were made for designing a new disposal site because capacity in the existing facility was nearly depleted. A cost study indicated that approximately $0.30 (U.S.) per ton of clean coal could be saved by operating a wet handling system as compared to a dry handling system. However, the capital costs for the wet handling system would be about $10,000,000 (U.S.) greater for the wet handling system than for the dry handling system. When amortized over the 30-year life of the facility, the dry handling system proved to the more economical system.

The new disposal site was designed to be situated adjacent to the previous refuse pile. The fine refuse will continue to be dewatered in the plant and mixed with the coarse refuse. The combined refuse will be conveyed to an existing refuse bin where it will be loaded on trucks and transported to the new site. The combined refuse will also continue to be spread and compacted at the new disposal site using bulldozers.

POTENTIAL COAL WASTE DISPOSAL IN THE LAKHRA AREA

General

In the development of the Lakhra area in Pakistan, it is likely that a coal preparation plant and a coal-fired power plant will be situated adjacent to the Lakhra coal field. This is a desirable arrangement because wastes produced at the preparation plant and the power plant can be co-mingled and disposed in a common disposal area. The actual mode of handling and disposing the wastes should be determined based on a cost assessment as previously described.



CANYONS WITHIN AND ADJACENT TO THE LAKHRA COAL FIELD

As shown by Photograph 2, several canyons are located within and adjacent to the Lakhra coal field. Most of these canyons will be suitable for disposal sites built from either wet handled wastes or dry handled wastes. Presented in the following sections are two potential options for the coal waste disposal system in Lakhra.

Potential Dry Handling System

One option for the Lakhra Coal Waste Disposal Facility consists of dry handling of the ash in the power plant and dewatering of the fine refuse and coarse refuse in the preparation plant. From each of the respective plants, the wastes could be conveyed to a central location. From there, the ash, fine refuse and coarse refuse could be transported along a single conveyor to discharge into the selected canyon. At the disposal site, the waste from the conveyor could be discharged over the edge of the canyon, and the bulldozers could be used to spread and compact the waste. As a portion of the canyon is filled with waste, the conveyor could be extended to discharge into an adjacent section of the canyon.

One advantage of the dry handling system is that water can be removed in the dewatering system at the plant and then recycled, thereby reducing the amount of operating water the plant will require. Also, dry handled wastes are more conducive to resource recovery (utilization) than are wet handled wastes. One disadvantage with the dry handling system is that a relatively large capital investment will be required to construct the extensive conveyor system and/or haul roads. Some of the capital and operating costs that will have to be estimated in the cost assessment of a dry handling system will include:

- thickener, including flocculent costs,
- dewatering equipment (vacuum filter, belt filter, filter press, etc.),
- transportation system (conveyors and/or trucks),
- access and haul roads,
- labor,
- equipment for spreading and compacting the wastes,
- waste site preparation,
- process water acquisition and recycling systems,

Wet Handling System

Another option for handling the wastes from a potential power plant and preparation plant in Lakhra would consist of

constructing a pipeline from the nearby Indus River to the power plant and the preparation plant. Coarse refuse from the preparation plant can be crushed and mixed with the fine refuse and the ash. The waste mixture can then be slurried and pumped to one of the selected canyons for disposal.

Prior to beginning of waste disposal, a relatively small starter dam would have to be built at the mouth of the canyon. The waste could then be discharged upstream of the starter dam. The coarser wastes will then settle near the dam, and the fine wastes will settle near the rear of the canyon. The settled coarse waste could then be used as borrow to build additional stages of the dam to provide additional disposal capacity for the slurried waste throughout the life of the plant. Water from the impoundment could either be discharged or returned to the plant for processing. If properly constructed, the impoundment can also be used to store rain runoff from the short rain season to aid in the plant operation.

Some of the capital and operating costs which will have to be estimated in the cost assessment of a wet handling system include:

- starter dam and decant system,
- pumping system from the Indus River to the plants and from the plants to the disposal canyon,
- access and haul roads,
- crushing equipment for the coarse refuse,
- labor,
- equipment for rehandling the coarse waste at the disposal site and using it to build additional stages of the dam,
- waste site preparation,
- process water recycling.

Selection of Waste Handling System

In our opinion, either of the above options would be feasible. The selection of the preferred disposal mode should be based on a detailed cost assessment of the various options. As a minimum, each option should provide disposal capacity for the life of the facilities. Also, each option should be constructed in a safe and environmentally acceptable manner. The facility which meets these requirements and has the lowest costs should be selected as the disposal mode.

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ENVIRONMENTAL CONSIDERATIONS IN COAL DEVELOPMENT AND UTILIZATION

Richard S. LeGore, Ph.D.
and
Patricia H. Markey, P.E.
Environmental Science and Engineering, Inc.
P.O. Box ESE
Gainesville, FL 32602 U.S.A.

James R. Newman, Ph.D.
and
Kennard F. Kosky, P.E.
KBN Engineering and Applied Sciences, Inc.
P.O. Box 14288
Gainesville, FL 32604 U.S.A.

ABSTRACT

Because the activities associated with coal utilization are diverse, analysis of their environmental impacts must consider all environmental media, including land, air, water, biological, and cultural resources. Major impacts on each of these media are discussed relative to coal mining, preparation, transportation, and use. Their relevance to Pakistan's regulatory apparatus and environment is then summarized, citing the Lakhra development as an example.

INTRODUCTION

We have been asked to use our few minutes to provide an overview of the environmental considerations associated with the development and use of coal resources. In order to do this, it is helpful to recognize that the several components of the coal utilization process have their own and sometimes unique impacts on their surroundings. Surface mines have different impacts, for example, than do underground mines, and both exert different environmental influences than does transportation of their product. For purposes of this discussion, therefore, we have segmented the process into the following divisions:

- Mining
  - Surface
  - Underground
- Beneficiation
- Transportation
  - Truck
  - Rail
  - Barge
  - Pipeline
- Industrial Burning
- Conversion
  - Gasification
  - Liquefaction
- Export

Similarly, when we discuss environmental impacts, we must recognize that the term "environment" includes everything around us, and it is helpful to consider components of this totality individually. For present purposes, we have elected to define these segments broadly as (1) biological resources, (2) land resources (land use), (3) water resources (ground water as well as surface water), (4) air resources, and (5) cultural resources (historical, traditional values, quality of life, etc.).

In the following presentation, we will attempt to relate each of these resource categories to each of the coal utilization components in order to conceptualize the environmental concerns that should be considered in an orderly and constructive manner. The major relationships are summarized in Table 1, which provides broadly generalized evaluations. Each of these will be discussed in closer detail below. The relative magnitudes of impacts associated with each activity will be examined, and certain approaches to impact mitigation will be considered. Finally, we will attempt to relate some of these generalizations to coal development in Pakistan.

Table 1. Summary of Resource Categories Potentially Impacted by Coal Utilization Activities. X = Potential Impact; ■ = Potential Major Impact.

	Resource Category				
Activity	Biological	Land	Water	Air	Cultural
Mining					
Surface	■	■	■	X	■
Underground	X	X	■	X	X
Beneficiation	X	X	■	X	X
Transportation					
Truck	X	X	-	X	■
Railroad	X	X	-	X	■
Barge	-	-	X	-	-
Pipeline	X	■	■	-	X
Industrial Burning	■	X	■	■	X
Conversion					
Gasification	X	■	■	■	X
Liquifaction	X	■	■	■	X
Export	-	-	-	-	X

LAND RESOURCE IMPACTS

Impacts on land use can result directly from coal utilization activities, or they may be secondary results of air or water pollution (Figure 1). This discussion concerns only direct land use impacts. Furthermore, it should be understood that the degree of impact associated with any industrial activity varies according to the characteristics of the region in which it occurs.

Mining

Direct impacts of mining on land use are generally very direct and restricted to the local mine area. Impacts are generally associated with mechanical alterations, such as habitat removal, erosion, floodplain changes, blasting effects, or subsidence.

Surface mining imposes the most obvious changes in an area, in that it renders the surface area completely unsuitable for previous or alternative uses while the mining is underway.

Since a surface mine is essentially a large hole in the ground, the former uses of the surface area are entirely disrupted, whether the site was used for a town, a forest, or as farmland.

Disruption of the land surface, and the sometimes loud activity associated with surface mining, generally decreases use of the surrounding area by wildlife as well as by people. Thus, the normal productivity of the area is lowered even beyond the boundaries of the mined area proper.

After the coal is removed from the site, surface mines may generally be "reclaimed" and returned to a desirable productive state, but this may generally be accomplished only if a well designed reclamation plan was followed from the outset of mining activity. Topsoil must be carefully saved, and must be properly replaced on fill material. The fill material itself must be selected and placed so it will not affect ground water quality, compact and slump, or allow fine topsoil particles to migrate through it. The land must be graded appropriately for its future uses, and to prevent subsequent erosion. The area must be reseeded with appropriate species, and fertilization and irrigation might be necessary to provide a healthy beginning to a self-sustaining and developing ecosystem. The proper planning and execution of reclamation is very complex, and can be difficult in fragile ecosystems, but it can often be successfully accomplished.

Aside from the obvious impacts of mine-mouth facilities and support roads, the primary land use impacts of underground mining are associated with "slumping". Slumping is the collapse of land structures caused by the caving in of underground rooms or caverns. Such slumping can damage manmade

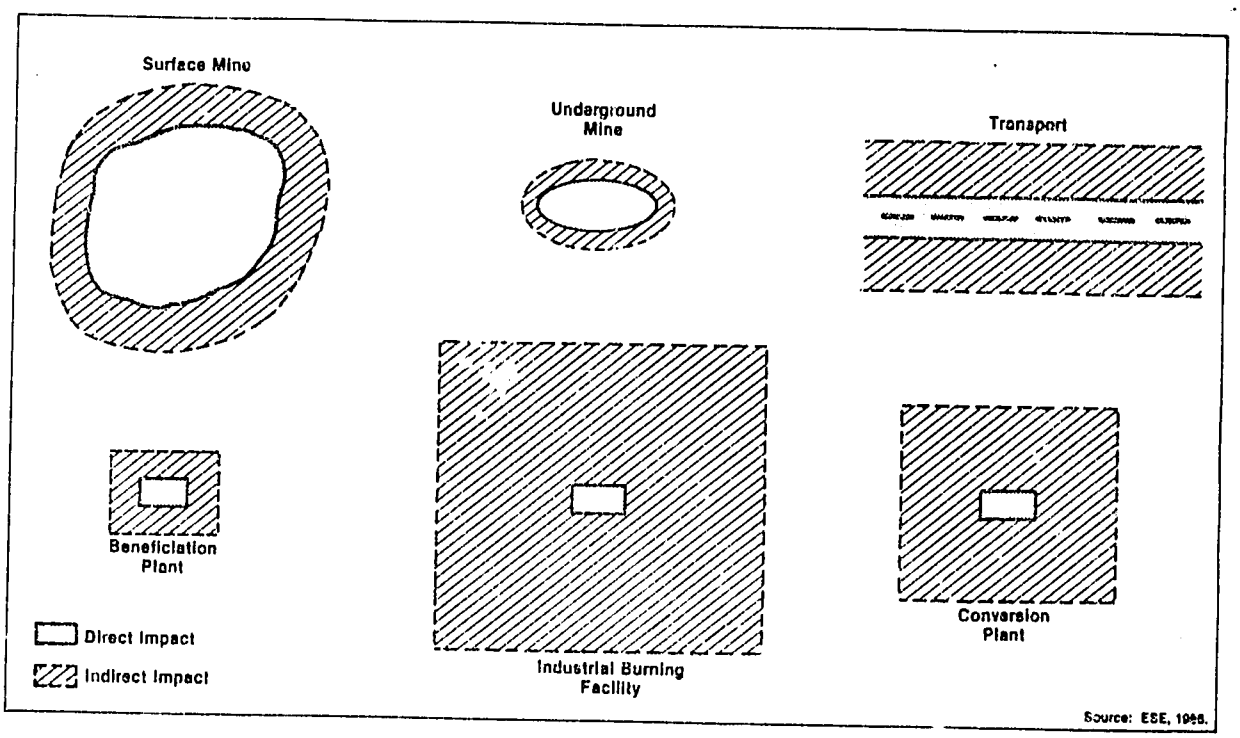

Figure 1. Generalized Land Use Impact Zones Associated with Coal Utilization Activities

structures such as roads, water and gas pipelines, and buildings, as well as change land drainage patterns, river flows, and ground water flow patterns. Severe and irregular slumping can also cause difficulties in using the land for agricultural purposes.

A major problem associated with slumping is that it may occur long after a mine is closed and abandoned, which makes long-term planning for construction or other uses of the land difficult. These problems can sometimes be avoided by leaving large pillars in place as mine roof supports, or to control slumping as the coal is mined, such as in longwall mining.

Beneficiation

Direct land use impacts associated with coal preparation are associated primarily with the removal of a small amount of land from its former uses. This land is used for the preparation facilities themselves, for coal storage and waste piles, and transportation corridors.

The visual or other impacts of beneficiation facilities may, however, affect the desirability of surrounding land for other uses such as residences.

Transportation

Surface transportation of coal imposes effects on the right-of-way of the transportation corridor. Roads and railroads require the dedicated use of strips of land that can in aggregate comprise very large acreage. Pipelines may or may not have similar impacts, depending on whether they are above or below ground, but even a buried pipeline requires maintenance of a service corridor. Barge transportation does not require such corridor construction unless canals must be constructed.

Industrial Burning

The direct land use effects of burning are associated with using the land for construction of the industrial facility, for storage of fuel coal, and for disposal of combustion wastes. The most severe of these is disposal of ashes and sludges, which can require up to several hundreds of acres, depending upon disposal practices, the type and amount of coal burned, pollution control equipment, and the type of facility.

Conversion

Direct land use impacts for coal conversion facilities are approximately the same as for burning, except that the land area required for waste disposal may be less extensive.

WATER RESOURCE IMPACTS

Impacts of coal utilization on water resources differ from those on land resources to the extent that pollutants introduced into water systems may be carried substantial distances and exert their effects somewhat distant from the coal use activity. Coal utilization can affect both water quality and water quantity, and it can alter land drainage characteristics and ground water supplies. An indication of relative impacts that coal utilization activities exert on surface and ground water resources is presented in Figure 2.

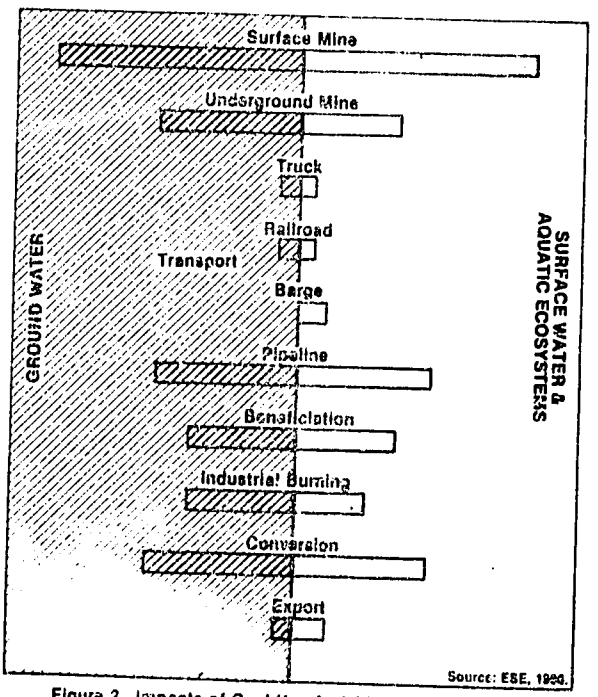

Figure 2. Impacts of Coal Use Activities on Surface and Groundwater Systems

Mining

The primary impacts of coal mining on water relate to the addition of dissolved or suspended components to the water system. Particulates are contributed to the water when rain washes through or over piles of stored overburden in the case of surface mining. Similarly, waste piles generate dissolved and suspended solids to the water, often indicated by elevated levels of sulfates, calcium, carbonates, and similar ionic contributors to water hardness.

A particularly troublesome problem associated with coal mines containing substantial amounts of pyrite (iron disulfide) is acid mine drainage. As the pyrite is exposed and reacts with water and air it forms sulfuric acid and iron. The resulting low pH exerts a direct effect on water quality, but it

also enhances conditions for the dissolution of the iron and other, potentially more harmful, metals, such as zinc, nickel, and manganese.

In addition to the direct toxic effects that low pH and metals exert on organisms in surface water ecosystems, some of these metals may be concentrated through the ecosystem's food chain, and be ultimately ingested by higher organisms, including man. It is possible that these materials can be sufficiently concentrated to exert toxic effects on these consumers; zinc and nickel are, for example, known carcinogens, while mercury and cadmium can cause severe neurological problems.

Just as surface water quality is impacted by such contaminants, so is ground water. Mine water and rainwater can seep into aquifers through soil layers, via fractures caused by mining activities, or by direct contact with intercepted aquifers. Once these materials enter the ground water, the contamination problem may, of course, be very persistent.

Acid rain is not generally a problem in areas with alkaline soils, but in such areas, water salinity may be greatly increased by the leeching of sulfates, chlorides, and other soluble ions from waste and overburden piles.

Sedimentation of surface waters by runoff and erosion at mine sites often has severe secondary effects. Heavy sedimentation can smother organisms and fish eggs living in or on stream and lake bottoms, thereby disrupting the aquatic food chain. Even lesser degrees of sedimentation can have similar effects if it alters the composition or physical characteristics of the natural sediment.

Flooding also sometimes occurs adjacent to mining operations that cause sedimentation of the area's surface waters. Heavy siltation decreases the carrying capacity of streambeds, impairing their ability to carry excess water away.

Well water supplies can be impaired if a mine is located below the water table and if conditions allow seepage of ground water into the mine sufficient to lower the water table. Additionally, if the mine intercepts the aquifer serving the wells, it may contribute contaminants, rendering the water unfit for its intended use.

Beneficiation

Coal and waste piles at beneficiation plants are capable of contributing to the same kinds of water quality problems as discussed relative to mining activities. The quantities involved are smaller, however, and are therefore easier to control by mechanical means.

Transportation

Transportation of coal by vehicles has little direct effect on water quality, although construction of roadbeds, loading facilities, etc. can cause sedimentation or other problems.

Coal slurry pipelines, on the other hand, exert a very substantial impact on water resources. In particular, a great deal of water must be used as a carrier in an operating pipeline system, which impacts the quantity of water available for other uses. At the discharge end of the pipeline, this water must be either removed and managed as a potentially polluting waste, or it must be "burned" with the coal.

Industrial Burning

The primary water quality impacts associated with burning coal in major industrial facilities, such as power plants, result from the need for large amounts of cooling water to carry waste heat from the system. This practice has three distinct and immediate effects:

1. It removes substantial quantities of water from the source water body;
2. It introduces potentially massive amounts of heat into the receiving water body; and
3. It damages or kills very large numbers of small organisms carried in the water through the cooling system, or larger organisms trapped against protective water intake structures, such as screens.

In systems that recirculate cooling water, salts and other water quality components become concentrated, and their discharge could potentially impact the quality of receiving waters. Adequate control technology for this pollution source is readily available, however.

Conversion

The conversion of coal to gaseous or liquid fuels consists to a degree of removing certain components of coal from the final product, including sulfur, some hydrocarbons and metals, ash, and other materials. Depending upon the processes used, some or all of these components can occur in plant wastewater, and must be controlled. Also, raw coal and waste piles can contribute to water quality

problems just as such storage facilities do at beneficiation facilities.

AIR RESOURCES

Emissions into the air from coal use activities are generally related to dust release or to combustion products. Most concern relates to combustion products, which are discussed separately below, but dust is capable of causing substantial negative impact in the immediate area of release. Air quality emissions are summarized in Figure 3.

Dust is released by virtually every coal handling facility, including mines, waste piles, beneficiation and conversion plants, transportation facilities (excepting pipelines), stockpiles, industrial sites, and transshipment facilities. Dust releases are usually controllable by covering the coal, watering it, or by chemically sealing it.

Combustion

The primary impact to air quality results from burning the coal, whether in a controlled industrial setting, or in uncontrolled or spontaneous fires in mines or stockpiles. The primary pollutants released include oxides of sulfur, nitrogen, and carbon; smaller amounts of trace organics, hydrocarbons, and radionuclides are also emitted. Depending upon local meteorological conditions, these materials may either be carried long distances by air currents, or they may accumulate in high concentrations under more stagnant conditions. Once released into the atmosphere, these materials may react with other compounds to form less or more bothersome compounds. Because all terrestrial organisms, including plants, live in a milieu of air required for continued life, these pollutants have the potential for exerting dramatic deleterious effects on all plant and animal life, including ourselves.

The primary cause of vegetation damage by coal combustion is release of sulfur dioxide (SO_2). Very low levels of SO_2 can reduce production in rye grasses, alfalfa, pine trees, and many lower plant species. Slightly higher levels can reduce important crop yields, such as fruits, nuts, and vegetables. These impacts are most notable under conditions of high SO_x (and NO_x) levels associated with direct plume contact with the ground in the presence of a temperature conversion.

In addition to direct toxicity, both SO_x and NO_x have been associated with the phenomenon of "acid rain". After being emitted as combustion products, these pollutants are oxidized, forming acids that lower the pH of subsequent rainfall. Acid rain pH commonly occurs within a range of 3 to 5 pH units as compared to a typically normal rainfall pH of 5.7. Resulting acidic conditions can have very severe impacts on crops and other vegetation, on soil chemistry, and on aquatic ecosystems; it is a major environmental problem in some industrialized areas of the world.

Of additional immediate importance are the effects that coal combustion products can exert on

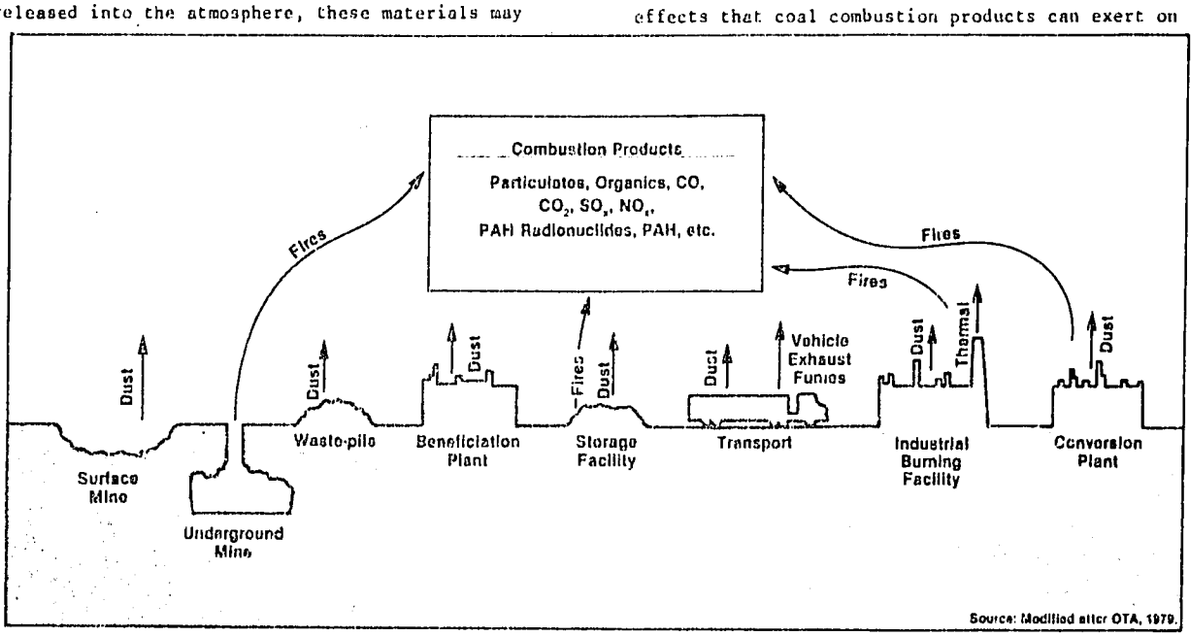

Figure 3. Generalized Air Quality Impacts from Coal Use Activities

public health. Prolonged inhalation of sulfates and suspended particulates have been associated with elevated public mortality levels. Although the degree of cause and effect within this association is difficult to quantify, that such an effect occurs under long-term, chronic exposure conditions is generally accepted.

BIOLOGICAL RESOURCES

Most impacts on biological resources are secondary impacts of factors already discussed. For example, removal of land acreage from biological productivity can impact the stability of wildlife or vegetative populations occurring beyond the zone of immediate impact. Water and air pollution can be directly toxic to components of the local biological system, which may have unanticipated but profound effects on food-chains, predator-prey relationships, stabilizing communal roles, and equally important community dynamics. Virtually every impact on land, water, and air resources has one or more impacts on the biological resources they support. The ultimate results of these impacts depend upon the interactions of the primary impacts with each other, and with the very specific environmental conditions occurring at the site of concern.

CULTURAL RESOURCES

Cultural impacts of coal use are also exceedingly site specific, and relate directly to the social values of people living in the area of development. For example, the aesthetic appearance of a small gravel pit may assault the sensibilities of inhabitants of a surrounding exclusive residential area, while a massive surface mine project in a remote area might offend almost no one. Similarly, the impacts of each component of the coal use cycle should be evaluated according to site-specific conditions relative to local values of visual, aesthetic, religious, historical, noise, and olfactory impacts.

Although these evaluations sometimes have to be accomplished on a subjective basis, a public concensus of standards of acceptability is generally achievable.

APPLICATION TO PAKISTAN COAL DEVELOPMENT

Most of the major coal deposits in Pakistan are located in the provinces of Baluchistan, Sind, and Punjab. Consideration of the potential environmental impacts of development of these resources is a function of the applicable policies and regulations which exist and the type of biological, land, water, air, and cultural resources found in the areas where such development will take place.

At the present time, there are no environmental standards or regulations relating to coal development specific to the Province of Sind or to Pakistan in general. The Government of Pakistan has initiated policies that will lead to the future development of standards and regulations.

Although the Pakistan Environmental Protection Council was administratively established by ordinance in 1984, its membership has yet to be approved. The Pakistan Environmental Protection Agency (PEPA), the executive arm of the council to be responsible for formulating national environmental policy and developing and enforcing national environmental quality standards, was also established by ordinance in 1984. PEPA has not yet been staffed or provided with an operating budget.

Environmental management activities at the Federal level are undertaken by a variety of organizations, including the Inspector General of Forests office and the National Council for Conservation of Wildlife in Pakistan (NCCW) within the Ministry of Food, Agriculture, and Cooperatives and the Water and Power Development Authority (WAPDA).

The Inspector General of Forests office is responsible for developing policies and coordinating programs and budgets for the management of Pakistan's Government-owned forests. This office advises the Ministry of Agriculture on forestry matters and coordinates the activities of the Provincial forest departments. In addition, it administers the Pakistan Forest Institute in Peshawar.

The NCCW is a division of the Ministry of Food, Agriculture, and Cooperatives and forms policies for the conservation of wildlife in Pakistan; it also coordinates the implementation of these policies by the Provinces and provides liaison with international agencies and non-governmental societies for conservation of wildlife. In addition, the Council allocates Federal funds for Provincial wildlife programs and provides assistance

to various Government bodies, such as the Pakistan Forest Institute.

WAPDA is charged with development and management of hydro-electric resources and with the overall operation of national irrigation schemes. It is concerned with problems relating to rapid sedimentation of hydro-electric reservoirs and with irrigation-related problems such as salinity and waterlogging. WAPDA has originated watershed management programs in the Mangla and Tarbela watersheds and operates land reclamation laboratories to combat the problems of salinity and waterlogging. Watershed programs include reforestation activities, institution of grazing controls and development of goat-resistant plants. Land reclamation labs test for salt contamination levels and water depths and devise reclamation plans.

At the Provincial level in Sind there are no institutions concerned specifically with environmental protection, although there are a number of Provincial Departments that are concerned with issues relating to environmental management. These include the Department of Forestry and Wildlife, the Department of Public Health Engineering, and the Provincial Irrigation and Power Department. The Department of Forestry in Sind, as in all other Provinces, is responsible for implementing forest policy decisions made by the Federal Government and for managing the government-controlled forests in the Province. The Wildlife Section of the Department of Forestry is responsible for implementing policy decisions made by the NCCW and for carrying out all wildlife management and protection activities. The Department of Public Health Engineering in Sind is responsible for water supply and sewage facilities throughout Sind (except in Karachi and Hyderabad). The Directorate of Land Reclamation within the Provincial Irrigation and Power Department is concerned with problems relating to waterlogging and salinity.

The Lakhra Project

In lieu of the lack of standards and regulations for the environmental analyses being conducted for the Lakhra Coal Project, the general environmental guidelines of the World Bank and environmental policies of USAID and applicable standards of the U.S. Environmental Protection Agency (EPA) are being used. Table 2 summarizes the application of these guidelines, policies, and

Table 2. Relationship of Applicable Environmental Policies and Guidelines to Resources Affected by Coal Development

Applicable Policies/ Guidelines	Air Resources	Land Resources	Water Resources	Biological Resources	Cultural Resources	Other
Government of Pakistan				endangered species		general environmental policy
World Bank	SO_2, NO_x particulate emissions fugitive dust noise	surface mining, sedimentation and erosion control, reclamation, solid wastes	cooling waters		secondary growth related effects	pesticides
U.S. Environmental Protection Agency	stack height		wastewater discharge and treatment			pesticides
World Health Organization			potable water supply			
U.S. Department of Interior				endangered species		
U.S. Agency for International Development						environmental assessment

standards to the major components of coal development.

Resource impact considerations can only be considered on a case-by-case, site-specific basis. For this paper, coal development at Lakhra in the Province of Sind will be used to illustrate some of these issues. The Lakhra coal site is an undeveloped location 35 km north and 25 km west of Hyderabad. Since there is no development in the area, the air quality is excellent. The topography is generally flat with a mixture of limestones, sandstones, and shale. There are no permanent surface water systems and the ground water is of poor quality. The region is characterized as a thorny scrub ecosystem and appears to contain flora and fauna representative of this ecosystem. Grazing by local tribal animal herds occurs in the area, which contains scattered villages of the Khosa Baluch group. A number of small mines occur in the area and are worked seasonally by miners from the Northwest Frontier Province. Roads and transportation systems are poorly developed in the area.

The procedure used at Lakhra was to apply a two-step test for determining the significance of impacts from a particular development activity. First, an evaluation was made as to whether the action violates some policy, guideline, standard, or regulation. Second, if no such guidelines exist, the predicted effect is examined to determine whether its magnitude or societal importance render it worthy of additional attention. If the proposed action meets either one of these criteria, then an alternative action or mitigation is sought.

For surface mine development at Lakhra, impacts to both air and cultural resources were considered most important. Potential fugitive dust from the mining will affect air quality in the area. The increase in the number of mine operators and miners will affect the existing cultural values and patterns in the area, as well as require development of community services such as hospitals, schools, police and fire protection, roads and communcation systems. Secondarily, land and biological resources will be affected by the impairment of these resources during mining. Although large areas will be mined, the sizes of these areas and the existence of wide expanses of similar undisturbed land and biological resources makes these impacts less significant than the impacts to air and cultural resources. Impact to water resources is considered high, but not as significant as the other resource impacts since no permanent surface water systems will be affected. Although ground water systems will be affected, these systems are not now used or planned for use in the future.

Transportation impacts are not considered particularly significant. Some combination of rail and truck transportation is likely, so only small amounts of land and biological resources will be affected by the transportation corridors. No water resources will be effected. Unless the roads are paved, significant fugitive dust will result. Because the major impacts will be on or adjacent to existing roads and highways, the road and highway system should be upgraded if large quantities of coal are to be transported out of the area.

Storage and cleaning impacts will involve air and cultural resource impacts such as fugitive dust from uncovered coal. Since this quality of coal is subject to spontaneous conbustion, safety problems can arise unless preventative measures are taken.

The most important impacts from the power plant will be to air and cultural resources. Sulfur dioxide and particulate emissions will result. As with the mine, a large number of people will be required to build and staff the power plant. The influx and presence of this population will affect the existing cultural and socioeconomic systems of the area. If the power plant is built in conjunction with the mine, therefore, a small town may have to be created to support workers and their families.

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COMPARISON OF DESIGN CONSIDERATIONS OF PAKISTAN COALS FOR POWER GENERATION APPLICATIONS

R. G. Fuller and R. L. Herrick
Gilbert/Commonwealth, Inc.
Jackson, Michigan

ABSTRACT

This paper discusses special considerations that must be applied to traditional thought and practices for power block and balance of plant design parameters to be able to successfully utilize indigenous Lakhra coals found in Pakistan.

A brief history of past and current studies and reports concerning Lakhra lignite is presented. Results of the comprehensive 1985 combustion testing program which burned both "run-of-mine" and washed Lakhra coals are presented. Results of the 1985 washability analyses are discussed. The effect on boiler design and plant effluents of washed versus run of mine fuel is discussed.

The various furnace design parameters for a 2 x 350 MW pulverized fuel power plant are defined and delineated. Other parameters defined for Lakhra lignite in a power boiler are the limits of the furnace envelope, maximum furnace exit gas temperature, excess combustion air and air heater exit gas temperature. These parameters are contrasted with those applicable to other fuels such as brown coal, sub-bituminous coals and bituminous coals. The impact of utilizing off-specification higher grade steam coals is discussed as are the effects of firing blended coals from different sources such as unrelated coal seams.

INTRODUCTION

In 1855 Baluch Nomads reportedly struck a seam of coal of about 2.43 m (8 ft.) while sinking a well for water at Lakhra. Systematic surveying was started in 1870 (1). Investigations were carried out by the Geological Survey of Pakistan (GSP) and the United States Geological Survey (USGS) in the 1960's. There followed other investigations by West Pakistan Industrial Development Corporation (WPIDC); Lurgi; a Polish Consultant; Japan International Cooperation Agency (JICA); Stone & Webster Engineering Corporation (SWEC) and the current work commissioned by the United States Agency for International Development and Pakistan's Water and Power Development Authority, (USAID/WAPDA), conducted by J. T. Boyd Company concerning mining and Gilbert/Commonwealth International Inc. (GC II) concerning Power Plant design considerations.

Qualitatively, previous investigations have shown that Pakistan coals were geologically immature and of inferior chemical quality. Conclusions from previous study work showed that the coals ranged from lignitic to sub-bituminous and had high volatile matter (26-45 percent), high sulfur (0.5-10.5 percent) and high ash (3-38 percent). The gross calorific value (GCV) ranged between 3390-6890 Kcal/kg (7000-12400 Btu/lb). Coal quality was known to vary widely from field to field and even within a specific seam in a given field. Lakhra coal demonstrates high moisture, high sulfur and low fixed carbon and it is about one half of Pakistan's known coal reserves (2).

CHARACTERISTICS OF LAKHRA COAL

The current investigation by J. T. Boyd Company has produced very definitive information about Lakhra coals in the

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Pakistan Mineral Development Corporation (PMDC) 52 square kilometer lease area of the Lakhra field. The data for various analyses of unwashed Lakhra coals are shown on Table 1 (3). The mean GCV of Lakhra coal is 3014 Kcal/kg (5100 Btu/lb) as received with 32 percent moisture. The 32 percent moisture as received range of GCV is 2289-3380 Kcal/kg (4121-6085 Btu/lb) compared to previous data of 3390-6890 Kcal/kg above. The proximate analysis on a dry basis is:

Ash	26.17-41.87 Percent
VM	32.15-39.56 Percent
FC	23.68-35.82 Percent
Sul	6.02 -9.85 Percent

These data compare fairly well with previous information concerning Lakhra coal, but are more specifically related to the PMDC Lakhra lease area. The J. T. Boyd survey is based on the 21 composite analyses and 6 arithmetic average analyses on Table 1. More specifically, the daily and monthly averages of expected production of coal for the Lakhra Power Plant shows a wide variation of quality as follows:

Daily Basis:	Aver.	Range
Kcal/kg Dry	4167	3500-4833
Btu/lb Dry	7500	6300-8700
Ash % Dry	36.0	26.0-46.0
Sulfur % Dry	7.4	6.5 -9.5
Moisture %	32.0	25.0-45.0

Monthly Basis:	Aver.	Range
Kcal/kg Dry	4167	3833-4500
Btu/lb Dry	7500	6900-8100
Ash % Dry	36.0	30.0-42.0
Sulfur % Dry	7.4	6.8- 8.3
Moisture %	32.0	28.0-40.0

Note the mean deviation of GCV on a daily basis is 943 Kcal/kg (1697 Btu/lb) compared to a mean deviation on a monthly basis of 472 Kcal/kg (849 Btu/lb). The expected monthly range in the GCV of coal received and burned at the Lakhra Power Plant will show a wide variation even though it is fifty percent of the daily basis. The range of ash is tighter, 26.0-46.0 percent, versus, 3.0-38.0 percent, as is sulfur at 6.5-9.5 percent, versus, 0.5-10.5 percent. The volatile matter range from Table 1 is 32.15-39.58 percent, again tighter than 26.0-45.0 percent as previously thought. The ash loading entering the furnace, neglecting that rejected with the pyrites, ranges from 56.5-124.4 kg/Million Kcal (31.4-69.0 lbs/Million Btu), with a mean value of 86.4 kg/Million Kcal (48 lbs/Million Btu). The mean coal flow rate per 350 MW Lakhra steam generator is expected to be 348 tonnes/hour (384 tons/hour). The ash will be 24.5 percent of that, at 85 tonnes/hour (94 tons/hour) and the sulfur flow at 5.0 percent of the coal input will be 17.4 tonnes/hour (19.2 tons/hour). The furnace bottom ash and flue gas fly ash collected will range from 25-34 tonnes/hour (28-38 tons/hour) and 51-60 tonnes/hour (56-66 tons/hour) respectively. The fuel consumption for the 2 x 350 MW Lakhra Power Plant is expected to be 4,300,000 tonnes per annum.

Data for the various composite analyses on a washed basis are shown on Table 2, (4). Note these are the same composite analyses as Table 1 except they are washed. The ash content is 23.0 percent as received, dry basis, compared to unwashed coal at 36.0 percent. This reduction in ash content is dramatically shown by the comparison of an ash loading of 43.6 kg/Million Kcal (24.2 lbs/Million Btu) for washed Lakhra coal versus 86.4 kg/Million Kcal (48 lbs/Million Btu) for unwashed, nearly a fifty percent reduction. The sulfur flow is reduced from 17.4 tonnes/hour (19.2 tons/hour) to 12.2 tonnes/hour (13.5 tons/hour), a reduction of nearly 30 percent.

A specific comparison of unwashed versus washed coal is shown on Table 3. It is interesting to note that washing reduces ash and sulfur loading in Lakhra coal and increases the GCV, but it does not significantly alter the mineral content, nor the slagging/fouling potential of the ash. The classic method of determining slagging and fouling indices used in this paper was developed for Eastern U.S. Bituminous coals. This method can be applied to Lakhra coals for comparison purposes only. No conclusions should be drawn from such a comparison that can not be supported by other qualitative methods such as laboratory testing or field testing in an operating unit or, preferably, both. The method of calculating the base to acid ratio, slagging index and fouling index is shown in Table 4 (5). Lakhra coal classifies as severe slagging and medium fouling. The potential for slagging and fouling can be determined with a high degree of confidence by laboratory testing of the coal in question and comparing the resulting data with the data that has been compiled for other coals tested in that same test facility. Ideally the test facility will have calibrated their test results of the many coals test fired with field data of the same coals in operating power plants.

TESTING OF LAKHRA COAL

GCII engaged Combustion Engineering, Inc. (CE) of Windsor, Conn., USA as a sub contractor to test burn Lakhra coals at the Kreisinger Development Laboratory (KDL) of CE in Windsor, Connecticut. The test burns were conducted in three phases:

1. Burn 45 tonnes (50 tons) of Lakhra coal from PMDC mine #2 to determine baseline data.

2. Burn the cleaned 32 tonnes (35 tons) output of PMDC #2 coal from a commercial scale washery to determine the effects on steam generator design of using washed Lakhra coal.

3. Burn 16 tonnes (17.5 tons) of Lakhra coal from a test shaft in the West area of the PMDC lease to determine the similarity of on-lease and off-lease area coals.

The Phase 1 test burn determined that Lakhra coal was severe slagging and medium fouling as expected. The critical test furnace temperature above which furnace deposits could not be cleaned was determined and verified by 8 sucessive burns of Lakhra baseline coal. These and other data were reduced by KDL and translated to furnace design parameters by CE's Steam Generator Engineering Department. The tests also determined that Lakhra coals are very corrosive in high temperature zones on those traditional metals used for high temperature service in the superheater and reheater sections of the boiler and in the burner zone where care must be taken to maintain an oxydizing rather than a reducing atmosphere.

The Phase 2 test burns with washed Lakhra coal determined that there is no difference with respect to furnace and boiler design parameters, nor for slagging and fouling potential for washed versus unwashed Lakhra coals, (6). The differences in the steam generator arrangement for washed versus unwashed Lakhra coals would be in the coal handling, ash handling and air quality control systems. The improved GCV of washed coal will reduce coal flow by nearly 20 percent from 340 tonnes/hour to 236 tonnes/hour.

The higher GCV and lower ash loading will allow the electrostatic precipitator to be reduced in size by about 15 percent from a specific collection area (SCA) of 100 meters squared per cubic meter per second to 85 meters squared per cubic meter per second. The ash loading to the electrostatic precipitator is still high even though the overall ash loading is reduced by nearly fifty percent.

The Phase 3 test burns with seams 1 & 2 coals from the test shaft at the BT-11 core bore holes showed that these coals were slightly worse in quality than unwashed or washed PMDC 2 coals. However, the differences are subjective. The slagging potential of PMDC 2 Lakhra coal is already severe, and "slightly more severe", for Lakhra coal from the PMDC lease area over PMDC 2 coal, does not materially affect the conclusions that were drawn about these coals from the results of the Phase 1 test burns. Lakhra coals will demand a large furnace with a relatively low furnace exit gas temperature limit, higher than normal excess combustion air, low gas pass velocities and specific requirements concerning the atmosphere in the burner zone of the furnace. The design parameters specified for any one of the Lakhra coals tested will be suitable for any of the other Lakhra coals. One conclusion of the J. T. Boyd study is that coal from PMDC mine #2 can be identified as one of the same seams of coal that occurs on the PMDC lease area at Lakhra. The fact that these are the same coals is further substantiated by the results of the combustion test burns.

DESIGN CONSIDERATIONS

The manufacturers of steam generators have standards set specifically for their design. Between suppliers these standards are related, but are not numerically the same for the various parameters of furnace and boiler design. For an operating company and his consultant to be able to evaluate tenders on a common and equitabe basis there must be a definition of these parameters specified to the manufacturer who is bidding. This procedure is not intended to dictate to the vendor how he designs, it is only intended to relate a common method of calculating the various heat release rates and other parameters for bid tabulation fill in sheets that must be adhered to and assessed during evaluation of proposals. These definitions are:

1. FURNACE LIMITS

   The furnace evelope is defined as the face of the furnace wall tubes, sloping hopper tubes, roof tubes and the vertical plane tangent to the face of the nose of the upper arch tubes, regardless of tube spacing or the location of water cooled tubes beyond that vertical plane.

2. NET HEAT AVAILABLE

   The net heat available shall be calculated on the basis of the hourly rate of energy released at the GCV of the fuel, less the sum of unaccounted loss, radiation loss, unburned combustible loss and latent heat of the water in the fuel and formed by burning hydrogen in the fuel, plus the sensible heat in the primary and secondary combustion air above a reference temperature of the ambient air entering the forced draft and primary air fans.

3. EFFECTIVE PROJECTED RADIANT SURFACE

   The effective projected radiant surface (EPRS) is the flat projected area of furnace walls, sloping hopper tubes, roof tubes and the vertical plane of the furnace exit.

4. BURNER ZONE SURFACE

The burner zone surface is the sum of the area of the six sides of a cube defined by the furnace width by the furnace depth by the height that is equal to 3 m (10 ft) above and below the upper and lower burner rows or fuel injection ports. If the lower row of burners or fuel injection ports is less than 3 m (10 ft) above the beginning of the tube bends forming the lower furnace hopper, then the lesser dimension shall be used.

5. FURNACE PLAN AREA

Furnace Plan area shall be calculated as the furnace width times the furnace depth at the centerline of the top row of burners or fuel injection ports.

For Lakhra coals it is important that there be no platen heating surfaces in the furnace, regardless of whether they are steam cooled or water cooled. Lakhra coals are severe slagging and corrosive on high temperature metals. The high ash loading and severe slagging potential will produce slag on platen heating surfaces and slag falls from such surfaces cannot be tolerated by the sloping tubes in the furnace bottom, nor in the ash hopper throat at the bottom of the hopper tubes. High temperature metals, normally in platen superheater and reheater surfaces, will not live as long as with other coals due to the high corrosive nature of Lakhra coals. These characteristics of Lakhra coals also dictated that the most technically acceptable steam conditions should be 12,515 kPa 510C/510C (1800 psig 950F/950F) as opposed to the more economical steam conditions of 16,650 kPa 538C/538C (2400 psig 1000F/1000F). This was a difficult decision to accept, but technical considerations had to over ride economical considerations for Lakhra coals. The maximum furnace exit gas temperature (FEGT) shall be considered as a maximum, otherwise, if the FEGT is specified as the average temperature leaving the furnace, then the lower of reducing versus oxydizing ash fusion temperatures shall be used as the value of this parameter, which for Lakhra coals is 1095C (2000F) versus 1230C (2250F).

The various design parameters for Lakhra coals are:

The maximum furnace exit gas temperature (FEGT) at any point entering the furnace exit plane shall not exceed 1232C (2250F).

The maximum net heat release rate per unit of EPRS shall not exceed 680 MJ/hr-m^2 (60,000 Btu/hr-ft^2).

The maximum heat release rate per unit of furnace plan area shall not exceed 14,750 MJ/hr-m^2 (1,300,000 Btu/hr-ft^2).

The maximum heat release rate per unit of burner zone shall not exceed 2850 MJ/hr-m^2 (250,000 Btu/hr-ft^2).

The gas velocity at any point in the furnace, leaving the furnace and within convection heating surfaces beyond the furnace shall not exceed 13.7 m/s (45 ft/sec).

The air heater exit gas temperature shall be not less than 150C (300F) corrected for air leakage. (Note: This limit could be increased to as high as 177C (350F) if the recommended future analysis of flue gas dew point condensation temperature results in that conclusion).

The distance from the top row of burners or fuel injection ports to the upper furnace arch shall be not less than 21.35 m (70 ft).

The clear space between water cooled and steam cooled tubes shall be as follows:

1150-1230C	560 MM
(2100-2250F	22.0 incnes)
1010-1150C	330 MM
(1850-2100F	13.0 inches)
845-1010C	165 MM
(1550-1850F	6.5 inches)
620- 845C	100 MM
(1150-1550F	4.0 inches)
Up to 620C	65 MM
(Up to 1150F	2.5 inches)

The maximum FEGT for brown coals would be the same or less than that for Lakhra, while sub-bituminous and bituminous coals would be the same or a bit higher depending on the value of the initial deformation temperature of the ash on an oxydizing basis. The maximum allowable FEGT is directly related to the initial deformation temperature of the ash and the slagging potential. A lower slagging potential may allow a higher FEGT and a higher slagging potential will demand a lower FEGT.

The heat release rates per unit of EPRS, furnace plan and burner zone areas are related to the slagging index of a coal and to the specified maximum FEGT. What follows for the allowable FEGT follows for these parameters.

The limits for gas velocity and clear tube spacing are related to the fouling potential of a coal. Lakhra coals are medium fouling and tighter spacing than specified would be indicated. The combustion test burns determined there was a high rate of ash fouling buildup directly related to the very high ash loading in and leaving the furnace. While the deposits were easy to clean and the low sodium content of the ash did not produce uncleanable deposits, the buildup was substantial and wide clear spacing between tubes is required for Lakhra coals. This requirement is valid for washed and unwashed Lakhra coals. The clear tube spacing for other fuels such as brown coal, sub-bituminous and bituminous coals is a function of sodium in the ash and ash loading to the convection heating surfaces, rather than the classification of the coal under consideration. The excess air at 25 percent is required for low grade fuels such as Lakhra coals that have a high content of inert material such as ash and moisture or that are not very reactive with respect to combustibility. Lakhra coals would dictate an even higher percentage of excess combustion air were it not for its high reactivity with respect to combustibility. It is very reactive and carbon burnout is very high, exceeding 99.9 percent (7).

A steam generator designed for Lakhra coal can accomodate a standby fuel such as Bunker "C" furnace oil or imported bituminous coal. There will be a derate on either fuel unless operational procedures are modified to reduce low superheat and reheat steam temperatures expected when firing a "clean burning" fuel such as oil or bituminous coal compared to burning a "dirty fuel" such as Lakhra coal. Examples of these modifications are to fire with higher than required excess combustion air; bias fire more fuel in the upper burners or "tilt" the burners upward or both; adjust back pass dampers; install a temporary refractory coating in the lower furnace; and install spare burners higher in the furnace to be utilized only when the standby fuel is being consumed. The combustion characteristics and quality of Lakhra coals are such that a 350 MW steam generator designed for them is approximately the same physical size as a 600 MW designed for a good quality bituminous steaming coal. This is illustrated by Figure 1 (8).

The firing of blended coals from different seams should be studied very carefully before such a procedure is implemented. Often the ash fusion temperatures of such a blend are lower than either of the two coals used in the blending demonstrated as individual coals. See Figure 2 (9).

The utilization of Lakhra coals domestically is limited compared to the 4,300,000 tonnes per annum of coal needed for a 2 x 350 megawatt power plant. Lakhra coal has been considered for blast furnace operations (10); gasification (11) and in cement plants (12). The latter paper mentions Fluidized Bed Technology as possible for use in power plants and cement plants. The Atmospheric Fluidized Bed Combustor (AFBC) is felt to be not quite ready for use as the steam supply system for a 350 MW power generating set. It is quite probable that multi-AFBC's could be headered together to produce enough steam to meet the required throttle flow of a 350 MW turbine-generator. This has been done in the power industry and is accepted technology for non-reheat units. The headered technique would be a little complicated controlwise. The high pressure exhaust steam would have to be split into individual flows to be reheated in each AFBC steam generator and then rejoined for admission to the intermediate pressure turbine. The next generation of power plants in Pakistan could well be the application of AFBC technology on a one boiler - one turbine basis. The application of fluidized bed combustors is progressing in logical steps to a size level that could well see their application in Pakistan in the late 1990's or very early in the 21st century. The presence of limestone overlying the Lakhra coal deposits will make for a ready source of a sorbent for SO_2 control. The sand from dredgings in the Indus might well produce a supply of the smooth round shaped bed material needed for an AFBC steam generator.

CONCLUSION

In conclusion, the application of Lakhra coals as boiler fuel in Pakistan is a step forward to displace imported fuels. The successful use of this low grade fuel can be accomplished if the required designed parameters are adhered to. Staying on the conservative side rather than the commercial side of these parameters is of paramount importance to the task of designing a power plant with high reliability, high availability and resonable maintenance. Burning coal successfully is not easy, even with a so called good bituminous steaming coal. It requires daily attention to removal of ashes and the filling of coal silos as well as preventive maintenance procedures (such as scheduled lubrication or pulverizer rebuilding), to reduce forced outage time. These facts are even more important when burning a low grade fuel such as Lakhra. Burning Lakhra coal will not be easy, but with the knowledge gained from the current investigations it can and will be successful.

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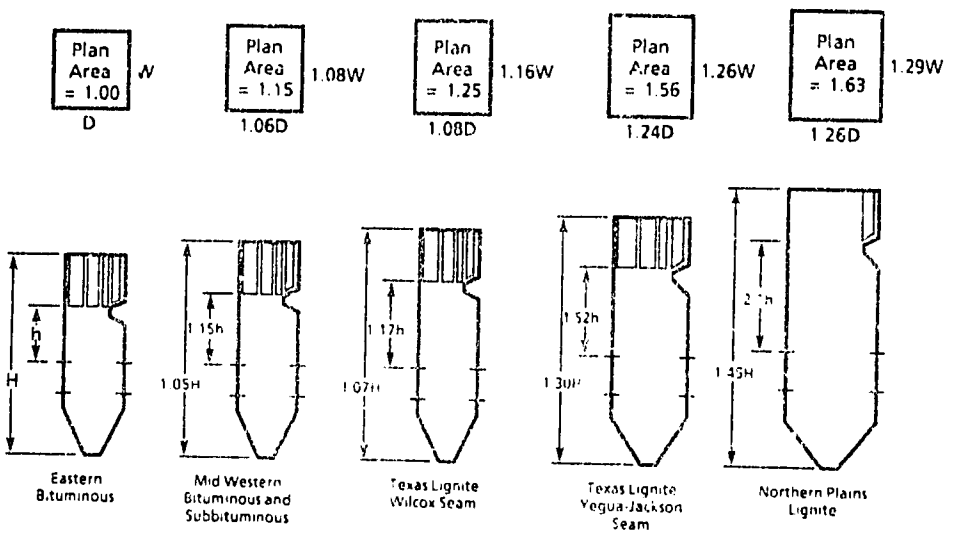
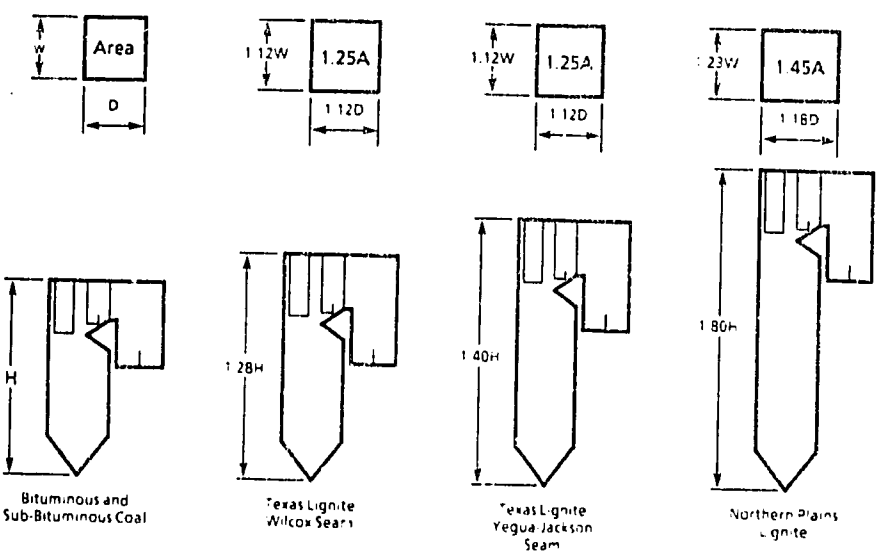
FIGURE 1

COMPARISON OF THE EFFECT OF COAL RANK ON FURNACE SIZING FOR A CONSTANT HEAT OUTPUT



A. For typical corner fired design.



B For typical opposed wall fired design.

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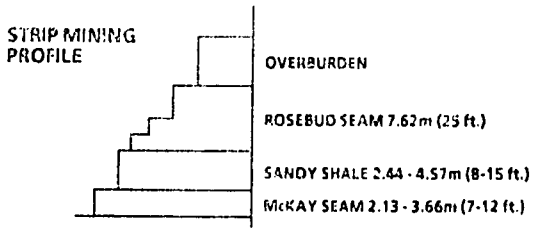
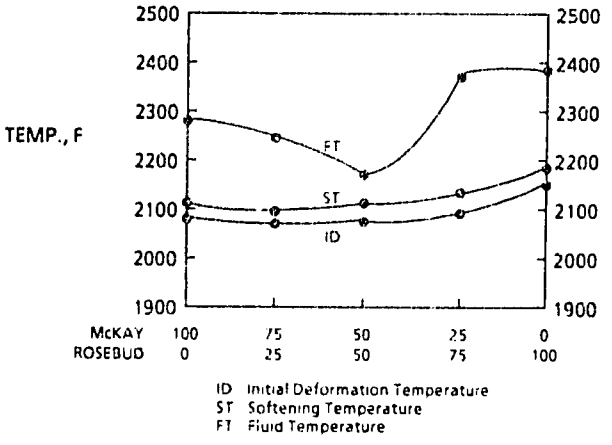
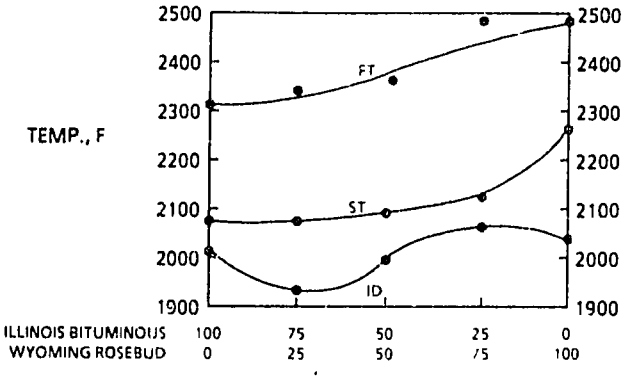
FIGURE 2

ASH FUSION TEMPERATURES OF SUB-BITUMINOUS COAL FROM THE ROSEBUD AND McKAY SEAMS, MONTANA, USA; AND THE ROSEBUD SUB-BITUMINOUS SEAM, WYOMING AND ILLINOIS BITUMINOUS COAL





A. Example of a blend of two sub-bituminous seams in the same field.



B. Example of a blend of bituminous and sub-bituminous coals from different locations.

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TABLE 1

COMPOSITE DRILL CORE ANALYSES
UNWASHED COAL (DRY BASIS)
LAKHRA COAL PROJECT
Sind Province, Pakistan

Sample Analysis	Seam No. 5 W-A5	Seam No. 3 W-A3	Seam No. 2 W-A2	Seam No. 2 W-B2	Seam No. 2 W-C2	Seam No. 2 Arith. Average	Seam No. 1 W-A1	Seam No. 1 W-B1	Seam No. 1 W-C1	Seam No. 1 Arith. Average
				WEST AREA						
Analysis:										
Ash (%)	32.15	28.07	27.77	30.51	41.87	33.38	29.42	29.23	41.00	33.22
Volatile Matter (%)	36.87	38.05	39.15	38.89	32.69	36.91	39.58	39.03	35.32	37.98
Fixed Carbon (%)	30.98	33.88	33.09	30.60	25.44	29.71	31.00	31.74	23.67	28.80
Sulfur (%)	8.87	7.54	8.26	8.37	8.46	8.36	8.85	9.85	7.65	8.78
Kcal/kg	4397	4734	4704	4465	3366	4190	4606	4471	3661	4246
Btu/lb.	7,917	8,540	8,534	8,039	6,060	7,544	8,292	8,050	6,592	7,645
Equ. Moisture (%)	40.58	34.63	34.78	35.49	36.93	35.73	36.14	35.77	33.77	35.23
Fusion Temperature of Ash (°F)										
Reducing:										
Initial	2066	2064	2065	2016	2140	2074	2017	2018	2108	2048
Softening	2070	2072	2076	2036	2162	2091	2035	2024	2152	2070
Hemp.	2073	2078	2079	2054	2197	2110	2051	2029	2208	2096
Final	2212	2254	2133	2136	2492	2254	2132	2235	2312	2226
Oxidizing:										
Initial	2262	2254	2268	2453	2462	2394	2306	2471	2382	2386
Softening	2309	2302	2321	2476	2497	2431	2398	2493	2451	2447
Hemp.	2362	2333	2391	2502	2515	2469	2486	2508	2483	2492
Final	2439	2395	2503	2543	2545	2530	2525	2552	2521	2533
Forms of Sulfur (%)										
Total Sulfur	8.87	7.54	8.26	8.37	8.46	8.36	8.85	9.85	7.65	8.79
Pyritic Sulfur	4.70	3.97	4.18	4.80	4.41	4.46	4.48	5.30	4.40	4.73
Sulfate Sulfur	0.69	0.56	0.55	0.58	1.56	0.90	0.61	0.69	0.40	0.57
Organic Sulfur	3.48	3.01	3.53	2.99	2.49	3.00	3.76	3.86	2.85	3.49
Ultimate Analysis of Coal (%)										
Ash	32.15	28.07	27.77	30.51	41.87	33.38	29.42	29.23	41.00	33.22
Hydrogen	3.15	3.43	3.48	3.36	2.76	3.20	3.51	3.32	2.85	3.27
Carbon	44.94	50.03	48.74	46.70	35.61	43.68	47.21	46.18	36.15	43.85
Nitrogen	0.77	0.94	0.80	1.08	0.75	0.83	0.87	1.04	0.66	0.86
Sulfur	8.87	7.54	8.26	8.37	8.46	8.36	8.85	9.85	7.65	8.79
Oxygen	10.12	9.99	11.22	9.98	10.55	10.58	10.14	10.38	9.69	10.07
Total Chlorine (%)	0.13	0.13	0.12	0.15	0.14	0.14	0.10	0.12	0.12	0.11
Water Soluble Chlorine (%)	0.10	0.12	0.08	0.12	0.10	0.10	0.04	0.07	0.10	0.07
Water Soluble Alkalies (%)										
Potassium Oxide	0.018	0.011	0.016	0.022	0.012	0.017	0.020	0.014	0.014	0.016
Sodium Oxide	0.293	0.228	0.250	0.226	0.092	0.19	0.197	0.198	0.108	0.168
Total	0.311	0.239	0.266	0.248	0.104	0.206	0.217	0.212	0.122	0.184
Mineral Analysis of Ash (% Ignited Basis):										
Silicon Dioxide	40.80	36.95	37.31	33.68	45.06	38.68	38.01	32.62	47.68	39.44
Aluminum Oxide	12.58	12.12	20.06	19.66	20.98	20.23	20.84	20.40	19.62	20.29
Titanium Dioxide	1.59	1.33	2.21	2.04	2.16	2.14	2.07	2.15	1.88	2.03
Calcium Oxide	7.54	8.39	3.52	2.64	3.86	3.35	2.89	2.80	3.06	2.94
Potassium Oxide	0.64	0.45	0.54	0.48	0.76	0.59	0.57	0.55	0.58	0.57
Magnesium Oxide	2.20	1.94	2.10	1.42	0.79	1.44	1.70	1.64	2.54	1.96
Sodium Oxide	0.75	0.64	0.74	0.65	0.48	0.62	0.58	0.64	0.32	0.51
Ferric Oxide	23.87	25.42	25.53	33.60	19.11	26.08	26.11	33.37	17.79	25.76
Phosphorus Pentoxide	0.56	0.62	0.64	0.68	0.66	0.66	0.76	0.72	0.59	0.69
Sulfur Trioxide	8.63	10.55	6.10	4.80	4.98	5.29	5.16	4.65	5.28	5.04
Phosphorus (% Dry Basis)	0.078	0.076	0.078	0.091	0.120	0.096	0.098	0.092	0.106	0.099
Slag Viscosity (T_{250} °F)	2230	2220	2280	2210	2460	2317	2300	2200	2470	2323
Slagging Index	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.
Fouling Index	Med.	Med.	Med.	Med.	Low	Med.	Med.	Med.	Low	Med.

TABLE 1 - Continued

Sample Analysis	Seam No. 3	Seam No. 2				Seam No. 1			
	E-A3	E-A2	E-B2	E-C2	Arith. Average	E-A1	E-B1	E-C1	Arith. Average
				EAST AREA					
Analysis:									
Ash (%)	34.93	35.07	26.17	39.89	33.71	27.26	27.83	35.10	30.06
Volatile Matter (%)	34.82	33.95	38.01	32.15	34.70	39.28	36.94	33.57	36.59
Fixed Carbon (%)	30.25	30.98	35.82	27.96	31.58	33.46	35.23	31.33	33.34
Sulfur (%)	6.03	6.02	6.94	6.48	6.48	7.45	7.36	6.79	7.20
Kcal/kg									
Btu/lb.	7870	7704	8950	6850	7834	8882	8821	7528	8410
Equ. Moisture (%)	44.86	40.45	39.72	41.75	40.64	40.64	44.20	50.06	44.96
Fusion Temperature of Ash (°F)									
Reducing:									
Initial	2232	2443	2081	2104	2209	2046	2047	2083	2058
Softening	2389	2453	2118	2155	2242	2076	2076	2130	2094
Hemp.	2420	2468	2133	2372	2324	2103	2132	2190	2141
Final	2453	2508	2230	2490	2409	2230	2195	2310	2245
Oxidizing:									
Initial	2492	2593	2460	2502	2518	2441	2445	2520	2468
Softening	2548	2621	2490	2543	2551	2488	2473	2552	2504
Hemp.	2589	2631	2503	2558	2564	2501	2491	2575	2522
Final	2635	2640	2536	2585	2587	2537	2538	2593	2556
Forms of Sulfur (%)									
Total Sulfur	6.03	6.02	6.94	6.48	6.48	7.45	7.36	6.79	7.20
Pyritic Sulfur	3.17	2.89	3.07	3.87	3.27	3.22	5.51	3.20	3.97
Sulfate Sulfur	0.44	0.31	0.60	0.68	0.53	0.46	0.42	0.86	0.58
Organic Sulfur	2.42	2.82	3.27	1.93	2.67	3.77	1.43	2.73	2.64
Ultimate Analysis of Coal (%)									
Ash	34.93	35.07	26.17	39.89	33.71	27.26	27.83	35.10	30.06
Hydrogen	3.33	3.23	3.58	2.91	3.24	3.58	3.66	2.99	3.41
Carbon	44.05	44.13	50.72	39.26	44.70	50.75	49.48	41.50	47.24
Nitrogen	0.82	0.87	0.95	0.74	0.85	0.92	0.91	0.78	0.87
Sulfur	6.03	6.02	6.94	6.48	6.48	7.45	7.36	6.79	7.20
Oxygen	10.84	10.68	11.64	10.72	11.01	10.04	10.76	12.84	11.21
Total Chlorine (%)	0.18	0.11	0.18	0.19	0.16	0.14	0.18	0.16	0.16
Water Soluble Chlorine (%)	0.15	0.08	0.16	0.16	0.13	0.10	0.14	0.14	0.12
Water Soluble Alkalies (%)									
Potassium Oxide	0.019	0.019	0.022	0.022	0.021	0.015	0.018	0.024	0.019
Sodium Oxide	0.344	0.231	0.269	0.241	0.247	0.108	0.266	0.303	0.225
Total	0.363	0.250	0.291	0.263	0.268	0.123	0.284	0.327	0.224
Mineral Analysis of Ash (% Ignited Basis):									
Silicon Dioxide	42.14	44.16	38.97	47.57	43.56	40.97	32.34	45.58	39.63
Aluminum Oxide	24.70	26.30	21.00	21.91	23.07	18.87	19.22	22.36	20.15
Titanium Dioxide	3.16	2.76	2.00	2.48	2.41	1.69	1.54	1.92	1.71
Calcium Oxide	2.11	2.88	3.48	2.13	2.83	3.63	4.28	2.61	3.50
Potassium Oxide	0.61	0.69	0.64	0.65	0.66	0.57	0.65	0.66	0.62
Magnesium Oxide	1.67	1.35	1.92	1.15	1.47	1.27	1.82	1.47	1.52
Sodium Oxide	1.02	0.03	0.90	0.70	0.81	0.69	0.94	0.80	0.81
Ferric Oxide	19.28	17.02	22.31	19.92	19.75	25.16	31.02	19.40	25.19
Phosphorus Pentoxide	0.81	0.75	0.81	0.82	0.79	0.87	0.90	0.76	0.84
Sulfur Trioxide	4.43	3.00	7.15	2.20	4.11	6.25	7.20	4.30	5.91
Phosphorus (% Dry Basis)	0.123	0.115	0.093	0.143	0.117	0.103	0.109	0.116	0.109
Slag Viscosity (T_{250} °F)	2470	2530	2330	2480	2446	2300	2200	2470	2323
Slagging Index	High	Med.	Sev.	High	High	Sev.	Sev.	High	Sev.
Fouling Index	Med.	Med.	Med.	Med.	Med.	Med.	High	Med.	Med.

TABLE 1 - Continued

Sample Analysis	Seam No. 3 C-A3	Seam No. 3 C-B3	Seam No. 3 Arith. Average	Seam No. 2 C-A2	Seam No. 2 C-B2	Seam No. 2 C-C2	Seam No. 2 Arith. Average	Seam No. 1 C-A1
			CENTRAL AREA					
Analysis:								
Ash (%)	31.87	32.18	32.02	27.68	31.97	31.89	30.51	29.66
Volatile Matter (%)	36.29	36.8[illegible]	36.58	30.13	37.15	37.09	37.68	38.54
Fixed Carbon (%)	31.84	30.95	31.39	34.14	30.88	31.02	32.01	31.08
Sulfur (%)	8.03	6.34	7.18	8.46	7.89	7.57	7.97	8.99
Kcal/kg	4,575	4,445	4,510	4,902	4,508	4,538	4,650	4,689
Btu/lb.	8,236	8,002	8,119	8,826	8,116	8,170	8,371	8,442
Equ. Moisture (%)	41.49	40.32	40.90	37.73	37.85	34.95	36.84	44.61
Fusion Temperature of Ash (°F)								
Reducing:								
Initial	2012	2047	2030	2001	2076	2086	2054	2014
Softening	2045	2074	2060	2005	2086	2118	2070	2039
Hemp.	2072	2102	2087	2012	2102	2130	2081	2075
Final	2189	2182	2186	2046	2180	2185	2137	2187
Oxidizing:								
Initial	2421	2483	2452	2488	2480	2506	2491	2505
Softening	2470	2511	2491	2510	2516	2545	2524	2502
Hemp.	2500	2524	2512	2527	2530	2560	2539	2531
Final	2541	2550	2546	2550	2561	2580	2564	2554
Forms of Sulfur (%)								
Total Sulfur	8.03	6.34	7.18	8.46	7.89	7.57	7.97	8.99
Pyritic Sulfur	4.47	3.42	3.94	5.00	4.31	4.01	4.14	5.81
Sulfate Sulfur	0.66	0.40	0.53	0.33	0.50	0.57	0.46	0.37
Organic Sulfur	2.90	2.72	2.81	3.13	3.08	2.99	3.06	2.81
Ultimate Analysis of Coal (%)								
Ash	31.87	32.18	32.02	27.63	31.97	31.89	30.51	29.66
Hydrogen	2.96	3.27	3.11	3.34	3.41	3.58	3.44	3.50
Carbon	45.99	47.00	45.49	48.79	45.71	45.96	46.82	47.02
Nitrogen	0.93	0.94	0.94	0.94	0.88	0.84	0.88	0.84
Sulfur	8.03	6.34	7.18	8.46	7.89	7.57	7.97	8.99
Oxygen	10.22	10.27	10.24	10.79	10.14	10.16	10.36	9.99
Chlorine (%)	0.14	0.17	0.15	0.14	0.12	0.10	0.12	0.12
Water Soluble Chlorine (%)	0.11	0.15	0.13	0.12	0.11	0.09	0.10	0.11
Water Soluble Alkalies (%)								
Potassium Oxide	0.020	0.020	0.020	0.016	0.020	0.020	0.018	0.017
Sodium Oxide	0.203	0.197	0.200	0.175	0.167	0.133	0.158	0.175
Total	0.223	0.217	0.220	0.191	0.187	0.153	0.177	0.192
Mineral Analysis of Ash (% Ignited Basis):								
Silicon Dioxide	37.05	42.43	39.74	36.44	35.29	37.15	36.29	34.94
Aluminum Oxide	20.84	20.97	20.90	17.61	21.15	23.77	20.84	20.53
Titanium Dioxide	2.77	2.34	2.55	1.68	1.81	1.87	1.79	1.48
Calcium Oxide	3.07	2.58	2.82	3.92	3.54	3.16	3.54	3.16
Potassium Oxide	0.63	0.62	0.63	0.58	0.62	0.66	0.62	0.54
Magnesium Oxide	1.16	1.17	1.17	1.33	1.28	1.24	1.28	1.13
Sodium Oxide	0.78	0.74	0.76	0.81	0.75	0.64	0.73	0.79
Ferric Oxide	27.55	22.94	25.24	31.88	27.57	25.22	28.22	31.17
Phosphorus Pentoxide	0.88	0.91	0.89	0.93	0.89	0.78	0.86	0.92
Sulfur Trioxide	5.13	4.93	5.03	4.35	6.75	5.50	5.53	4.65
Phosphorus (% Dry Basis)	0.118	0.128	0.123	0.112	0.124	0.108	0.114	0.119
Slag Viscosity (T_{250} °F)	2270	2370	2320	2210	2260	2320	2263	2230
Slagging Index	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.
Fouling Index	Med.	Med.	Med.	High	Med.	Med.	Med.	High

TABLE 2

COMPOSITE DRILL CORE ANALYSES
FLOAT 1.80 SPECIFIC GRAVITY (DRY BASIS)
LAKHRA COAL PROJECT
Sind Province, Pakistan

Sample Analysis	Seam No. 5 W-A5	Seam No. 3 W-A3	Seam No. 2 W-A2	Seam No. 2 W-B2	Seam No. 2 W-C2	Seam No. 2 Arith. Average	Seam No. 1 W-A1	Seam No. 1 W-B1	Seam No. 1 W-C1	Seam No. 1 Arith. Average
				WEST AREA						
Cum. 1.80 Float Composite										
% Total Sample	72.14	78.69	80.32	77.23	53.94	70.50	87.77	83.45	64.78	78.67
Analysis:										
Ash (%)	17.58	16.86	20.69	18.69	20.72	20.03	24.33	22.22	24.13	23.56
Volatile Matter (%)	41.70	42.51	40.99	41.34	39.56	40.63	40.68	40.89	39.79	40.45
Fixed Carbon (%)	40.72	40.63	38.32	39.97	39.72	39.34	34.99	36.89	36.08	35.99
Sulfur (%)	6.53	5.24	7.03	5.99	6.28	6.43	7.42	8.07	6.80	7.43
Kcal/kg	5614	5689	5335	5598	5232	5388	5088	5141	5116	5065
Btu/lb.	10,108	10,243	9,605	10,079	9,420	9,701	9,160	9,256	9,210	9,118
Equ. Moisture (%)	29.48	26.30	30.30	24.85	27.85	27.66	25.44	24.24	28.27	25.98
Fusion Temperature of Ash (°F)										
Reducing:										
Initial	2057	2108	2003	2005	2016	2008	1990	1986	2007	1994
Softening	2072	2122	2026	2022	2051	2033	2014	1998	2030	2014
Hemp.	2085	2127	2036	2037	2098	2057	2048	2004	2049	2034
Final	2100	2163	2124	2119	2173	2139	2121	2038	2125	2095
Oxidizing:										
Initial	2382	2342	2431	2458	2535	2475	2493	2483	2392	2456
Softening	2410	2383	2474	2495	2552	2507	2512	2510	2434	2492
Hemp.	2438	2411	2490	2529	2571	2530	2532	2520	2453	2502
Final	2576	2521	2532	2735	2614	2627	2582	2565	2541	2563
Forms of Sulfur (%):										
Total Sulfur	6.35	5.24	7.03	5.99	6.28	6.43	7.42	8.07	6.80	7.43
Pyritic Sulfur	1.95	1.65	2.63	2.42	2.30	2.45	2.86	2.94	2.34	2.71
Sulfate Sulfur	0.39	0.31	0.49	0.32	0.90	0.57	0.51	0.63	0.50	0.55
Organic Sulfur	4.19	3.28	3.91	3.25	3.08	3.41	4.05	4.50	3.96	4.17
Ultimate Analysis of Coal (%)										
Ash	17.58	16.86	20.69	18.69	20.72	20.03	24.33	22.22	24.13	23.56
Hydrogen	3.83	3.93	3.75	4.04	3.71	3.83	3.69	3.75	3.77	3.74
Carbon	57.09	58.25	53.92	56.63	53.08	54.54	50.60	51.61	52.23	51.48
Nitrogen	1.22	1.15	1.01	1.14	1.05	1.07	0.98	0.95	1.06	1.00
Sulfur	6.53	5.24	7.03	5.99	6.28	6.43	7.42	8.07	6.80	7.43
Oxygen	13.75	14.57	13.60	13.51	15.16	14.09	12.98	13.40	12.01	12.80
Water Soluble Alkalies (%)										
Potassium Oxide	0.018	0.014	0.019	0.022	0.011	0.017	0.023	0.023	0.014	0.020
Sodium Oxide	0.321	0.289	0.273	0.279	0.122	0.223	0.245	0.260	0.169	0.225
Total	0.339	0.303	0.292	0.296	0.133	0.240	0.268	0.283	0.183	0.245
Mineral Analysis of Ash (% Ignited Basis):										
Silicon Dioxide	29.78	31.75	34.50	32.64	37.88	35.01	37.24	34.02	40.34	37.20
Aluminum Oxide	15.34	17.48	20.36	21.06	24.59	22.00	22.60	19.92	18.89	20.47
Titanium Dioxide	1.68	1.74	2.20	1.92	2.15	2.09	2.17	1.89	1.94	2.00
Calcium Oxide	7.00	5.91	3.24	3.12	1.88	2.75	2.93	2.38	3.23	2.85
Potassium Oxide	0.65	0.57	0.62	0.46	0.70	0.59	0.69	0.65	0.55	0.63
Magnesium Oxide	4.28	3.48	2.83	2.48	1.62	2.31	2.16	2.21	2.87	2.41
Sodium Oxide	1.69	1.40	1.10	1.24	1.00	1.11	0.96	1.02	0.75	0.91
Ferric Oxide	28.48	24.32	30.15	32.89	26.85	29.96	27.24	31.76	23.86	27.62
Phosphorus Pentoxide	0.57	0.57	0.64	0.62	0.56	0.61	0.84	0.81	0.49	0.71
Sulfur Trioxide	10.01	12.70	4.35	3.40	2.68	3.48	3.15	5.00	7.00	5.05
Phosphorus (% Dry Basis)	0.044	0.042	0.058	0.051	0.051	0.070	0.099	0.078	0.052	0.073
Slag Viscosity (T_{250}°F)	2160	2220	2210	2220	2310	2240	2280	2210	2300	2263
Slagging Index	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.	Sev.
Fouling Index	Sev.	High	High	High	Low	High	High	High	Med.	High

TABLE 2 - Continued

Sample Analysis	Seam No. 3 E-A3	Seam No. 2 E-A2	Seam No. 2 E-B2	Seam No. 2 E-C2	Arith. Average	Seam No. 1 E-A1	Seam No. 1 E-B1	Seam No. 1 E-C1	Arith. Average
			EAST AREA						
Cum. 1.80 Float Composite									
% Total Sample	87.74	69.52	83.15	78.16	76.94	78.69	86.54	78.59	41.27
Analysis:									
Ash (%)	29.25	17.90	17.04	31.39	22.11	17.37	21.91	26.09	21.79
Volatile Matter (%)	36.88	40.73	41.73	34.71	39.06	43.64	39.75	37.70	40.37
Fixed Carbon (%)	33.87	41.37	41.23	33.90	38.96	38.99	38.34	36.21	37.85
Sulfur (%)	5.10	5.19	5.87	5.72	5.60	5.65	5.94	6.43	6.01
Kcal/kg	4,777	5,766	5,735	4,606	5,369	5,771	5,498	4,900	5,390
Btu/lb.	8,601	10,381	10,325	8,293	9,666	10,389	9,899	8,821	9,703
Equ. Moisture (%)	24.71	23.55	20.50	22.97	22.34	16.55	25.24	25.97	22.59
Fusion Temperature of Ash (°F)									
Reducing:									
Initial	2308	2157	2100	2086	2114	2065	2086	2250	2134
Softening	2458	2177	2130	2114	2147	2115	2113	2298	2175
Hemp.	2480	2225	2170	2166	2187	2170	2166	2340	2225
Final	2512	2254	2210	2204	2223	2204	2204	2399	2269
Oxidizing:									
Initial	2501	2381	2309	2482	2391	2157	2302	2476	2312
Softening	2582	2390	2365	2512	2422	2230	2364	2497	2364
Hemp.	2625	2395	2430	2522	2449	2305	2441	2512	2419
Final	2654	2452	2545	2558	2518	2510	2518	2552	2527
Forms of Sulfur (%)									
Total Sulfur	5.19	5.19	5.87	5.72	5.60	5.65	5.94	6.43	6.01
Pyritic Sulfur	2.61	1.61	1.82	3.12	2.19	1.91	2.95	2.43	2.43
Sulfate Sulfur	0.32	0.20	0.30	0.59	0.37	0.29	0.21	0.55	0.35
Organic Sulfur	2.17	3.38	3.75	2.01	3.05	3.45	2.78	3.45	3.23
Ultimate Analysis of Coal (%)									
Ash	29.25	17.90	17.04	31.39	22.11	17.37	21.91	26.09	21.79
Hydrogen	3.95	4.48	4.43	4.78	4.57	4.52	4.30	4.02	4.28
Carbon	49.73	59.96	60.04	46.54	55.52	59.50	55.98	50.48	55.32
Nitrogen	0.90	1.04	1.07	0.85	0.99	0.97	0.89	0.88	0.92
Sulfur	5.10	5.19	5.87	5.72	5.60	5.65	5.94	6.43	6.01
Oxygen	11.07	11.43	11.64	10.72	11.27	11.99	10.98	12.10	11.69
Water Soluble Alkalies (%)									
Potassium Oxide	0.014	0.012	0.015	0.016	0.015	0.013	0.014	0.014	0.014
Sodium Oxide	0.286	0.282	0.279	0.283	0.282	0.151	0.276	0.286	0.238
Total	0.300	0.294	0.294	0.299	0.296	0.164	0.290	0.300	0.252
Mineral Analysis of Ash (% Ignited Basis):									
Silicon Dioxide	43.99	34.47	34.20	49.06	39.25	33.55	35.38	49.33	39.42
Aluminum Oxide	26.46	21.92	21.03	20.21	21.06	21.24	23.55	19.42	21.41
Titanium Dioxide	3.55	2.06	1.96	2.51	2.18	1.82	1.97	1.93	1.91
Calcium Oxide	1.86	7.26	3.33	2.20	4.27	4.38	4.49	1.91	3.60
Potassium Oxide	0.64	0.69	0.64	0.64	0.68	0.58	0.74	0.70	0.68
Magnesium Oxide	1.96	2.63	3.37	1.57	2.53	2.05	2.71	1.82	2.20
Sodium Oxide	1.09	1.68	1.42	0.85	1.32	1.02	1.37	0.99	1.13
Ferric Oxide	16.64	20.25	23.40	19.97	21.21	25.82	21.91	20.73	22.82
Phosphorus Pentoxide	0.56	0.48	0.59	0.61	0.56	0.68	0.57	0.55	0.60
Sulfur Trioxide	2.90	8.13	9.63	2.39	2.24	8.53	7.10	2.30	5.98
Phosphorus (% Dry Basis)	0.071	0.037	0.044	0.084	0.055	0.052	0.055	0.063	0.057
Slag Viscosity (T_{250}°F)	2540	2260	2270	2470	2333	2200	2300	2440	2330
Slagging Index	Med.	Sev.	Sev.	High	Sev.	Sev.	Sev.	High	Sev.
Fouling Index	Med.	High	High	Med.	High	High	High	Med.	High

TABLE 2 - Continued

Sample Analysis	Seam No. 3 C-A3	Seam No. 3 C-B3	Seam No. 3 Arith. Average	Seam No. 2 C-A2	Seam No. 2 C-B2	Seam No. 2 C-C2	Seam No. 2 Arith. Average	Seam No. 1 C-A1
			CENTRAL AREA					
Cum. 1.80 Float Composite % Total Sample	88.46	87.47	87.96	86.66	75.14	75.93	79.24	74.58
Analysis:								
Ash (%)	27.49	28.26	27.87	22.75	21.57	23.03	22.45	18.74
Volatile Matter (%)	37.61	37.53	37.57	39.89	40.93	41.33	40.73	42.89
Fixed Carbon (%)	34.90	34.21	34.55	37.36	37.44	35.64	36.81	38.37
Sulfur (%)	7.09	5.34	6.21	7.12	6.71	5.98	6.60	7.02
Kcal/kg	4,900	4,805	4,852	5,347	5,376	5,357	5,360	5,683
Btu/lb.	8,821	8,651	8,736	9,627	9,679	9,645	9,650	10,232
Equ. Moisture (%)	23.51	21.67	22.59	19.22	24.56	19.21	20.99	21.96
Fusion Temperature of Ash (°F)								
Reducing:								
Initial	2001	2057	2029	2008	2023	2125	2052	2026
Softening	2021	2058	2040	2035	2040	2160	2078	2040
Hemp.	2035	2106	2071	2065	2056	2192	2104	2082
Final	2100	2198	2149	2110	2150	2282	2181	2150
Oxidizing:								
Initial	2475	2495	2485	2434	2495	2560	2496	2434
Softening	2517	2513	2518	2472	2517	2570	2520	2460
Hemp.	2533	2534	2534	2510	2533	2588	2544	2490
Final	2560	2560	2560	2545	2560	2614	2573	2525
Forms of Sulfur (%)								
Total Sulfur	7.09	5.34	6.21	7.12	6.71	5.98	6.60	7.02
Pyritic Sulfur	3.00	2.32	2.66	2.80	2.45	1.92	2.39	2.36
Sulfate Sulfur	0.67	0.65	0.66	0.25	0.31	0.20	0.25	0.22
Organic Sulfur	3.64	2.37	3.00	4.07	3.95	3.86	3.96	4.44
Ultimate Analysis of Coal (%)								
Ash	27.49	28.26	27.87	22.75	21.57	23.03	22.45	18.74
Hydrogen	3.47	3.54	3.50	4.03	4.03	3.89	3.98	4.26
Carbon	50.57	49.29	49.93	52.82	53.92	53.71	53.48	56.08
Nitrogen	0.98	0.94	0.96	0.98	0.98	0.95	0.97	1.03
Sulfur	7.09	5.34	6.21	7.12	6.71	5.98	6.60	7.02
Oxygen	10.40	12.63	11.51	12.30	12.79	12.44	12.51	12.87
Water Soluble Alkalies (%)								
Potassium Oxide	0.016	0.018	0.017	0.014	0.015	0.014	0.014	0.013
Sodium Oxide	0.230	0.224	0.227	0.196	0.201	0.216	0.204	0.200
Total	0.246	0.242	0.244	0.210	0.216	0.230	0.218	0.213
Mineral Analysis of Ash (% Ignited Basis):								
Silicon Dioxide	38.19	43.99	41.09	38.13	33.74	39.04	36.97	36.46
Aluminum Oxide	19.49	20.58	20.03	18.17	20.57	25.66	21.46	22.27
Titanium Dioxide	2.60	2.34	2.47	1.79	1.77	2.16	1.90	1.80
Calcium Oxide	3.59	3.10	3.34	4.28	5.60	4.45	4.77	4.00
Potassium Oxide	0.70	0.76	0.73	0.68	0.50	0.81	0.66	0.76
Magnesium Oxide	1.39	1.30	1.34	1.55	1.95	1.71	1.73	1.89
Sodium Oxide	0.94	0.95	0.95	1.02	1.21	0.91	1.04	1.12
Ferric Oxide	27.63	21.61	24.62	27.14	26.46	20.37	24.65	26.62
Phosphorus Pentoxide	0.63	0.56	0.59	0.64	0.69	0.55	0.62	0.65
Sulfur Trioxide	4.68	4.15	4.41	6.13	6.80	3.65	5.52	4.13
Phosphorus (% Dry Basis)	0.076	0.069	0.072	0.064	0.065	0.055	0.061	0.053
Slag Viscosity (T_{250}°F)	2260	2400	2330	2250	2230	2370	2283	2260
Slagging Index	Sev.	High	Sev.	Sev.	Sev.	High	Sev.	Sev.
Fouling Index	High	Med.	Med.	High	High	Med.	High	High

TABLE 3
UNWASHED VERSUS WASHED LAKHRA COAL

	UNWASHED LAKHRA COAL		WASHED LAKHRA COAL	
	Mean	Range	Mean	Range
Dry Proximate:	%	%	%	%
Ash	36.00	26.17-41.87	23.00	16.86-31.39
VM	34.60	32.15-39.58	38.14	34.71-43.64
FC	29.40	23.68-35.82	38.86	33.87-41.37
Sulfur	7.35	6.02- 9.85	6.34	5.10- 8.07
Kcal/kg	4167	3366-4971	5300	4606-5771
Btu/lb	7500	6060-8950	9540	8293-10389
Eq. Moist	38.91	33.77-50.06	24.02	16.55-30.30
Fusion Temperature of Ash:				
Reducing Basis-	F	F	F	F
Initial	2094	2001-2443	2066	1986-2308
Softening	2124	2005-2453	2097	1998-2458
Hemisph.	2157	2012-2463	2126	2004-2480
Final	2263	2046-2508	2185	2038-2512
Oxydizing Basis-	F	F	F	F
Initial	2433	2254-2593	2431	2157-2560
Softening	2474	2302-2621	2466	2230-2582
Hemisph.	2503	2333-2631	2494	2305-2625
Final	2543	2395-2640	2562	2452-2735
Forms of Sulfur:	%	%	%	%
Total	7.35	6.02-9.85	6.34	5.10-8.07
Pyritic	3.95	2.89-5.51	2.42	1.61-3.12
Sulfate	0.57	0.31-1.56	0.43	0.20-0.90
Organic	2.83	1.43-3.86	3.49	2.01-4.50
Ultimate Analysis:				
H_2O	32.00	Dry	35.00	Dry
Ash	24.50	26.17-41.87	15.00	16.86-31.39
H_2	2.12	2.76- 3.66	2.57	3.47- 4.78
C	29.12	35.61-50.75	34.50	46.54-50.04
N_2	0.55	0.66- 1.08	0.64	0.85- 1.22
Sul	5.00	6.02- 9.85	4.30	5.10- 8.07
O_2	6.71	9.69-12.84	7.99	10.40-15.16
Water Soluble Alkalies:				
K_2O	0.018	0.011-0.024	0.016	0.011-0.023
Na_2O	0.253	0.092-0.344	0.240	0.122-0.321
Total	0.271	0.104-0.363	0.255	0.133-0.339
Mineral Analysis:				
SiO_2	39.60	32.34-47.68	37.65	29.78-49.33
Al_2O_3	20.17	12.12-26.30	21.03	15.84-26.46
TiO_2	2.02	1.33- 3.16	2.00	1.68- 3.55
CaO	3.70	2.11- 8.39	3.77	1.86- 7.26
K_2O	0.61	0.45- 0.76	0.66	0.46- 0.81
MgO	1.60	0.79- 2.64	2.24	1.30- 4.28
Na_2O	0.72	0.32- 1.02	1.12	0.75- 1.69
Fe_2O_3	24.64	17.02-33.60	25.00	16.64-32.89
P_2O_5	0.75	0.56- 0.93	0.61	0.48- 0.84
SO_3	5.63	2.20-10.55	5.39	2.24-12.70
Phosphorus-Dry	0.105	0.076-0.143	0.061	0.037-0.089
Slag Viscosity:			2296	2160-2540
Slagging Index:	Sev.	Sev.-Sev.	Sev.	Sev.-Sev.
Fouling Index:	Med.	Low-High	High	Med.-Sev.

TABLE 4

BASE TO ACID RATIO, FOULING AND SLAGGING INDICES

$$\frac{\text{Base}}{\text{Acid}} = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

B/A

Fouling Index = B/A times Na_2O
Slagging Index = B/A times Dry Sulfur

Fouling Index		Slagging Index	
0.2	Low	0.6	Low
0.2-0.5	Medium	0.6-2.0	Medium
0.5-1.0	High	2.0-2.6	High
1.0	Severe	2.6	Severe

NOTE: These indices are applicable to Eastern USA Bituminous Coals Only. These indices should be used for other coals for comparison purposes only.

STATUS OF FLUIDIZED-BED COMBUSTION FOR ELECTRIC UTILITIES

Shelton Ehrlich
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303

ABSTRACT

Fluidized-bed combustion is a technique wherein a fuel is burned in a bed of particles suspended by a flow of air. This technology is applied to steam generating boilers primarily fired with solid fuels. Fluidized-bed boilers are capable of better pollution control and lower capital cost than conventional boilers. There were over 160 industrial fluidized-bed boilers in operation in 1985 in the western nations. In addition, 6 major utility demonstration plants were in development, scheduled to be operating by 1990.

INTRODUCTION

Fluidized-bed combustion is an evolutionary development in boiler technology. The design feature that distinguishes fluidized-bed boilers from conventional boilers is that the fuel is burned in a bed of inert particles suspended in an upward flow of air. Two important features result from this design: 1) the bed can contain limestone and thus capture sulfurous gases before they escape the boiler, and 2) increased heat transfer rates due to the addition of conduction heat transfer from the bed particles to the boiler tubes in the bed and on the walls. Fluidized-bed boilers are primarily designed for the combustion of coal and waste fuels but liquid fuels can be utilized. These boilers may be operated at atmospheric pressure as are conventional boilers, or they may be run with pressurized air, exhausting the flue gas through an expansion turbine to produce useful work.

Figure 1 shows the essential features of a fluidized-bed boiler. The main feature is the bed, which is suspended by an upward flow of air that supplies the oxygen necessary for combustion. As the fuel burns, it heats the bed material which then transfers the energy to boiler tubes mounted in the bed and walls of the boiler.

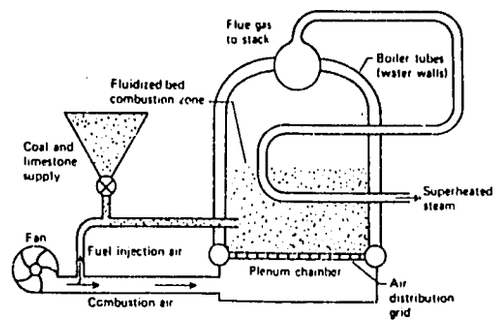

Figure 1. Schematic Drawing of a Fluidized-Bed Boiler.

Coal and sorbent material are fed to the bed through over-bed spreaders or under-bed pneumatic feed systems. The space above the bed, called the "freeboard", provides additional combustion volume. Convective heat exchangers are placed in the gas flow after the freeboard. The larger particles of fly ash carried out of the bed with the gases is captured by cyclones and returned to the bed.

There are several potential advantages of fluidized-bed boilers over conventional boilers, listed below:

(1) The capability of controlling sulfur emissions utilizing sorbent materials in the bed, thus eliminating the need for adding costly flue gas desulfurizing equipment after the boiler. To capture sulfur dioxide, limestone is fed with the coal.

(2) The limestone calcines to lime (CaO) which reacts with the sulfur dioxide to produce anhydrous gypsum ($CaSO_4$). The gypsum and unused lime are in dry, solid form and can be easily removed from the bed, whereas in common flue gas desulfurization plants the wastes are in the

TABLE 1

COMPARISON OF CONVENTIONAL BOILERS AND FLUIDIZED-BED BOILERS

Item	Conventional Boiler	Fluidized-Bed Boiler
Emission control	Coal cleaning prior to firing or flue gas desulfurization	Sorbent material in bed reduces SO_2 emissions
Fuels	Limited to high quality coals	Can burn any coal, lignite, or woodwaste
Heat transfer rate	50-100 W/m^2 - °K	> 315 W/m^2 - °K
Waste materials	Sludge of sulfur containing compounds	Primarily gypsum ($CaSO_4$)
Ash	Fouls superheater boiler tubes	Not a problem

form of a hydrated sludge. FBC solid wastes, a mixture of limestone-sulfur reaction products and coal-ash, are being evaluated for use as construction materials.

(3) The rate of heat transfer to the boiler tubes is greater than in conventional boilers, thus a lower total heat transfer surface area is required, reducing the cost.

(4) Fluidized beds operate at much lower combustion temperatures than conventional boilers and thus the problem of slagging, which results from the resolidification of molten ash on the furnace walls, is reduced. Fluidized-bed boilers also experience less fouling than do pulverized coal boilers. Fouling is caused by ash sublimation followed by recondensation on boiler convection tubes. Ash does not sublime at the operating temperature of fluidized-bed boilers.

(5) Fluidized beds can burn lower-quality fuels such as lignite, peat and woodwaste due to the lower temperatures used as well as the fact that the fuels do not need to be pulverized. Tables A-1 and A-2 in the Appendix list the properties of low-grade fuels that have been tested or are actually being used.

These advantages are listed on Table 1.

Distinctions are made between fluidized-bed combustors based chiefly on two fundamental characteristics: 1) the combustor gas pressure and 2) the ratio of the operating velocity, U to the particle terminal velocity U_t. The gas pressure can be either atmospheric or an elevated pressure which characterizes the boiler as an atmospheric fluidized bed or a pressurized fluidized bed. The operating-to-terminal velocity ratio characterizes the combustors as bubbling ($U/U_t < 1$) or circulating bed ($U/U_t > 1$).

Atmospheric fluidized-bed combustors (AFBC) perform the same function as conventional boilers, i.e., to raise steam for an application or to generate electric power via a steam turbine. If a pressurized fluidized-bed combustor (PFBC) is used, in addition to the generation of steam, the high-pressure flue gases can be expanded in a turbine to produce useful work. If the gas turbine in this concept produces electricity, the system is termed a combined cycle. If the gases are cooled, by raising additional steam so that no excess power, over that needed to drive the compressor, is available, the system is termed a turbocharged boiler.

In bubbling-bed boilers, particles of greater than 500 micron diameter are used, and fluidization velocities are less than 4 m/s. The particles that are entrained in the gas flow leaving the bed can be recycled to improve performance but generally at ratios of recycle-to-fresh coal of less

TABLE 2
FLUIDIZATION REGIMES

			Bubbling	Circulating
Combustion Pressure (atm)	1 (AFBC)	Particle Size	500 μm	500 μm
		Fluidizing Velocity	4 m/s	4 m/s
		Recycle Rate	0 - 4	100
	10-20 (PFBC)	Particle Size	1000 μm	500 μm
		Fluidizing Velocity	1 - 3 m/s	4 m/s
		Recycle Rate	0 - 4	100

than 5 to 1. In circulating fluidized-bed boilers (CFB) particle sizes are generally below 500 microns, and fluidization velocities are greater than 4 m/s so that terminal particle velocities are exceeded. These combustors utilize a very high recycle ratio (more than 20 to 1). Table 2 summarizes the fluidization regimes discussed above. Currently (1985) there are over 160 industrial fluidized-bed boilers in service in the Western nations and many more in China. There is also one major pilot-plant boiler operating for a utility, and there are six utility-scale demonstration plant installations in development that will be operational by 1990.

HISTORY OF DEVELOPMENT OF THE FLUIDIZED-BED COMBUSTOR

Evolution of the Fluidized-Bed Concept

In the 1920s Fritz Winkler developed the Winkler gas generator in Germany beginning the implementation of fluidized-bed combustion technology. Winkler was able to use small fuel particles, less than 10 mm in diameter, which had previously been discarded because they were not suitable for fixed-bed gasifiers.

Also in the 1920s W. W. Odell developed a catalytic cracker in the U.S., based on fluidizing a bed of particles. Concurrently, engineers from the M. W. Kellogg and Standard Oil Development Company (now Exxon Research and Engineering) began a project to develop a similar fluidized-bed cat cracker. Standard Oil eventually bought the rights to Odell's patent.

In 1950 Albert Godel of France developed a combined gasifier/boiler based on the fluidized-bed concept. This boiler was commercialized in 1955; manufactured by Babcock Atlantique, it is known as the Ignifluid Boiler.

Douglas Elliot of the Marchwood Laboratories of the Central Electricity Generating Board of the U.K. embarked on his own development effort in 1961 as a means of improving heat transfer, fuel flexibility and the reliability of utility-scale boilers. Elliot is credited with initiating the most recent and successful era of fluidized-bed boiler development.

In 1962, John Bishop, an employee of a small U.S. engineering company, started the U.S. effort on fluidized-bed boilers. In less than a year he had an actual AFBC boiler running successfully; t first unit based on Elliot's principals.

Over the period of time from 1958 to 1970 Babcock Atlantique sold 22 Ignifluid Boilers. Since 1970 these boilers have been marketed by Fives-Cail Babcock, who have sold 10 of the Ignifluid Boilers to date.

Another manufacturer of industrial-sized boilers is Babcock Power Ltd. of the U.K. (BPL). (The Babcock companies in different countries operate independently.) They retrofitted a boiler producing 13.5 MW (th), at Renfrew, Scotland. Foster Wheeler Corporation, using the concepts developed by John Bishop and his team, installed the first U.S. commercial boiler in 1979 at Georgetown University in Washington, D.C. The boiler produces 45,000 kg/h of steam and has operated for over 20,000 hours burning medium-sulfur coal with low emissions. Initially, severe problems were encountered with erosion and the in-bed tubes had to be replaced after only around 4,000 hours of operation.

A similar boiler was installed at the Midwest Solvents Company and initiated operation in August 1984. It has run trouble-free since that time.

Recent Development

Over the last 10 years in the United States, the Electric Power Research Institute (EPRI), the Department of Energy (DOE), and the Tennessee Valley Authority (TVA) have supported fluidized-bed development programs. Outside of the U.S., the International Energy Agency and individual government agencies have supported research in the U.K., Japan, West Germany and elsewhere. The EPRI program led to the construction of a 2 MW (th) experimental fluidized bed at the Babcock & Wilcox test station at Alliance, Ohio. The successful testing at the 2 MW (th) scale provided useful data for the design of a 20 MW electric output equivalent [20 MW (e)] pilot plant that was built and operated by TVA starting in May 1982.

The first utility-sponsored fluidized-bed boiler was retrofitted to a small Northern States Power boiler at French Island, Wisconsin. This unit, initially built in 1948 as a stoker-fired coal-burning boiler and later converted to oil-fired operation now burns waste wood in a bed of inert particles.

In the United States, three utilities are constructing fluidized-bed plants. The first to go on line will be Northern States Power's Black Dog unit near Minneapolis, Minnesota. This is a 125 MW (e) plant using a bubbling-bed design and is planned to start in 1986. The second commercial plant will be a circulating-bed AFBC at Colorado-Ute Electric Association's Nucla power plant. The size of this unit is 110 MW (e) and it will start in 1987. Finally, the Tennessee Valley Authority is constructing a 160 MW (e) plant at Paducah, Kentucky which will start operating in 1988. These units are described in detail later.

Lurgi, in Germany, pioneered the development of circulating bed boilers. The city of Duisberg, West Germany has installed a Lurgi-designed fluidized-bed boiler plant for a cogeneration system to develop 140 MW (th) of district heat and up to 98.5 MW of electric power. Ahlstrom of Finland has sold a number of waste-fuel burning circulating AFBCs.

In Japan, the Electric Power Development Corporation is constructing a bubbling-bed system to generate 40 MW of power. The scheduled start date is April 1987.

AFBC DEMONSTRATION PROJECTS

Utilizing the experience gained from the TVA/EPRI 20 MW (e) pilot plant, EPRI with a number of electric utilities began a program to demonstrate AFBC technology by building and operating three utility-size units (110 to 160 MW (e)):

(1) The new 160 MW (e) boiler will be built at TVA's Shawnee steam plant near Paducah, Kentucky. The bubbling bed boiler will use underbed coal feed and will provide steam to the existing turbine/balance-of-plant of Unit #10.

(2) The conversion of an existing 100 MW (e) pulverized coal unit (Black Dog #2) to a 125 MW (e) fluidized bed is underway by Northern States Power Co. This unit utilizes underbed feed.

(3) Colorado-Ute Electric Association chose a 110 MW (e) circulating AFB boiler for repowering its Nucla generation station.

The differing types of applications, scopes of supply, time frames, fuel fired and locations (see Tables 3 and 4) make the three demonstration projects complementary in terms of data they will provide to the U.S. electric utility industry and, because much data will be published, to the world. Upon completion of these projects, the following features will have been demonstrated:

- o Operability of the specific designs.
- o Reliability of critical power plant components.
- o Unique features of AFBC technology such as emission control, fuel flexibility, good combustion efficiency, etc.
- o Economics of AFBC technology.

TVA'S 160 MW Project

TVA, in cooperation with EPRI, the State of Kentucky, Duke Power, Combustion Engineering and others, is designing a bubbling bed boiler to replace Unit #10 of its Shawnee power station. The boiler will be nominally rated at 160 MW (e) and it will utilize the existing steam turbine and the balance-of-plant of Unit #10. Completion of construction of the $220-million project (cost includes a test and evaluation program) is expected in 1988.

Unit Description. The boiler (See Figure 2) will be a balanced-draft, bubbling bed type and it will provide steam at 126 kg/cm /540 °C to the existing high-pressure turbine and 32 kg/cm /540 °C reheat steam to the low-pressure turbine from burning high-sulfur bituminous coal (Kentucky #9). The furnace of the unit is divided into six firing zones that can be fired independently to accomplish good boiler turndown.

Superheater surface is installed in both the bed and the convection pass, while all reheat and economizer surface is in the convection pass.

A regenerative air heater is used that reduces the flue gas temperature to 132 °C. Further flexibility will exist for reducing the gas temperature to 110 C. Two cyclones are located upstream of the air heater to separate the unburned carbon and elutriated bed material/limestone and to recycle it to the furnace. Recycling of these solids improves combustion efficiency and limestone utilization considerably. Gas from the top of the cyclone passes through the fabric bag filter to the stack.

Boiler efficiency is guaranteed to be 87.5% at the maximum continuous rating with calcium to sulfur molar ratio of 2.3.

The coal/limestone feed system is designed by Combustion Engineering Inc. (see Figure 3). This system uses a crusher/dryer to prepare the coal to: 1/4-in x 0 and less than 6% moisture. Limestone and coal are fed from their respective silos through a system of gravimetric feeders/charging hoppers to twelve (12) fuel distributors, so-called bottles. Each bottle is a fluidized feeder with a central inlet and ten 2 1/2-in diameter outlet fuel lines arranged concentrically around the inlet. Fuel transport blowers pressurize the bottles to between 0.25 and 0.28 kg/cm , enough to transport the coal/sorbent mixture to the furnace. Each firing zone is fed by two bottles.

This particular feed system was tested at the 20 MW (e) pilot plant and demonstrated satisfactory performance. An overbed limestone feed system will also be tested at the 160 MW scale to further simplify the auxiliary system design for future units.

Schedule. Currently, a number of studies are under way along with testing at the 20 MW (e) pilot plant to finalize the design of key components of the boiler, such as:

- o Overfire air system.
- o Coal feed system (further simplification).
- o In-bed bundle design (to improve load following characteristics).
- o Recycle system (to improve reliability)

Major milestones for the project are identified in Table 4.

Following startup, a 4-year test program is planned consisting of shakedown, parametric testing, and an extended commercial demonstration run. A 6-year commercial operation will follow resulting in a total of 10 years of data acquisition.

TABLE 3

COMPARISON OF BASE FUEL ANALYSES FOR AFBC DEMONSTRATIONS

	TVA (WESTERN KENTUCKY)	NSP (MONTANA)	COLORADO-UTE (COLORADO)
Carbon, %	53.8	49.7	55.17
Hydrogen, %	3.7	3.2	3.63
Oxygen, %	5.3	10.7	7.51
Nitrogen, %	1.1	.7	.98
Sulfur, %	4.4	.9	.73
Moisture, %	12.8	23.9	5.06
Ash, %	19.2	10.8	26.08
HHV, Btu/Lb.	10,300	8,500	9,693

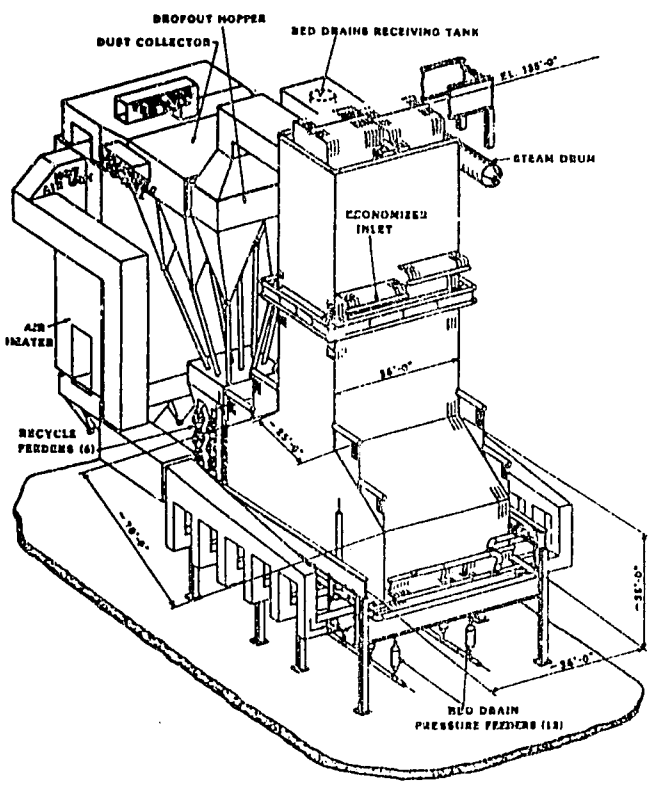

Figure 2. The TVA 160 MW Demonstration Plant.

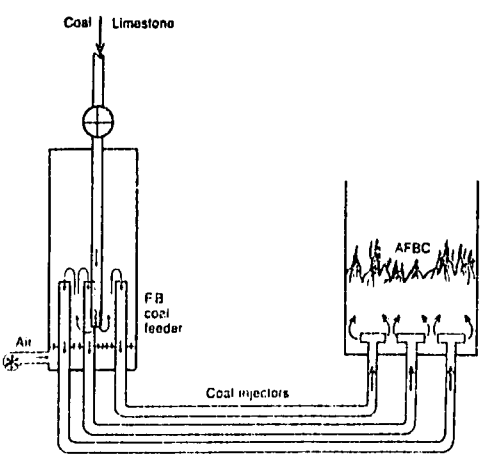

Figure 3. The Underbed Feed System for the TVA 160 MW Plant.

TABLE 4
TVA SCHEDULE MILESTONES

Activity	Date
Complete Integrated Project Construction Schedule	4/15/85
Complete Conceptual Design	6/01/85
Submit Air Permit Application	8/01/85
Begin Site Preparation	9/01/85
Detailed Integrated Construction Schedule	9/01/85
Technical Readiness (Release Boiler for Fabrication)	11/01/85
Start Construction	4/01/86
First Fire and Begin Test Plan	2/01/88
Steam to Turbine	4/01/88
Begin Commercial Demonstration	2/01/90
Begin Commercial Operation	2/01/92

Northern States Power AFBC Conversion/Upgrade

After Northern States Power (NSP) converted a 15 MW (e) unit (French Island #2) to AFBC boiler firing waste wood, a study was initiated in 1982, to investigate the possibility of upgrading and extending the life of a larger unit. As a result of this study, which was partially funded by EPRI, Black Dog Unit #2 was selected for fluidized-bed retrofit and life extension. Although the unit was originally designed for 100 MW (e), capacity was reduced to 85 MW (e) to meet environmental standards firing a blend of low-sulfur western subbituminous and eastern bituminous coal.

NSP selected to:

- o extend the operating life of the unit by 25 years,
- o convert the unit to a bubbling bed boiler firing western coal (Sarpy Creek coal), and
- o increase the present capacity of the unit from 85 MW (e) to 125 MW (e) by upgrading the steam turbine.

Unit Description. Black Dog Unit #2 was built by Foster Wheeler in 1954 with a maximum working pressure of 125.4 kg/cm at 390,000 kg/hr steam flow and final steam temperature of 540°C. The unit was designed to fire pulverized coal, oil or natural gas with burners located in the front wall. Ball mill pulverizers with an exhauster fan arrangement were utilized. The plant originally contained a single electrostatic precipitator. As a result of switching to a blend of eastern high-sulfur and low-sulfur western coal, a second electrostatic precipitator was installed to control particulate emissions to required levels. The same precipitators will be utilized after the conversion to bubbling bed boiler.

The Black Dog #2 retrofit (See Figure 4) is designed to generate 471,290 kg/hr firing Sarpy Creek sub-bituminous coal with provisions to fire higher-sulfur bituminous coals, lignites, petroleum coke, and a mixture of coal/RDF as alternate fuels. This kind of fuel flexibility, typical for fluidized-bed systems, will permit the fuel procurement personnel of the utility to take advantage of the lowest fuel prices.

The bottom half of the existing furnace is replaced by three fluidized-bed cells totally enclosed by waterwall construction and supported by water-cooled air distributor floor. The center bed contains basically steam generating tubes. Each of the two beds located in the "wing cells" contains both steam generating and superheating surfaces; 50% load can be achieved by firing only the center bed. As load is further increased the "wing cells" are brought into service. Five to one boiler turndown can be achieved with this arrangement.

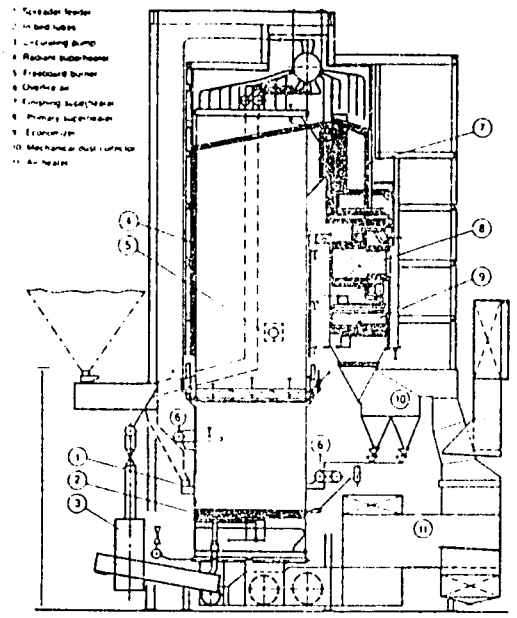

Figure 4. The Black Dog #2 Unit After AFBC Retrofit.

The unit will be operated in a cycling mode (two shifts per day operation, with weekend shutdowns). The existing steam turbine/ generator will be changed to variable pressure operation along with upgrading to 125 MW (e).

Project Schedule. The boiler contract for retrofit of the steam generator and auxiliary systems to AFBC operation was awarded to Foster Wheeler Energy Corporation by Stone and Webster Engineering Corporation as NSP's agent in May 1984. Northern States Power Company performed the demolition work, which was initiated in September 1984 and completed in January 1985. Stone and Webster is providing procurement and detailed engineering design services for the project. Erection of the new components for the steam generator retrofit began in April 1985 with completion of all work expected by June 1986. Following initiation of operation a shakedown and initial operation period of approximately 6 months will be carried out. This will be followed by a 3-year test and operation program during which the unit performance and operating characteristics will be monitored by EPRI, ESEERCO and Consolidated Edison Company of New York.

Colorado-Ute CFB Project

Colorado-Ute is installing the first utility-scale, circulating fluidized-bed steam generator in the U.S. at its 25-year-old Nucla generating station.

This is part of a major life-extension and upgrading of plant output project, which includes:

- a new 110 MW (e) circulating fluidized-bed boiler that replaces three stoker-fired boilers (12 MW (e) each),
- a new 75 MW steam turbine, and
- life extension work on the balance-of-plant.

These changes will result in:

- improved station heat rate by 15%,
- increase of plant capacity from 36 MW (e) to 110 MW (e) for an investment of approximately $840/kW,
- reduction in fuel cost by 30%, and
- emission reduction.

Participants in the $90 million project that share some of the financial risks with the utility are: Pyropower Corp. (boiler vendor), Stearns-Catalytic Corp., Peabody Coal Corp., Westinghouse Electric Corp. (turbine/generator manufacturer), and the Electric Power Research Institute (test program).

Unit Description. The new steam generator (See Figure 5) will provide 419,580 kg/hr of steam at 106 kg/cm /540°C. It consists of two independent combustion chambers, each one with its own fuel and air supply, ash removal system, and structural support.

Refractory-lined cyclone separators are provided downstream of the furnace. Mixing of the gas occurs downstream of the two cyclones.

Solids, including unburned carbon and unused limestone return to the combustion chamber via a non-mechanical loop seal located at the bottom of the cyclones. Flue gas flows through the convective heat transfer sections, tubular air heater and fabric filters to the stack. The existing fabric filters will be utilized along with some new modules.

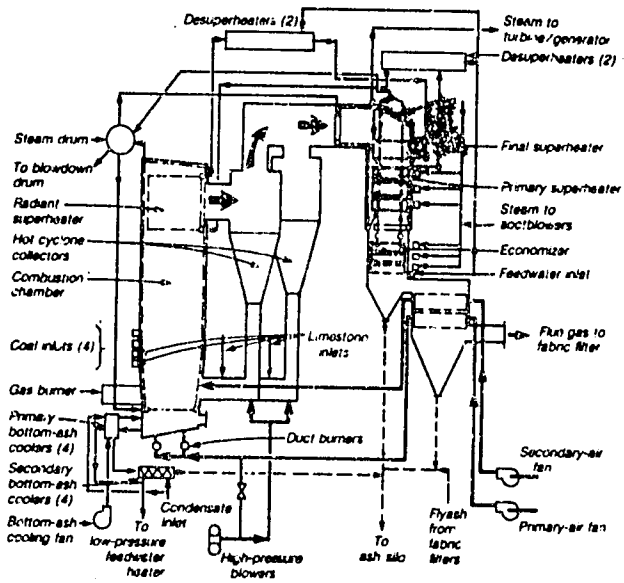

Figure 5. The Colorado-Ute CFB Boiler.

Project Status/Schedule: Awards have been made for most of the plant components, such as, boiler, steam turbine, feedwater pumps, and other balance-of-plant components. Project activities are proceeding on schedule. Project milestones are given in Table 5.

TABLE 5
COLORADO-UTE SCHEDULE MILESTONES

Activity	Date
Start Construction	6/08/85
Raise Drum	12/15/85
Start Turbine Installation	9/01/86
Hydro Test	12/15/86
Steam to Turbine	4/15/87
Begin Commercial Demonstration	8/15/87
Begin Commercial Operation	8/15/89

Following startup a comprehensive test program will be carried out by EPRI and Colorado-Ute to:

- o Provide performance data for the primary design fuel.
- o Demonstrate fuel flexibility of the unit.
- o Provide reliability data for the critical components of the system.
- o Address scale-up uncertainties, such as horsepower requirements, process performance, startup and transient operation.

AFBC Technology Transfer

The complementary nature of the three demonstration projects and EPRI's participation in them will assure that the utility industry will get the data and tools required to assess AFBC technology and compare it to other power generating options.

During the generation expansion planning phase, the required technology related data will be provided to compare AFBC to competing technologies (pulverized coal, combined cycles, hydroelectric, nuclear, etc.).

After AFBC has been selected as the future power generating option, the tools and data provided to the utilities will assist them in evaluating different design configurations considering capital costs, unit performance, reliability and operating/maintenance costs.

EPRI is planning to deliver to the utilities the following data bases and computer codes:

Data Bases:

- o Cost data base by subsystem as a function of critical design parameters.
- o Fuels characteristics data base.
- o Reliability data base.

Computer Codes:

- o AFB TREE (Cost Model) for evaluating different design configurations.
- o FBC BAL (Performance Model) for generating heat and material balances given the fuel combustion properties. FBC BAL will also enable performance assessment of a given boiler design firing a variety of fuels.
- o The Modular Modeling System (MMS) will be used for dynamic modeling of the plant to:
  - assist in the design of the control system.
  - study basic transient conditions
  - train plant operators.

TECHNOLOGY DEVELOPMENT ISSUES

Although industrial-scale steam users have accepted the concept of fluidized-bed combustion, the more conservative electric utility industry still must be convinced of the viability of this technology at the vastly larger scale of utility boilers. Several important differences between industrial-scale boilers and utility-scale boilers make the choice for utilities more difficult.

The most obvious difference is size. Industrial boilers can be as small as 1 or 2 MW whereas utility boilers range up to 500 MW in size or even greater. The early problems with the ambitious Rivesville power plant in the U.S. made the utility industry justifiably nervous. The step from the bench-scale combustor to the full-scale unit is a big one. However, successful testing with the 2 MW and 20 MW boilers has shown that combustion efficiency, sulfur retention, and NO_x emission all improve with scale. The next step to the size of the demonstration plant boilers 3 will be a significant test of the scaling laws that have been developed.

Related to scaling is reliability. Utilities need boilers with high reliabilities in order to run their plants economically. Potential problems exist in the coal feed system and in boiler tube erosion. Plugging caused by moisture in the coal supply and erosion of feed system components have been experienced in the under-bed feed system at the TVA 20 MW plant. Redesign of the plant to include wear resistant materials and lower transport velocities has improved the reliability considerably. Data from many industrial boilers shows that availability is typically greater than 90% (availability is the ratio of the time the boiler could have operated (had it been called for) to calendar time.

All boilers must be designed to operate at a reduced load. In some cases, especially for utilities, the load may fall to as low as 25% of the design load for the boiler (or even lower in the middle of the night). With pulverized-coal boilers, this is accomplished by turning off one (or more) of the many burners in the boiler. With fluidized-bed boilers, a choice has to be made to use either velocity turn down or bed slumping. The latter is similar to turning off a burner in the pulverized-coal system, but more research has to be done to determine definitively which (if either) method is better.

One of the early promises about fluidized-bed boilers was that the total heat transfer surface area would be significantly less than that in pulverized-coal boilers, due to the high heat transfer rates available to the in-bed boiler tubes. Some reduction has been achieved but not as much as expected 15 years ago.

Another development issue has to do with the reduction of the Ca/S molar ratio. The theoretical ratio is 1 but a typical operating ratio is closer to 2. High Ca/S ratios mean more limestone or dolomite in the bed which increases raw material and waste disposal costs.

Primarily due to the problems associated with a hot, solids-laden gas, the development of a true combined-cycle pressurized fluidized-bed combustor is expected to lag that of the atmospheric pressure fluidized beds. A method of cleaning the particles that are entrained in the gas flow out of the bed must be chosen from the several alternatives that are shown in Table 6. In addition, the required degree of cleanliness must be determined, based on expected turbine design and operation. The major alternatives are to use current turbine designs requiring a high degree of gas cleaning or to redesign the turbine so that some particles can be admitted without causing excessive turbine blade damage or efficiency loss. Other cycle-related design issues include the operating pressure, feed system design, and unit size. Table 6 outlines the development issues that are considered to be the most important. Commercial scale development will probably occur in the mid-1990s.

CONCLUSIONS

Atmospheric fluidized-bed technology has reached a significant stage of development with the three utility-scale demonstration projects (Tennessee Valley Authority, Northern States Power and Colorado-Ute). Although each project is different, reflecting the needs of each utility, the overall objective is to broaden the industry's knowledge base on AFBC technology and validate the design

TABLE 6
TECHNICAL ISSUES FOR COMBINED-CYCLE FLUIDIZED-BED COMBUSTORS

Issue	Alternative Approaches
1. Feeding coal across pressure barrier	Slurry pump Lock hoppers Dry solids pump
2. Hot-gas cleanup	Cyclones in series Electrostatic precipitators Ceramic fabric filter Electrostatic granular filter Rigid ceramic filter
3. Pressure ratio	As low as 6:1 As high as 30:1
4. Gas turbine development	None; operate existing turbines Modify blade paths and materials Optimize a new design for maximum efficiency
5. Turbine gas erosion	Use "dirty gas" in turbine Clean gas to <10 ppm of 4 micron diameter particles
6. Turbine corrosion	Clad blades Feed alkali "getter"

correlations need to scale up to 500 MW (e) size.

Successful completion of these demonstration projects will confirm that AFBC is a viable power generating alternative, and it will provide technical, economic and environmental data for assessing AFBC and comparing it to other competing technologies.

APPENDIX

EQUATIONS USED IN THE DESIGN OF FLUIDIZED-BED COMBUSTORS

Fluidization

In a fluidized-bed combustor, the bed consists of coal, lime- tone, and ash particles supported by the upward flow of gas. At start-up the particles lie on an air distributor through which the combustion air flows. The bed offers a resistance to gas flow and thus there is a pressure drop across the bed and as the gas flow increases the pressure drop also increases (Figure A-1). At the point where the drag force on each particle is equal to the gravitational force, the fluid-particle system begins to behave as a viscous fluid.

This point is known as the point of minimum fluidization and the pressure drop across the bed will be approximately equal to the weight of the bed,

$$\Delta P_b A_b = \frac{g m_b}{\rho_p} (\rho_p - \rho_g) \qquad (1)$$

where in this equation, ρ_p is the effective density of the particles; ΔP_b is the pressure drop across the bed, A_b the bed area, m_b the mass of the bed, ρ_g the gas density and g is the standard acceleration of gravity (9.807 m/s). The hump in the curve of Figure A-1 is due to the extra force required to overcome residual interlocking of particles.

The bed pressure drop is used to estimate the height of the fluidized bed (see Figure A-2). If the total pressure drop across the bed is measured and the pressure drop, ΔP_1, for a calibrated height. H_1, is also measured, the bed height, ΔH_b can be determined as,

$$H_b = \frac{\Delta P_b}{\Delta P_1} \cdot H_1 \qquad (2)$$

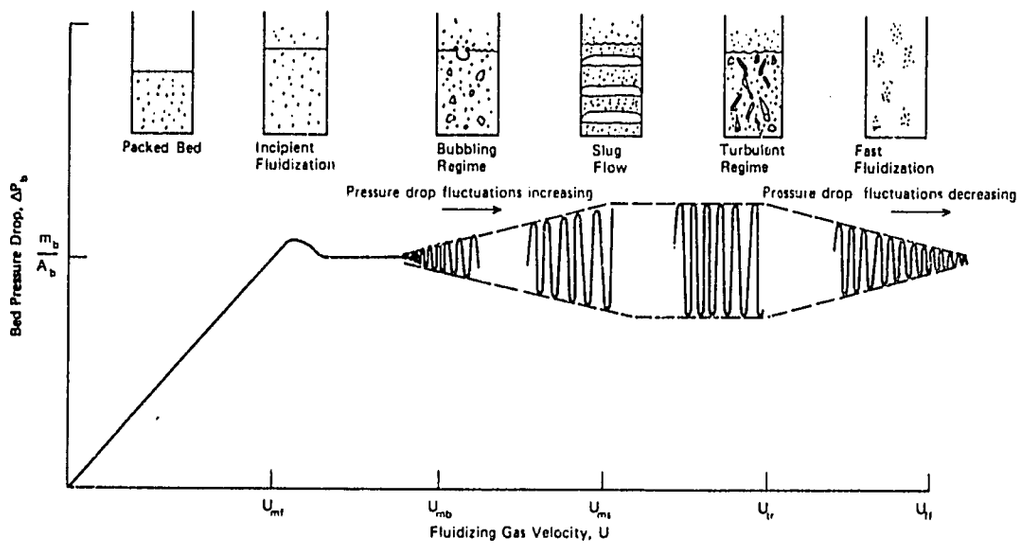

Figure A-1. Various Regimes of Fluidized-bed Operation.

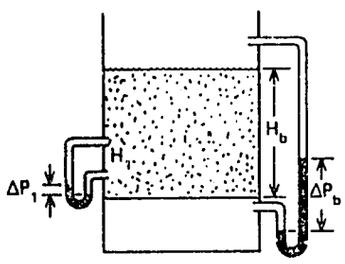

Figure A-2. Pressure Measurements to Determine Bed Height.

A classification scheme first developed by Geldart is commonly used to describe the fluidized behavior of various bed materials. Geldart's scheme, based on the particle diameter, density and adhesive properties, divides particles into the four different groups shown in Figure A-3. The bed material is sorted by size using sieves to determine a mean particle diameter, d_p,

$$d_p = \frac{1}{\sum_i \frac{x_i}{d_i}}, \qquad (3)$$

where x_i is the mass fraction of particles passing through a sieve opening of diameter d_i.

Several correlations have been used to determine the value of the minimum fluidization velocity, however the most popular method determines the velocity for the flow that produces a drag force equal to the weight of the bed.

The equation used is known as Ergun's correlation and is of the form,

$$Ar = 150 \frac{1 - \varepsilon_{mf}}{\phi^2 \varepsilon^3_{mf}} Re_{mf} + \frac{1.75}{\phi \varepsilon^3_{mf}} Re^2_{mf} \qquad (4)$$

where

$$Ar = \text{Archimedes number} = \frac{\rho_g(\rho_p - \rho_g) g d_p^3}{\mu_g^2}$$

and Re_{mf} = Reynolds number at minimum

$$\text{fluidizing velocity} = \frac{\rho_g d_p U_{mf}}{\mu_g}.$$

In this correlation, U_{mf} and ε_{mf} are velocity and the voidage of the bed at the point of incipient fluidization, ϕ is a shape factor that accounts for the non-spherical shape of the particles and μ_g is the gas viscosity. Typically the voidage is between 0.4 and 0.6 and the shape factor is close to 1.

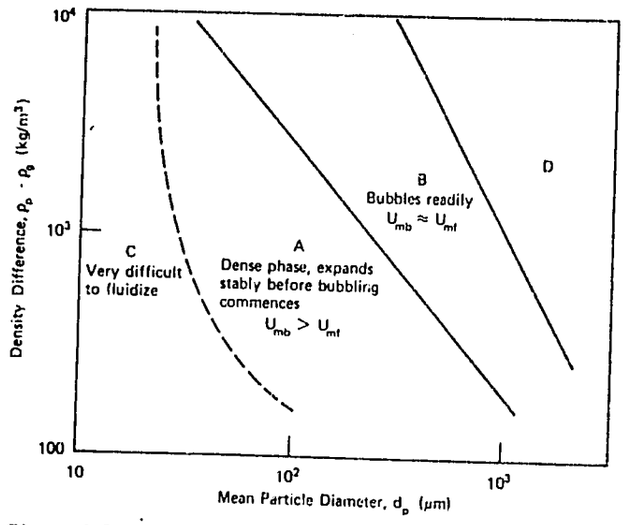

Figure A-3. Particle Classifications According to Geldart

In order to avoid the problem of averaging out shape and voidage factors, Ergun's correlation can be rearranged to solve for the Reynolds' number,

$$Re_{mf} = (C_1^2 + C_2 Ar)^{1/2} - C_1 \quad , \qquad (5)$$

where C_1 and C_2 are empirically determined constants.

Common values of ϕ and ϵ_{mf} are 0.82 and 0.42 respectively which yield a C_1 of 30.3 and C_2 of 0.035.

Typically, for a given bed material, the bed voidage can be measured by using the bed height both when at rest (packed state) and at fluidization,

$$\epsilon_{mf} = 1 - \frac{H_o}{H_{mf}} (1 - \epsilon_o) \qquad (6)$$

where $\epsilon_o = \frac{\rho_{bulk}}{\rho_{solids}}$

In Equation 6, H_{mf} is the bed height at the point of minimum fluidization, H_o is the height when there is no flow, ρ_{bulk} is the loosely packed bulk density while ρ_{solids} is the density of the particles. By measuring the flow velocity and other bed parameters, Equation 4 can be used to estimate an average particle shape factor.

As the gas velocity is increased beyond minimum fluidization, instabilities occur and packets of gas form, rising through the bed material as bubbles of gas rise through a liquid. Since the particles are carried in the wake of a bubble, this bubbling causes circulation of the particles, the primary mechanism for the efficient heat transfer of fluidized beds. Bubbles also provide a bypass path for gas which reduces the amount of oxygen available for combustion in the bed.

For the Group A materials, the minimum bubbling velocity, U_{mb}, can be predicted by

$$U_{mb} = 33\ d_p \left(\frac{\rho_g}{\mu_g}\right)^{0.1} \qquad (7)$$

A similar equation holds for the Group B materials, but it is somewhat more complex.

As they burst, splashing particles into the freeboard, the smaller particles are swept away with the gas and lost from the bed but the larger particles return. The loss of fine particles is termed elutriation by designers and must be controlled in order to ensure proper combustion and sulfur capture.

If the gas velocity is further increased, pressure-drop fluctuations become more violent. With deep and narrow beds the bubbles may grow until they are as large as the bed cross-section and particles move upward as a slug until the bubble collapses. Stewart and Davidson have determined the velocity of slugging, U_{ms}, to be

$$U_{ms} = U_{mf} + 0.07 \sqrt{gD_b} \quad , \qquad (8)$$

where D_b is the bed diameter (in meters).

As the velocity is further increased the bed moves from the slugging regime to a turbulent regime. As shown on Figure A-1, the pressure drop fluctuations decrease significantly. The onset of the turbulent bed occurs at an operating gas velocity to terminal particle velocity ratio (U/U_t) of approximately one-half.

With a further increase in gas velocity the bed enters the "fast fluidization" regime used in circulating fluidized-bed boilers. This is characterized by the rapid removal of solids from the top of the furnace as well as clustering or stranding of particles that then move downward through the furnace.

Heat Transfer

The primary heat transfer mechanisms in the fluidized-bed boiler are conduction for the bed-to-surface heat transfer, radiation for the upper freeboard region and convection in the convective pass zone. This is in contrast to pulverized coal boilers where radiation is the main method of heat transfer in the furnace.

The fluidized-bed boiler designer is interested in the total heat transfer area of the boiler tubes needed. The basic equation that is used to size the heat transfer area is the following,

$$\dot{Q} = U_o A \quad \Delta T_{LM} \quad . \tag{9}$$

In Equation 9 the area, A, referred to is the total surface area of the tubes, and ΔT_{LM} is the log mean temperature difference for a crossflow heat exchanger. The overall heat transfer coefficient, U_o, is determined by combining the heat transfer coefficients inside and outside the boiler tube as well as the conduction through the tube. Since the internal heat transfer coefficient and the tube wall conduction are very high, the heat transfer is normally limited by the heat transfer on the bed-side of the boiler tubes. The exterior heat transfer coefficient, h, will be set by the values of several operating parameters, such as particle diameter, superficial gas velocity, bed material, and bed temperature.

Bed Heat Transfer

The particles in the bed have a volumetric heat capacity that is roughly 1000 times greater than that of the gas that surrounds them. The bed particles exchange energy with the gas flowing through the bed by convection and by conduction. The bubbling action of the bed circulates the particles and thus the bed stays at a uniform temperature. Packets of particles are swept into the neighborhood of the heat transfer surface. When this occurs, there is a high heat transfer rate between the hot particles and relatively cold heat transfer surface. Although particle-to-surface contact area is too small for significant solid-solid conduction heat transfer, energy is transferred via conduction through the gas and also by radiation from the particles to the heat transfer surface. As much as one third of the total energy transferred from the bed to the tubes is radiational.

Concurrent with the particle conduction is the action of convective heat transfer from the hot gases to the heat transfer surface. Those gases can be flowing through the particle packets or in bubbles of gas in the bed. The exterior convective heat transfer coefficient for a single tube depends on both the particles and the gas and may be expressed as

$$h = (1 - f_c)\, h_b + f_c h_e \quad , \tag{10}$$

where the fraction of the tubes covered by particles is expressed as f_c and the heat transfer coefficient of the particle or dense phase is h_e and bubbles is h_b. Each of these heat transfer coefficients is calculated separately.

The heat transfer coefficient is generally expressed in terms of a dimensionless Nusselt number, Nu,

$$Nu \equiv \frac{hd}{k} \quad , \tag{11}$$

where in the case of fluidized beds, the relevant diameter, d, is the particle diameter and the thermal conductivity, k, is that of the surrounding gas.

For heat transfer between the particle packets and the tubes, the Nusselt number can be modelled in three parts: conduction, convection, and radiation,

$$Nu = Nu_{cond} + Nu_{conv} + Nu_{rad} \tag{12}$$

Some empirical relationships which have been used for each of these components are,

$$6 < Nu_{cond} < 12 \qquad (12a)$$

$$Nu_{conv} = 0.05\ RePr \quad , \quad Re < 2000 \qquad (12b)$$

$$Nu_{conv} = 0.18\ Re^{0.8} Pr^{1/3} \quad , \quad Re > 2000 \qquad (12c)$$

where $Re = \frac{\rho_g d_p U}{\mu_g}$

Pr = Prandtl number $= \frac{C_p \mu_g}{k_g}$

and

$$Nu_{rad} = \frac{d_p}{k_g} \frac{\sigma \epsilon_r (T_b^4 - T_w^4)}{(T_b - T_w)} \quad . \qquad (13)$$

$$\epsilon_r = \frac{1}{\frac{1}{\epsilon_w} + \frac{1}{\epsilon_p} - 1} \quad .$$

In these equations, C_p is the specific heat of the gas, ϵ_w and ϵ_p are the emissivities of the tube walls and particles respectively, T_b and T_w are the bed and wall temperatures (in °K) and σ is the Stefan-Boltzmann constant (5.669×10^{-2} W/m °K).

For the heat transfer from the gas bubbles to the heat transfer surfaces, two correlations exist for the Nusselt number,

$$Nu = 0.0175\ Ar^{0.46}\ Pr^{0.33} \quad , \quad U > U_m \qquad (14a)$$

and

$$Nu = 0.0175\ Ar^{0.46}\ Pr^{0.33} \left(\frac{U}{U_m}\right)^{0.3} \quad , \quad U_{mf} > U > U_m \qquad (14b)$$

where U_m is the velocity that yields maximum bed-to-surface heat transfer. Here the Archimedes number is the same as defined previously in Equation 4.

Heat Transfer in the Freeboard and Convective Zone

The freeboard section and convective pass in a fluidized bed boiler are similar to conventional pulverized coal boilers. In the freeboard zone thermal energy is released by the combustion of the fines elutriated from the bed, heating the gas flow in the region and also radiating energy to the water walls. As the hot flue gas flows by the boiler tubes on the wall, heat is transferred from the gas to the tubes. In addition, some energy reaches the water walls in the freeboard due to radiation from the top of the fluidized bed.

The relevant equations for heat transfer and steam temperature rise are those used in the design of conventional pulverized coal boilers, are widely available and will not be repeated here.

Coal Combustion

The description of coal combustion is generally broken into three distinct steps:

1. Heating of the coal particle to the ignition temperature, evaporating any trapped moisture.

2. Pyrolysis of volatile matter that subsequently combusts outside of the particle surface.

3. Oxidation of the remaining char material which is mostly carbon.

Figure A-4 illustrates these three steps showing the relative time to complete each step.

As in pulverized coal combustion, the time for the pyrolysis of volatiles is short compared with the time required for char oxidation (seconds versus tens of seconds). Completion of char combustion is the most important parameter in designing an efficient AFBC. In contrast to pulverized coal combustion, the char particle temperature is lower due to the higher heat transfer rate as discussed in the previous section. Measurement using infrared-sensitive film showed char particles were no more than 100 to 200 C hotter than the mean bed temperature. This results in particle temperatures lower than the ash fusion temperature. Therefore ash does not melt and subsequently foul heat transfer surfaces. Typically the ash remains in one of two

forms: either small particles of less than 100 micron diameter or much larger particles that remain in the bed as part of the inert matter of the bed. The small particulate ash (fly ash) is captured by cyclones, in a baghouse, or by electrostatic precipitators. The inert ash that accumulates in the bed is drawn off for disposal.

Once the coal particle has been pyrolyzed what remains is a porous particle with a large C/H ratio, and thus it is often considered to be a pure carbon particle. This carbon combusts with the oxygen in the air. It is generally believed that the reactions with oxygen occur at the surface of the particle and involve five steps:

1. oxygen diffusion to the surface of the particles,

2. absorption of the oxygen molecule on the surface,

3. reaction of the oxygen with solid carbon forming absorbed products (CO, CO_2),

4. desorption of the products, and

5. diffusion of the products away from the particle.

For the carbon oxidation process, steps (2) and (4) are known to be extremely fast. Two rate-limiting cases then are possible: 1) kinetically-controlled reactions where step (3) is much slower than the other steps and 2) diffusion-controlled reactions where step (1) limits the rate of reaction. For the cases with very high gas velocities and for small (less than 50 μm) diameter particles, the reactions will be kinetically controlled. Diffusion-controlled reactions occur at high temperatures, large particle diameters (greater than 100 μm) and lower Reynolds' numbers. For diffusionally-controlled combustion of a carbon particle, stoichiometry is an important variable. Three mechanisms of combustion occur:

Firstly, oxygen can diffuse to the surface and react to form CO_2,

$$C + O_2 \rightarrow CO_2 \quad . \qquad (15)$$

The second mechanism is the reaction of oxygen to form CO,

$$2C + O_2 \rightarrow 2CO \quad , \qquad (16)$$

which occurs when there is no free oxygen present.

The third mechanism is more complex, oxygen diffuses to the carbon surface and reacts to form CO. The CO diffuses away from the particle, and reacts with the free oxygen to form CO_2. Some of the carbon dioxide then returns to the surface and reacts to form CO,

$$CO_2 + C \rightarrow 2CO \qquad (17)$$

Thus a continual production of carbon monoxide is maintained. It is generally believed that this mechanism is the most appropriate for fluidized beds, and the species concentration profiles will be as shown on Figure A-5. Many models have been developed in order to predict the combustion efficiency, defined as the fraction of the coal calorific value which is released by combustion, in a fluidized-bed combustor.

Unfortunately, no model developed to date (1985) accurately predicts the combustion efficiency.

Combustion efficiency is proportional to the residence time of the coal particle in the combustor. In the fluidized bed, the parameters that affect residence time are gas velocity, bed depth, freeboard height, and recycle ratio. Typically, the recycle ratio has been used to control efficiency as shown in Figure A-6 for the data from the TVA 20 MW pilot plant. There is also a scaling effect, combustion efficiency increasing with increases in scale.

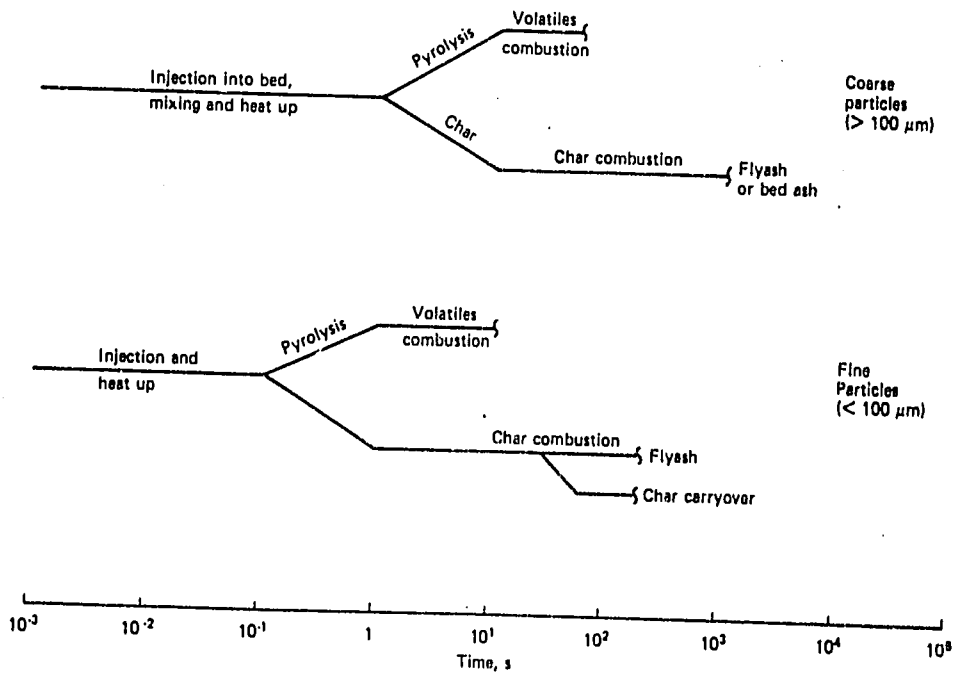

Figure A-4. Combustion Mechanisms.

Source: Adapted from D.L. Kearns, et al, "Fluidized-bed Combustor Design", Chapter 6 in Fluidized-Bed Boilers: Design and Application, Pergamon Press, Toronto, 1984

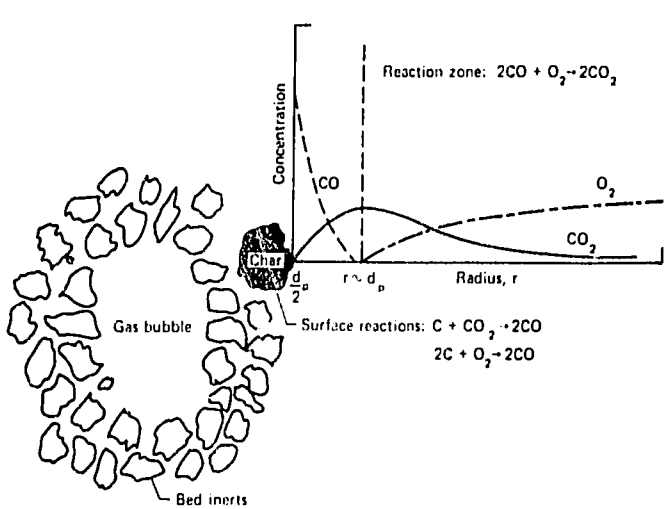

Figure A-5. Char Oxidation in the Bed.

Source: Adapted from M.M. Averdsian, J.F. Davidson, "Combustion of Carbon Particles in a Fluidzed Bed", Trans. I.Ch.E., Vol 51., 1973, pp. 121-131

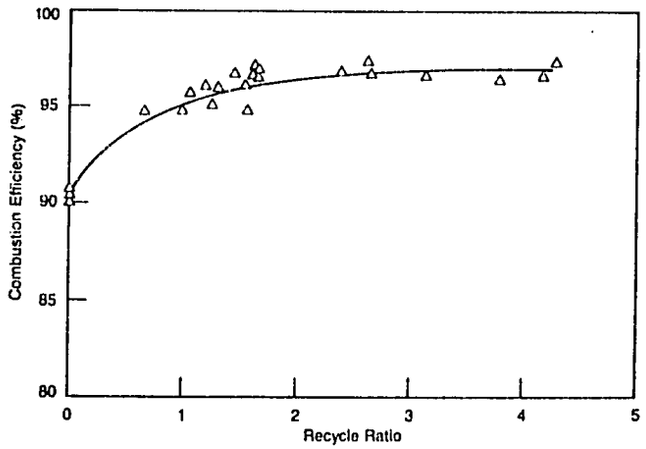

Figure A-6. Combustion Efficiency for the TVA 20 MW Pilot Plant.

TABLE A-1

APPROXIMATE ANALYSIS OF LOW-GRADE FUELS USED IN FLUIDIZED-BED BOILERS

	Plant Name, Location			
	Luenen, FRG VAW	Sumitomo Coliery, Japan	French Island, WI, NSP	Wilkes-Barre, PA
Type of Fuel	Coal Waste	Washery Waste	Waste Wood	Anthracite Culm
HHV, Btu/lb.	5,700	3,900	4,300	3,600
Ash, %	48.	36.	3.	66.
Moisture, %	12.	30.	50.	5.
Sulfur, %	1.4	0.1	0.1	0.7

5000 Btu/lb. = 11.63 KJ/Kg

TABLE A-2

LOW GRADE FUELS TESTED IN PILOT PLANTS FOR FBC APPLICATIONS

	Sulfur, %	Ash, %	Moisture, %	HHV, Btu/lb
Anthracite Culm	2.4	59.4	4.5	2,207
Bark	0.6	2.0	56.0	8,000 (Dry)
Coke Breeze	0.6	10.9	6.3	13,200
Cow Manure	0.5	38.6	20.4	3,253
Industrial Sludge	0.8	31.1	58.0	2,600
Irish Coal	0.4	54.8	4.4	5,073
Lignite	1.7	7.0	52.8	5,100
Oil Shale	2.1	60.7	3.5	1,200
Peat	0.2	2.6	40.0	6,880
Petroleum Coke	5.3	0.6	1.0	13,900
Sewage Sludge	1.3	37.9	17.4	5,145 (Dry)

Sources: Ahlstrom, Foster-Wheeler, Lurgi; 5000 Btu/lb. = 11.63 KJ/Kg

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WAPDA'S FIRST LARGE THERMAL POWER STATION BASED ON DOMESTIC COAL

GHULAM MURTAZA ILIAS
B.Sc.(Engg), Fellow, I.E.E.(PAK),
Sr. Member, I.E.E.E.(USA)
Chief Engineer,
Coal Power Projects,
Water & Power Development Authority,
192-WAPDA House, Lahore.

Preamble on Lakhra Project

Pakistan Water and Power Development Authority (WAPDA) is embarking upon the project of a power plant consisting of two steam turbo-generating units of 350 MW each, using domestic coal. The fuel will be supplied by Pakistan's largest lignite mine named "LAKHRA", which is about 50 km north-west of Hyderabad nearly 217 km north-east of Karachi and about 20 km away from the right bank of the River Indus as shown in Fig. 1. The mine is estimated to produce 4.3 million tonnes of coal per annum predominantly through surface mining methods. The lignite possesses an average heating value of 5120 BTU per pound or 2840 kilo-Calorie per kilogram. The proven coal reserves are over 111 million tonnes and the total estimated reserves in-place are 234 million tonnes in an area of 62 sq. km. The power plant will be built by WAPDA, a semi-autonomous corporation of Pakistan, and the mine is being planned to be developed by the private sector.

It is heartening to note that the efforts made in the past 18 years in studying various aspects of this complex project are now going to bear fruit.

In this connection the guidance of of the World Bank and the Asian Development Bank has played an important role, while the technical assistance of USAID and the direct participation of USAID's staff, both in Islamabad and Washington are the keynote of the achievement. The work on the project is expected to commence during the calendar year 1986 and the first power unit of 350 MW is scheduled to be commissioned by 1991, the second one a year later.

Water and Power Development Authority (WAPDA)

As shown in Figure 2 WAPDA has the responsibility to develop the water and power resources of the country. Its organization chart is given in Figure 3.

The Generation Department of WAPDA is divided into two sections. One is the Hydel Department and the other Thermal Department which is shown in Figure 4. The Thermal Organization is headed by a General Manager who is supported by several Chief Engineers. One of them is looking after all the coal related projects as per Figure 5.

This is a relatively new cell set up

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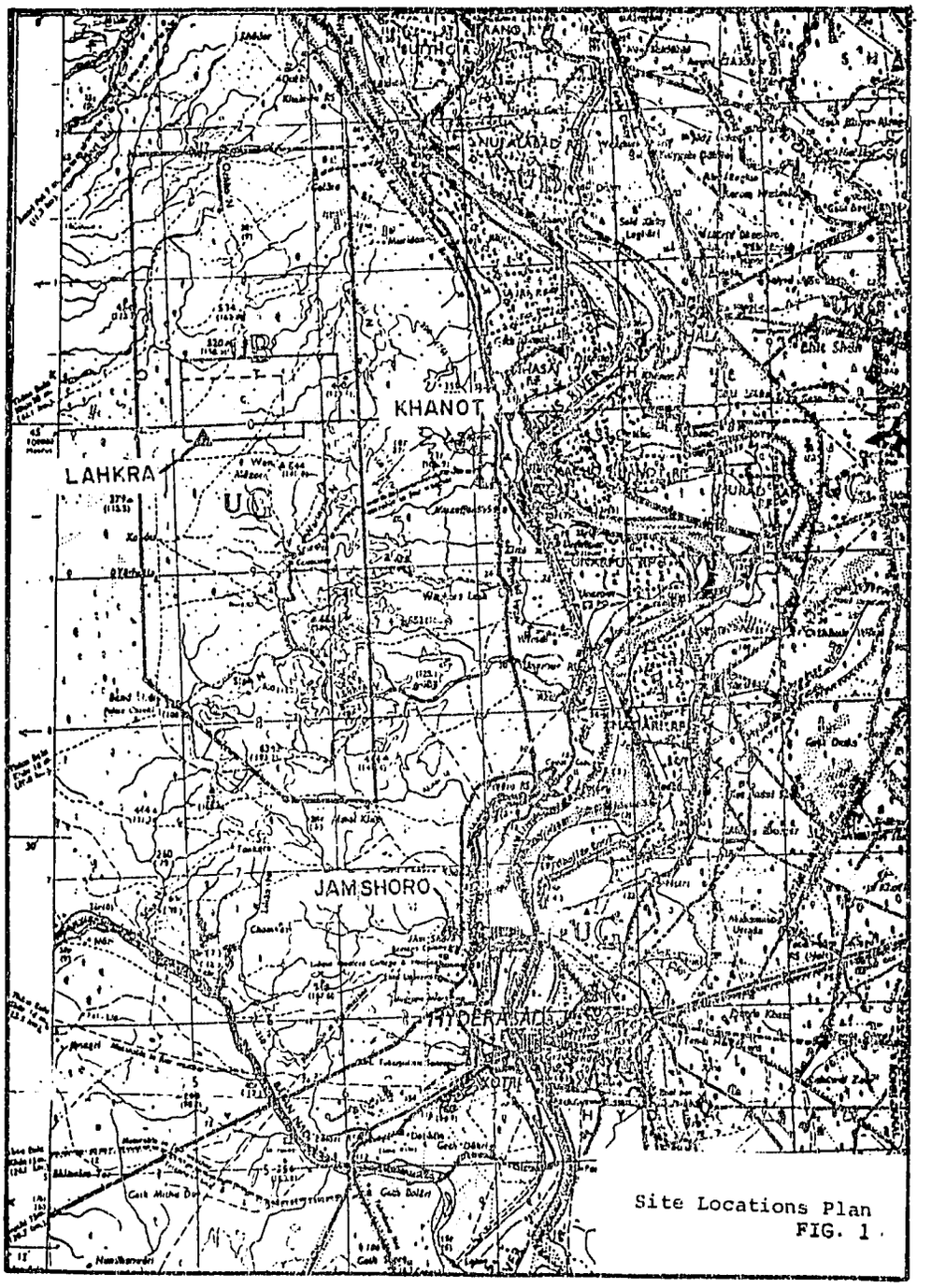


Site Locations Plan
FIG. 1

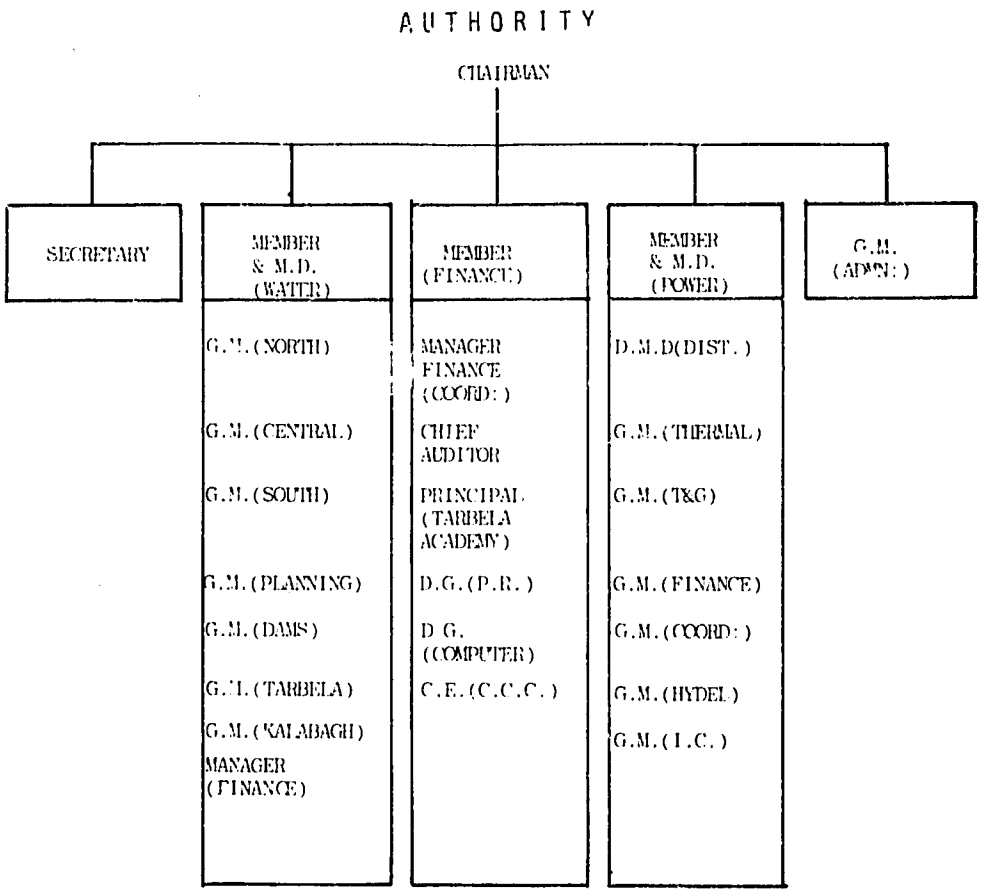
FIGURE-2

THE CHARTER OF DUTIES OF WAPDA
INCLUDES INVESTIGATIONS, PLANNING & EREECTION
OF SCHEMES IN THE FOLLOWING FIELDS

- GENERATION, TRANSMISSION AND DISTRIBUTION OF POWER
- IRRIGATION, WATER SUPPLY AND DRAINAGE.
- PREVENTION OF WATERLOGGING AND RECLAMATION OF WATERLOGGED AND SALINE LANDS.
- INLAND NAVIGATION.

WAPDA'S CHARTER OF DUTIES

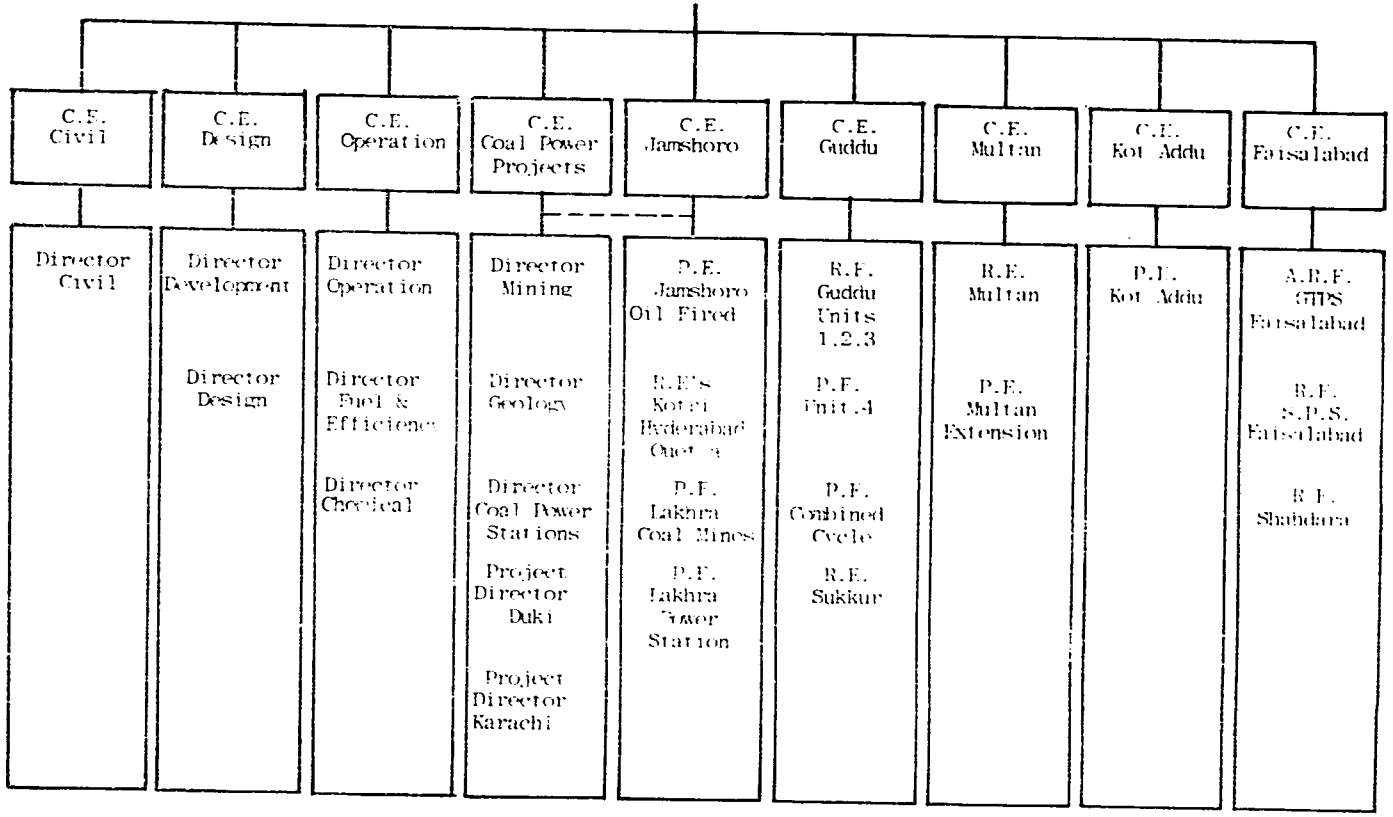
FIGURE-3



WAPDA'S ORGANISATION CHART

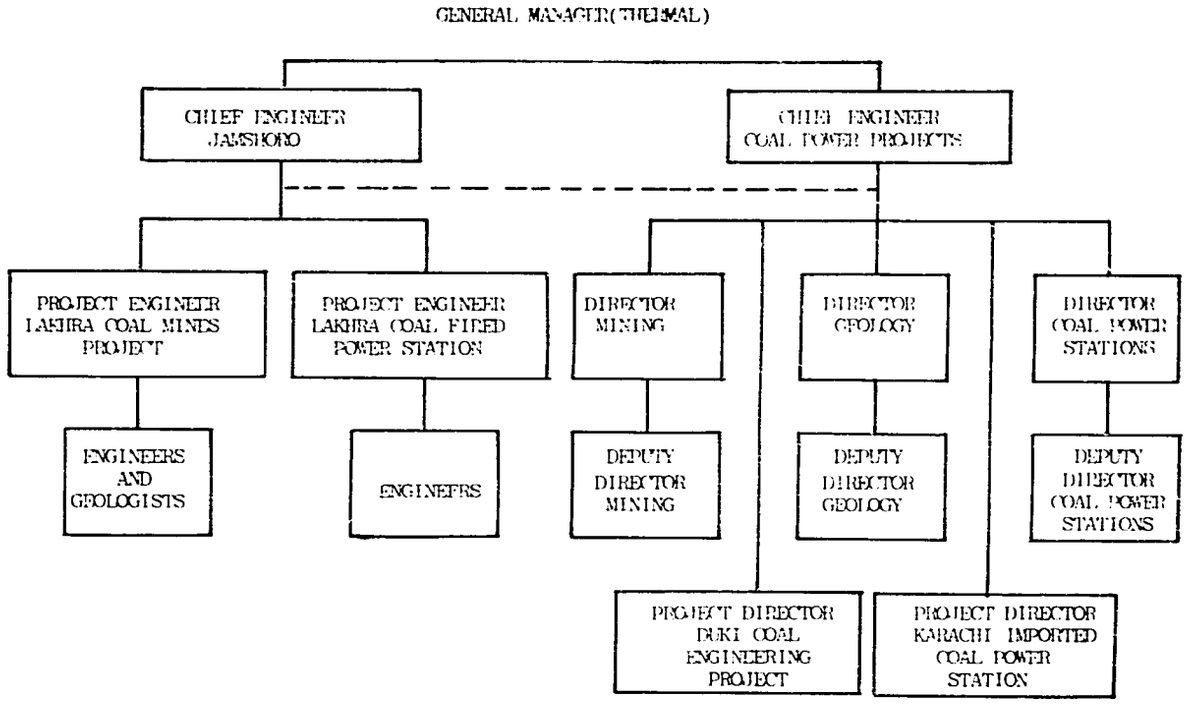
FIGURE-4

GENERAL MANAGER (THERMAL)



ORGANISATION CHART OF GENERAL MANAGER (THERMAL)

FIGURE-5



ORGANIZATION CHART OF
COAL POWER PROJECTS DEPARTMENT

specially to plan design, implement and manage coal-based power plants of the country. In view of the dwindling gas reserves of the country and the lack of domestic oil, coal has acquired great importance as a fuel for WAPDA's thermal power plants.

The present policy of the Government is that no future power station be based on natural gas and the oil-fired power generation should be restricted to a minimum. Therefore the new Department has an overwhelming task of developing several large coal-fired power plants to meet the growing power demand and Lakhra coal offers a great promise for the future.

When the present scheme is in full operation, the Lakhra mine will produce coal which will be equivalent to approximately 1.20 million tonnes of oil per year. In other words it will save nearly US$ 180.00 million per annum by substituting oil-imports taking a figure of US$ 20.00 per barrel in 1991. This coal will also be equivalent to 2.0 million tonnes, valuing US$ 120.00 million per annum, of high grade imported coal having a heating value of 11,000 BTU per pound or 6,110 k cal per kg and costing US$ 60.00 per tonne. The power station will reduce the power shortage by 700 MW and produce 4300 million KWH of energy at 70 % plant factor each year which will help in providing electricity to a large number of industrial and domestic consumers as well as agricultural tubewells and permit WAPDA to electrify thousands of villages.

The integrated project will provide job opportunities and living accommodation to over 3000 workers, apart from giving rise to the development of roads, railway line, hospitals, colleges, schools and shopping centres in an entirely under-developed section of Sind Province. The source of fuel which has been lying dormant for millions of years will be put to use for large-scale power production for the first time heralding an era of a new technology in Pakistan, where there is mainly hydro-power supplemented by gas and oil-based thermal generation. Only a tiny power plant of 15 MW using Baluchistan coal is in operation at Quetta.

Firm Capability versus Power Demand of Power System

Table 1 shows WAPDA's latest calculations of the Firm System Capability v/s Power Demand upto the year 1997-98. The schemes proposed to meet the system demand are also given in it. As you can see, a large portion of the thermal power units will operate on coal in the years to come. The first plant will run on Lakhra coal. The second large plant is planned to be set up near Karachi using good quality imported coal in preference to imported oil. In this connection a feasibility study is in hand. Recently, on-shore and off-shore survey and drilling have helped us in determining two potential sites where port facilities as also power plant can be set up. Further detailed investigations are in progress. The third plant may be set up at Sondha-Thatta coal-field, for which detailed investigations are yet to be commenced.

TABLE-1

YEAR	LOAD FORECAST (MW)	FIRM GEN. CAPABILITY (MW)	PROPOSED SCHEMES		
1985-86	4345	4883	KOT ADU GAS TURBINES	400	MW
1986-87	4745	5354	COMBINED CYCLE GUDDU	150	MW
			KOT ADU GAS TURBINES	400	MW
1987-88	5295	5877	KESC STEAM	210	MW
			JAMSHORO OIL FIRED	250	MW
1988-89	5688	6440	LOW HEAD HYDELS	35	MW
			TARBELA	864	MW
			MANGLA	200	MW
			JAMSHORO OIL FIRED	210	MW
			KESC STEAM	210	MW
			C.C. AT KOT ADU	200	MW
			C.C. AT FAISALABAD	100	MW
1989-90	6975	7055	TARBELA	864	MW
			MULTAN STEAM	210	MW
			KESC STEAM	210	MW
			JAMSHORO OIL FIRED	300	MW
1990-91	7888	7731	MULTAN STEAM	210	MW
			JAMSHORO OIL FIRED	300	MW
			LAKHRA COAL	300/350	MW
1991-92	8666	8472	LOW HEAD HYDELS	256	MW
			LAHORE THERMAL	800	MW
1992-93	9622	9283	KALABAGH	1500	MW
			TARBELA	400	MW
1993-94	10350	10155	LAKHRA COAL	300/350	MW
			TARBELA	800	MW
			KALABAGH	600	MW
			LOW HEAD HYDELS	122	MW
1994-95	11409	11110	LAKHRA COAL	300/350	MW
			KALABAGH	600	MW
			UNITS ON IMP.COAL	600	MW
1995-96	12257	12155	UNITS ON IMP.COAL	1200	MW
			KALABAGH	600	MW
1996-97	13647	13299	KALABAGH	600	MW
			CHASHMA NUCLEAR	900	MW
			LOW HEAD HYDELS	114	MW
1997-98	14462	14551	BASHA	840	MW
			CHASHMA NUCLEAR	900	MW

FIRM CAPABILITY VERSUS POWER DEMAND
OF WAPDA - KESC SYSTEM

Lakhra Studies

Over the past 18 years several studies have been made. A list of the studies concluded upto 1985 is given in Figure 6.

In early 1960's the Geological Survey of Pakistan (GSP) with the assistance of United States Geological Survey (USGS) carried out drilling operations in the Lakhra coal field. 34 widely spaced holes were drilled in an area of about 200 to 250 sq. km. The estimated reserves were placed at more than 240 million metric tonnes.

In 1967, West Pakistan Industrial Development Corporation (WPIDC), engaged Polish Consultants to examine the feasibility of a coal mine and a coal-fired power station at Lakhra. Using the GSP drill-hole data as well as the information obtained through geological mapping the consultants expressed the view that a 250 MW power generating facility and a mine providing 3000 tonnes of brown coal per day should be feasible. But they emphasised the need for further drilling and detailed study of the coal characteristics. The project could not take off, probably because inadequate data were available for the decision makers to give a go-ahead signal for the project.

In early 1970's Pakistan Mineral Development Corporation (PMDC) was set up for the development of various mineral resources in the country. This organization undertook drilling of 19 holes in the leases obtained by it in Lakhra. Geological analysis of these holes and their correlation with the previous holes gave some more information about the coal seams occurring in the area. A project was prepared by PMDC for a coal mine of 1.0 million tonnes per annum. On the other hand WAPDA, who was anxious to make a coal-fired power plant prepared a scheme for a 2x125 MW power plant. The two schemes came up for consideration by the Government of Pakistan in 1976 where it was decided that thorough investigations should be carried out about the coal quantum, coal quality and cost of coal per tonne. It was also desired that the project may be implemented as an integrated scheme and WAPDA should play the role of a lead-agency.

Out of the 34 holes mentioned earlier, 3 holes were located in the area of PMDC lease where 19 holes were drilled by PMDC itself. These holes were also widely spaced and no concrete plans for underground or surface mines could be prepared.

In 1977, negotiations were started with the Japanese Government, who provided technical assistance for the detailed feasibility study of a mine and a power plant. Consultants were appointed by the Japanese International Cooperation Agency (JICA), to undertake the feasibility. Field work was started in 1979 and after drilling 50 holes in a compact area of 26 sq. km, a mining feasibility for production of 1.2 million tonnes per year was prepared in February 1981 alongwith a power plant feasibility for a single unit of 300 MW to be set up at Jamshoro near Hyderabad. Keeping a stripping

FIGURE-6

S.NO.	NAME OF AGENCY	PERIOD	FINDINGS OR RECOMMENDATIONS
1.	POLISH CONSULTANTS OF WPIDC	1966-67	i) UNDERGROUND MINING OF 3000 TONNES PER DAY BY LONGWALL OPERATION. FURTHER DRILLING RECOMMENDED. ii) 250 MW POWER PLANT.
2.	ZAFAR & ASSOCIATES CONSULTANTS OF WAPDA WITH PCR OF U.K.	1976	i) 4000 TONNES PER DAY COAL PRODUCTION BY PMDC. ii) 250 MW(2x125MW REHEAT UNITS)POWER PLANT BY WAPDA.
3.	PMDC AND WAPDA	1976	BOTH ORGANIZATIONS SUBMITTED PC-I'S. THE GOVERNMENT DECIDED THAT THE PROJECT BE INTEGRATED AND WAPDA SHOULD ACT AS LEAD AGENCY.
4.	CIDA CONSULTANTS OF WAPDA	1977	RECONNAISSANCE STUDY INDICATED ENOUGH RESERVES OF COAL FOR A 250 MW POWER PLANT. AVAILABLE COAL RESERVE DATA INADEQUATE AND FURTHER STUDY REQUIRED.
5.	JICA CONSULTANTS OF WAPDA	1979-81	i) 50 HOLES DRILLED IN 26 SQ.KM. 1.2 MILLION TONNES OF COAL ANNUALLY BY BOTH SURFACE AND UNDERGROUND MINING METHODS. ii) 300 MW POWER PLANT AT JAMSHORO.
6.	STONE & WEBSTER CORPORATION OF USA RETAINED BY USAID.	1983	CONFIRMED THE ABOVE FINDINGS OF JICA. RECOMMENDED DETAILED GEOLOGICAL INVESTIGATIONS TO ESTABLISH THE FINAL MINE AREA AND MINE DESIGN.
7.	WAPDA-USAID CONSULTANTS i) J.T.BOYD	1984-85	65 HOLES DRILLED. 4.3 MILLION TONNES OF COAL BY TWO LARGE SURFACE MINES AND ONE SMALL UNDERGROUND MINE IN 62 SQ.KM. OF PMDC LEASE CONTAINING PROVEN RESERVES OF 111 MILLION TONNES.

Contd.on next page

LAKHRA COAL MINE AND POWER PLANT STUDIES

FIGURE-6 (CONTD)

ii) GILBERT COMMONWEALTH INC.	1985	TWO POWER UNITS OF 350 MW EACH AT KHANOT
iii) DESE-INC.	1985	STUDY OF ENVIRONMENTAL IMPACT OF MINE AND POWER PLANT. NO DESULPHURISATION PLANT NEEDED FOR 2x350 MW UNITS WITH ONE CHIMNEY OF 190 METERS. TO MEET WORLD BANK GUIDLINES FOR GROUND CONCENTRATIONS AND EMISSIONS OF SO_2.
iv) ICF - INC.	1985	ECONOMIC AND FINANCIAL ANALYSIS OF INTEGRATED PROJECT. PROJECT FOUND ECONOMICALLY AND FINANCIALLY FEASIBLE.

LAKHRA COAL MINE AND POWER PLANT STUDIES

ratio of 15:1 as the upper limit and dividing the area into three blocks i.e. Western, Central & Eastern, the Japanese gave the following recommendations:-

i) Surface mining may be carried out in the west and east pit and underground mining in the central block to produce a cumulative quantity of 1.2 million tonnes per annum.

ii) A power plant of 300 MW may be set up at Jamshoro about 40-50 km from the mine and a new railway line may be installed from Lakhra to Khanot. From Khanot to Jamshoro the existing Pakistan Railways' line may be used for coal transportation upto the power plant.

The cost of coal in December 1987 was calculated at US$ 98.3 per tonne @ Rs.10.00 per dollar and that of electricity at 14.4 cents per KWH.

The aggregate capital cost of the 300 MW power plant and the mine was estimated at $ 1.2 billion. The overall capital cost and the unit cost of producing coal and electricity was found by the Government of Pakistan and WAPDA very much on the high side. Therefore the project was not implemented.

USAID Technical Assistance

In September 1981, the Government of Pakistan requested USAID to get a review of the JICA report by American experts to see if the capital cost of the project and the cost of production of coal and electicity could be brought down to acceptable levels through the application of American technologies.

USAID agreed to provide technical assistance. Arrangements were made for WAPDA, PMDC and an American consulting company Stone and Webster Corporation.

The review started in October 1982 and was completed in April 1983. As no fresh drilling was carried out during this review, the data for mining feasibility were the same as available from JICA Report and earlier studies. The experts were, however, able to bring down the capital cost of the project to US$ 815 million calculated @ Rs. 12.75 per dollar. Also the cost per tonne of coal came down to US$ 34.00 and the cost of generation to 4.8 cents per KWH.

World Bank's Views

A meeting was held in Washington in October 1983 where officials of WAPDA, Government of Pakistan, PMDC, Stone & Webster and USAID were present. While the World Bank agreed that the coal reserves in Lakhra were adequate to support a 300 MW power plant, its officials insisted on further drilling of the area to have better appreciation of coal seam continuity and seam correlation. They also advised that the quality of coal should be thoroughly examined as they found deficiencies in the JICA's quality reports. It was also emphasised that a proper study should be made to establish that Lakhra Power Plant was a component of the least cost power generation programme of WAPDA and the cost of coal from Lakhra mine was able to produce electricity which was more economical to the economy of Pakistan than through any other available source of fuel like imported coal or imported oil.

Views of Asian Development Bank

The views expressed by the Asian Development Bank were similar and the matter boiled down to the situation that a detailed final feasibility study would be imperative before any donor agency would consider the Lakhra Mine and Power Plant Project for financing. The bank desired that the siting of the power plant and the environmental impact of mining as well as coal burning should be re-examined.

USAID's Financial Support

The USAID provided a sum of over US$ 10.0 million to enable WAPDA and PMDC to carry out various studies necessary to address the issue raised by the potential donors. After careful thinking it was decided to engage highly specialised firms for the following jobs:-

1) Mining Feasibility including coal quality, washability and transportation systems.

2) Power Plant Feasibility including site location, system studies and coal burning properties.

3) Social soundness of the two projects.

4) Environmental Impact of the Mine and the Power Plant, keeping in view the World Bank Guidelines for developing countries.

5) Economic and Financial Analysis of the Integrated Scheme in the light of various alternative options and to recommend the best option.

6) Financial Packaging for Private Sector Participation in Lakhra Mine Development.

It was also decided that the firms engaged on the above tasks shall be precluded from any future participation in the project. The purpose was that the feasibility consultants do their job without any vested interest in future consultancy work.

Participation of Private Sector in Mine Development

An important requirement of USAID's funding for the feasibility work or the construction of Lakhra Power Plant was that the coal mine should be developed by the private sector. So, while the feasibility work was being executed, notices were issued in local and international press inviting the private sector from Pakistan and abroad for participation in the mine. Today, not only the feasibility studies have been satisfactorily concluded but also the idea of substantial private sector participation in the project has taken some definite shape. A separate paper will be read on this subject tomorrow morning.

Latest Studies on Lakhra Project

- Lakhra Mine Feasibility

(a) Messrs J.T. Boyd Company were engaged by USAID/WAPDA in November 1984. They carried out drilling, with the help of a Pakistani drilling company, Mineral Engineering Services Limited (MESL), within the PMDC

tract upto 21st. May '1985. The details of drill-holes is as under:-

	Coring	Non-coring	Total
West Pit	22	9	31
East Pit	12	9	21
Central Block	13	-	13
	47	18	65

These 65 holes plus the 72 holes drilled by other organizations i.e. GSP, PMDC & JICA Consultants before September 1984 make a total of 137 holes in an area of approximately 62 sq. km. The drilling density is internationally accepted for the purposes of feasibility studies. A few of these holes were drilled close to JICA holes and called "twin-holes" to reconfirm the drilling results of JICA. The entire drilling upto May 1985 is shown in Table 2.

(b) Geophysical Logging

Of the 65 holes, 61 hole were geophysically logged with the help of a special electric logging equipment brought from USA. The logging not only confirmed the actual drilling results of the holes but also helped in making inference of the missing seam thickness in case of poor recovery of cores. Such an activity was undertaken in the field of coal-exploration for the first time in Pakistan. Previously it was confined to oil and gas exploration only.

(c) Aerial Photography

About 700 sq. km of Lakhra rea was subjected to aerial photography with the help of the survey of Pakistan. The aerial photographs were used in preparing topographic maps of various alternative sites of the power plant, the water supply routes and the coal transport routes. More areas are intended to be photographed in the near future.

(d) Chemical Analysis of Coal-Cores

More than 200 coal samples, covering all the 5 seams occurring in the project area were carefully collected, packed, sealed and air-lifted to USA for detailed analysis in Standard Laboratories, Charleston, W. Virginia. The in-place raw coal quality has been determined. The results are substantially different from those obtained by JICA consultants. The average weighted heating value has been found to be 5120 BTU/pound or 2840 kcal/kg instead of 6060 to 6912 BTU/pound, miosture 32 % instead of the assumed value of 25 %, sulphur 5 % instead of 6.0 % and ash 24.7 % instead of 19.7 %.

(e) Coal Reserves

Table 3 shows the estimates of coal reserves at Lakhra made by various parties in the past. According to the recent

TABLE-2

S.NO.	NAME OF AGENCY	PERIOD	NO. OF DRILL-HOLES	APPROX. AREA COVERED (SQ.KM)
1.	GSP/USGS	1960-65	34 (3 IN PMDC LEASE)	205 (GENERAL LAKHRA AREA)
2.	PMDC	1975-76	19	52 (PMDC LEASE)
3.	WAPDA/PMDC/ JICA (MITSUI)	1979	50	26 (PMDC LEASE)
4.	WAPDA/USAID (DOWD)	1984-85	65	62 (PMDC LEASE)

DRILLING ACTIVITIES IN LAKHRA UPTO MAY, 1985

TABLE-3

AGENCY		TOTAL (MILL. Tonnes)	PROVEN/ RECOVERABLE	REMARKS
1. GSP/USGS (1960-65)		240	NOT MENTIONED	VERY WIDELY SPACED DRILL-HOLES
2. WPHC/GLIWICE POLAND(1967)		83.6	NOT MENTIONED	NO ADDITIONAL DRILLING, RESERVES CALCULATED IN 62 SQ.KM.
3. PMDC(1975)		173	21.4	-
4. JICA(1980-81) (MITSUI/ EPDCI) BASED ON 62 DRILL HOLES IN 26 SQ.KM	(a)	39	22	i. WORKING HEIGHT OVER 1.5 M ii. STRIP RATIO UNDER 1:10
	(b)	79	54	i. WORKING HEIGHT OVER 0.75M ii. STRIP RATIO UNDER 1:15
	(c)	107	75	i. WORKING HEIGHT OVER 0.75M ii. STRIP RATIO UNDER 1:20
5. STONE AND WEBSTER(1963)		-	64.4	NO ADDITIONAL DRILLING
6. J.T.BOYD(1985)		233	111	BASED ON 137 DRILL-HOLES IN AN AREA OF 62 SQ.KM. 65 HOLES DRILLED UNDER USAID ASSISTANCE. STRIPPING RATIOS UPTO 1:20 IN EXPANDED EAST AND WEST PITS.

LAKHRA COAL RESERVES

calculations of the consultants, M/s J.T. Boyd the demonstrated reserves (proven and indicated) in the PMDC's investigated area through various combinations of mining systems are as under:-

	(Mill. Tonnes)
(1) Surface Mining in expanded West and East Pits, underground mining in reduced Central Block.	110.0
(2) Surface Mining in the restricted West Pit only, Underground mining in large Central and Eastern areas.	42.5
(3) All underground Mining in the West, East and Central Blocks.	23.3

The above findings lead to the conclusion that the application of surface mining will produce nearly five times the coal quantity that can be extracted through underground mining in the same area. Surface mining will, however, cover some areas of higher stripping ratios, which will be mined at a later stage.

(f) Alternate Mine Plans

The mining consultants examined three alternative systems for surface mining and two alternative systems for underground mining. The alternatives considered are:

A. Surface Mining

(1) All dragline.
(2) All truck/shovel.
(3) Combination of dragline & T/Shovel.

B. Underground Mining

(1) Partial Mechanisation of existing mining methods.
(2) Total Mechanisation.

Of the above, they have recommended the following:-

A. Combination of draglines and Trucks/Shovels to ensure maximum reliability.

B. Partial mechanisation in the beginning and gradual upgradation to total mechanisation of one mine for demonstration to private mine-owners.

(h) Capital Cost of Mine and Cost of Coal/tonne

The capital cost of the scheme worked out by consultants is as follows:-

	(Million Dollars)
(1) Surface Mines in West and East Pits to produce 4.0 million tonnes per annum.	340 (Foreign) 110 (Local)
(2) Underground Mine in the Central Block to produce 0.3 million tonnes per annum.	13 (Foreign) 4 (Local)

(3) Infrastructure	3 (Foreign) 4 (Local)
Total Cost without custom duty	356 (Foreign) 141 (Local)
Custom duty & taxes	159 (Local)
Sub-totals:	356 (Foreign) 300 (Local)
Grand Total:	656

The cost of production of coal per tonne in 1991 from the surface mines is estimated at US$ 32.00 and the cost per tonne through underground mining is US$ 26.00 per tonne. The overall cost of coal per tonne at the rate of production of 4.3 million tonnes is likely to be US$30.00 per tonne without custom duty and US$ 32.0/ tonne with custom duty.

Alternate Transportation Systems

M/s J.T. Boyd examined various alternative systems for coal transportation. At Lakhra mine-mouth plant, only belt conveyors were considered. But for Khanot and Jamshoro sites, road, rail and belt conveyor were examined. It was found that an independent railway line and unitrain system from Lakhra to either site was the most reliable although a trifle more expensive than the others.

Coal Quality

According to J.T. Boyd's laboratory testing of coal samples, the quality of raw coal on As Received basis is as follows:-

	Moisture %	Ash %	Sulphur %	BTU/Lb
Weighted Average of all 5 seams in West Pit.	32	24.7	5.38	5130
Weighted Average of all 3 seams in East Pit.	32	24.5	4.72	5130
Seam 2 in Central Underground Block.	32	24.7	5.00	5050
Weighted Average Total.	32	24.7	5.00	5120

Coal Washing

In the opinion of J.T. Boyd physical washing of Lakhra coal in a jig washing system will reduce ash by 36 % and sulphur by 11 % thereby improving heating value by 20 %. But there is coal loss and overall BTU loss due to 64 % yield. The reduction in sulphur is low and the quality of coal deteriorates due to exposure to washing. Therefore washing may not be desirable for Lakhra lignite. However, if environmental and economic considerations dictate, a 1300 ton per hour washing plant consisting of a Baum jig has been recommended for installation near the mine.

Spontaneous Combustion

Lakhra lignite, like any other lignite, is prone to spontaneous combustion. Careful handling and storage will be required to keep the coal from self-ignition. Several precautions have been adivsed by the consultants that will ensure safe operations. There exist lignites in other parts of the world which have greater proneness to spontaneous combustion than Lakhra coal but proper care has ensured trouble-free operation.

Mine Site Laboratory

A mine site laboratory has been proposed for continuous sample testing to guarantee uniform quality of coal supplies to power plant.

Power Plant Feasibility Study

M/s Gilbert Commonwealth International Inc. (GCII) were appointed by USAID/ WAPDA as Lakhra power plant feasibility consultants in December 1984. They have covered quite a few aspects of the project in an attempt to address the issues raised by the World Bank, USAID, Asian Development Bank and WAPDA. The noteworthy investigations completed by GCII are briefly described in the following paragraphs:

(a) System Planning

An important requirement of the World Bank was that Lakhra power plant should be a component of an optimum long-term generation programme for the WAPDA System. Therefore, Gilbert Commongwealth conducted two studies, one in March 1985 and the second in August 1985 on the computer of WAPDA using WASP-3 programme. The studies were made for the period from 1986 to 2005. The load forecast prepared by WAPDA and agreed upon by the Planning Commission was taken as the basis of the studies. The corresponding energy requirements for each year were taken into account. Capital costs and the prices of various fuels were developed and sensitivity studies were undertaken. Comparison was also made with power plant using imported oil and imported coal. Transmission costs were also worked out for each alternative location of Lakhra plant viz, Jamshoro Khanot and Lakhra mine-mouth. The cost of transmission of power from the power plant operating on imported coal at Karachi to Jamshoro was also factored in. The study showed that the first 300 MW domestic coal-fired unit in 1991 was accepted as part of the optimum generation expansion plan to the year 2005. Additional units based on Lakhra coal were also required by 1993. The WASP-3 studies also indicated the desirability of installing 2 x 600 MW plants near Karachi based on imported coal by 1995

In October 1985, a meeting was held with various consultants. M/s John T. Boyd, the mining

consultants, revealed the following information:-

i) that about 110 million tonnes of coal could be mined from the investigated project area if subjected to surface mining, except a small portion of the central block where only underground mining was feasible.

ii) the heating value of the coal was 5120 BTU/lb and not 6800 BTU/lb previously determined by JICA. Therefore relatively more coal would be required for the same amount of power i.e. 1.8 million tonnes per annum for a 300 MW plant instead of 1.4 million tonnes as previously estimated.

iii) The reserves now calculated could support a 700 MW power plant in lieu of 300 MW envisaged earlier and adequate coal could be produced annaully for the higher capacity at a reasonable price.

M/s Gilbert Commonwealth, the power plant feasibility consultants, were advised to revise the contents of their feasibility study to incorporate 2 units of 350 MW each to update their findings of the system studies.

(b) Site Selection

The three potential sites i.e. Jamshoro, Khanot and Lakhra minemouth were investigated by GCII. Field exploration, laboratory testing and analysis were conducted to determine the surface, sub-surface and groundwater conditions of each site. It was found that all three sites had similar geology, all were in the same seismic zone although more detailed seimic studies were needed, the bearing capacity of the soil at Jamshoro and Khanot was equal but that of Lakhra was a little lower. It was determined that ground water supply was limited at all the three sites. All cooling and fresh water supplies would be taken from the River Indus. The site closest to the River was Khanot. The quality of river water is poor at Kotri and Khanot and therefore appropriate chemical cleaning would be required.

Apart from general hydrogeological surveys, geo-electric studies were conducted to find ground water at Khanot. No promising results were obtained. From these investigations, it was concluded that only economic and environmental considerations would finally decide the ranking of the sites.

Jamshoro has the longest distance from the mines. Therefore, the cost of coal transportation is the maximum for this site. Nearness to the city of Hyderabad, the Sind University and the Liaqat Medical College makes the Jamshoro site less attractive than the other two sites from the point of view of

potential pollution problem posed by large-scale burning of coal. Availability of water and labour at this place is better assured than at Khanot or Lakhra. Closeness to railway line, super highway and the city minimises the cost of infrastructure at Jamshoro site. But the commitment of space for the several oil-fired units that are planned to be located at Jamshoro site makes it a very unattractive choice for installing many coal-fired power units.

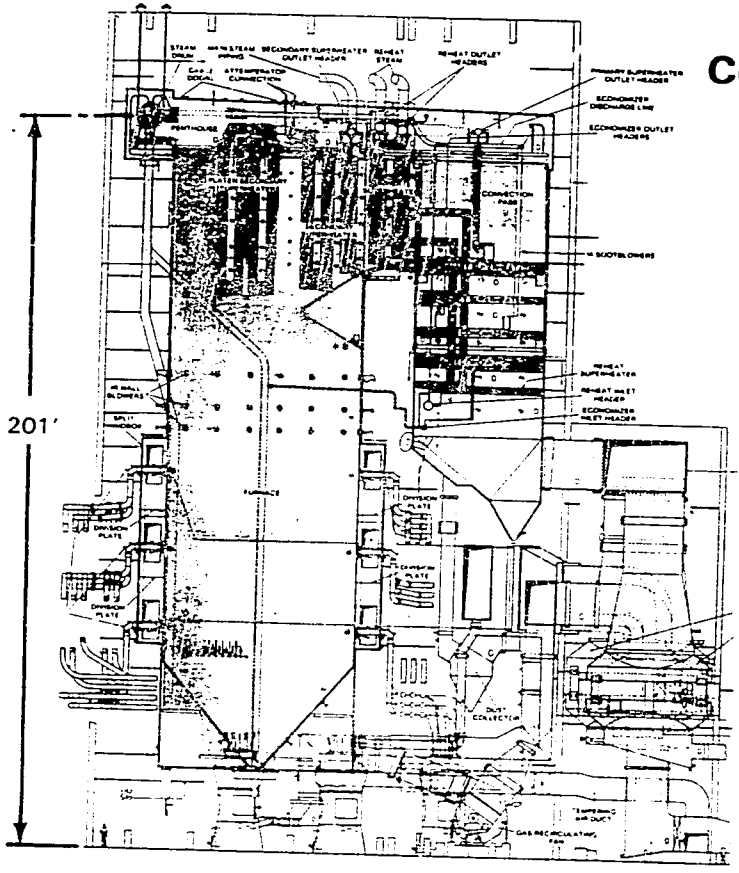
Khanot and Lakhra are, therefore, close competitors of each other for various considerations. The technical, economical and environmental reasons favour the Khanot site.

(c) Testing of coal for Boiler Design

Apart from the fact that several hundred samples of coal were tested by John T. Boyd Company, G.C.I.I. put the Lakhra coal to detailed testing in order to develop appropriate criteria for boiler design. A bulk sample of 50 tonnes raw coal was shipped from Lakhra in January 1985 to USA and subjected to actual burn-testing in a simulated furnace of KDL laboratories in the works of Combustion Engineering, situated at Windsor, (Connecticut), U.S.A. This test gave all the necessary characteristics of the raw coal such as slagging, fouling, erosion/abrasion and corrosion that can occur in various parts of the boiler. Useful information was obtained that has helped us in deciding the size of the furnace, the velocity of the flue gases, the spacing between tubes bundles, the number of soot-blowers and the materials needed to minimise corrosion or erosion of the various components of the boiler and allied equipment. Several bench tests have assisted us in understanding the type of materials to be used in pulverisers, pipes, burners, superheater tubes, ducts, air heaters, electrostatic precipatator and chimney (stack) etc. The redeeming feature of the coal is that it ignites easily and produces good, stable flame even at low loads. It is also easy to grind in a pulveriser.

In Figure 7, I have tried to show a comparison between the sizes of two boilers, one fired with gas or oil and the other fired with good quality coal. This will give you an idea how much bigger the furnace of a coal fired boiler in all dimensions than an oil-fired boiler of equal capacity is. In case of Lakhra coal, which has a lower heating value and contains high sulphur and ash the boiler would be still bigger as can be judged from Fig. 8.

The coal quality is given in Tables 4 & 5. The ash of Lakhra


Coal fired
201'

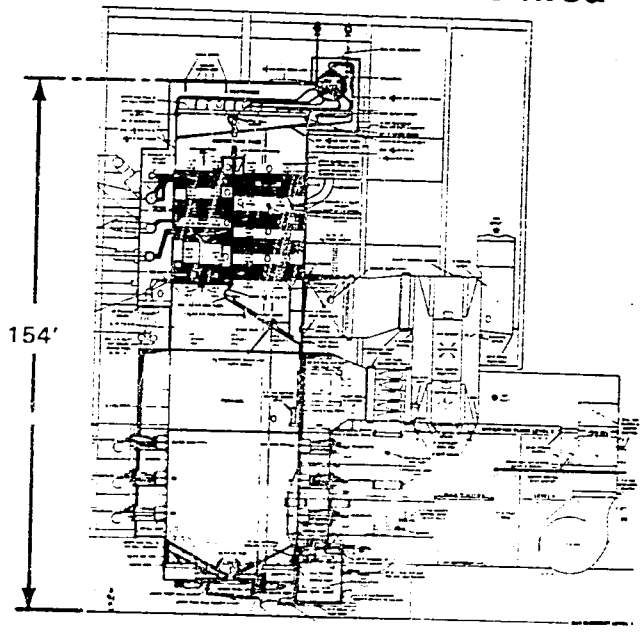
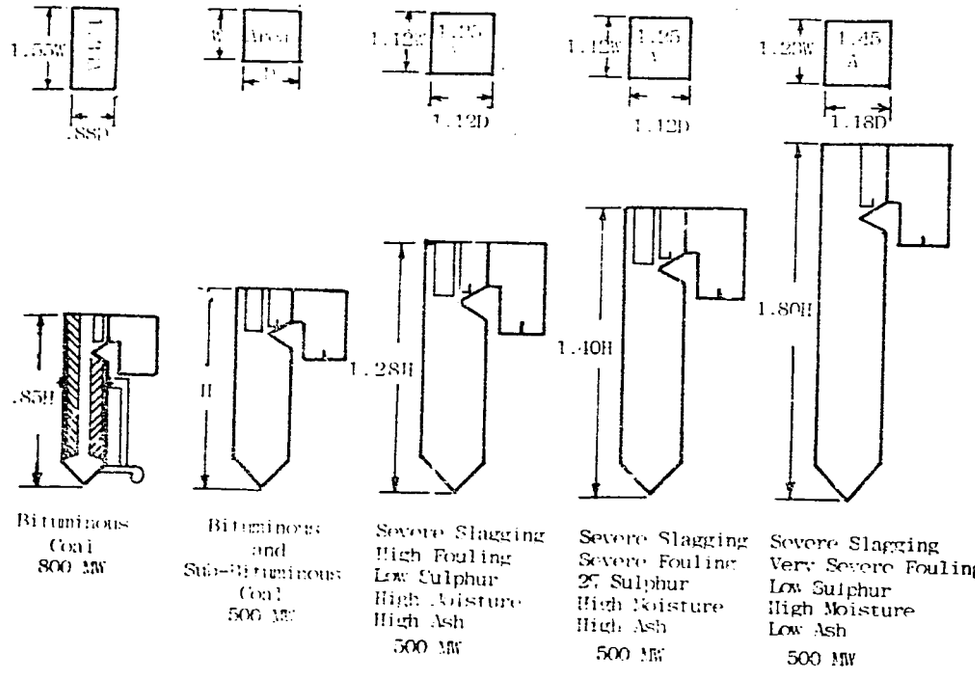

Gas fired
154'

FIGURE-8



EFFECT OF FUEL SOURCE ON BOILER SIZE FOR PULVERIZED COAL FIRING

TABLE-4

AGENCY CONDUCTING ANALYSIS	MOISTURE %	ASH %	VOLATILES %	SULPHUR %	FIXED CARBON %	HEATING VALUE (BTU/LB)
1. GSP, USBM PITTSBURGH USA, LURGI FRG AND JAPAN CONSULTING INSTITUTE AS REPORTED BY GLIVICE POLAND(1970)	30-40	7.4-15	30-40	3.3-7.5	-	6300-6840
2. JICA CONSULTANTS (1979-81)	25	19.7	28.7	5.9	-	6912
3. COMBUSTION ENGG. OF USA AS SUB CONTRACTORS OF GILBERT COMMONWEALTH INTERNATIONAL INC. USAID CONSULTANTS FOR POWER PLANT FEASIBILITY OF LAKHRA (1985)	30.0	25.5	24.5	4.3	20.0	5140
4. J.T.BOYD(1985) USAID MINING CONSULTANTS FOR LAKHRA MINE FEASIBILITY.	32.64	20.59	24.88	4.25	21.89	5960

LAKHRA COAL QUALITY(AS RECEIVED BASIS)

TABLE-5

	PMDC-2 CE/KDL Ist 50 Tons Raw Coal	PMDC-2 2nd 50 Tons Raw Coal -	PMDC-2 CE/KDL 35 Tons washed From 2nd 50 T. Sample.
Proximate Analysis (As received)	%	%	%
Moisture	30.0	28.79	32.3
Ash	25.5	23.18	12.9
Volatile Matter	24.5	27.82	28.2
Fixed Carbon	20.0	20.21	26.6
Sulfur	4.3	3.49	3.2
HHV	5140	5995	6990
HGI	71	77	67
Forms of Sulfur			
Pyrite	-	2.93	-
Sulphate	-	0.25	-
Organic	-	1.72	-
Total (Dry)	6.1	4.90	4.7
Ultimate Analysis (Dry Basis)			
Ash	36.4	32.55	19.1
H_2	3.6	3.59	4.7
C	40.6	46.94	57.2
N_2	0.7	0.73	1.2
S	6.1	4.90	4.7
O_2	12.6	10.74	13.1
Cl	-	0.55	-

Continued on next page.

LAKHRA COAL ANALYSIS BY COMBUSTION ENGINEERING

TABLE-5 (CONTD)

Ash Analysis (Minerals)			
SiO_2	43.6	41.63	39.0
Al_2O_3	27.2	28.46	22.9
TiO_2	1.9	2.09	1.5
CaO	3.3	3.03	5.3
K_2O	0.7	0.53	0.06
MgO	1.3	1.76	2.3
Na_2O	0.7	0.59	1.2
Fe_2O_3	17.2	16.79	19.3
P_2O_3	-	0.09	-
SO_3	3.9	4.23	6.4
SrO	-	0.19	-
BaO	-	0.07	-
Mn_3O_4	-	0.03	-
Undet.	0.2	0.31	1.6
Base/Acid Ratio	0.32	0.31	0.45
Fouling	0.22 (L)	0.18 (L)	0.54 (H)
Slagging	1.95 (M)	1.52 (M)	2.13 (H)

Ash Fusion

a) Reducing Atmosphere(^{o}F)

Initial	1980	2470	2040
Softening	2430	2530	2350
Hemispherical	2470	2570	2410
Fluid	2520	2616	2440

b) Oxidising Atmosphere(^{o}F)

Initial	-	2610	-
Softening	-	2670	-
Hemispherical	-	2700 +	-
Fluid	-	2700 +	-

LAKHRA COAL ANALYSIS BY COMBUSTION ENGINEERING

coal has been found to be of severe slagging and medium to high fouling nature. Several factors cause these properties in coal. Most important are the mineral constituents found in the ash. The ash analysis of Lakhra coal alongwith slagging and fouling indices is given in Table 6. Fig. 9 shows the slagging Index of different coals. Lakhra coal falls in the last category, which is high to severe slagging. Fig. 10 shows the fouling index of coals. Lakhra coal falls in the category of mederate to high fouling.

The propensity of severe slagging and medium or high foulding needs a low temperature of the tube metal, carrying water or steam. Therefore the furnace temperature has to be kept low. This condition can be attained by enlarged dimensions of the furnace and high excess air of at least 20 to 25 %. Appropriate number of soot-blowers located at suitable places will further help in avoiding build up.

Fig. 11 shows the difference between the strong deposit of the same coal around a tube that is carrying 1050° F steam and the loose deposit around another tube carrying 900° F steam. It will be seen that the deposit on the tube of 900° F is much easier to remove than in the case of 1050°F.

In the light of these studies, it would be necessary to design Lakhra boilers with large furnaces operating on a pressure of 1800 psig (125 kg cm^{2}) and a temperature of 950° F (510° C). The flue gas velocity will be kept low i.e. 40-50 ft/sec (12 to 15 meter/sec) to have minimum erosion. Use of acid resisting materials and high grade steel will be necessary in many parts of the boiler to avoid corrosion, particularly at the back end. With these design criteria the boilers are expected to operate satisfactorily for well over 80 % of the time of the year, although the efficiency will have to be sacrificed by 1 to 2 %.

(d) Coal Washing Tests

Roberts & Schaefer Company was appointed as sub-contractors by GCII to determine the cleanability of the Lakhra coal. This task was split into two operations. One operation encompassed laboratory investigations of a three tonne sample from Lakhra mines and the other envisaged the shipment of a 50 tonne raw coal sample for washing in a commercial heavy media cyclone washery. In these operations J.T. Boyd Company, the mining consultants also participated.

The washing was carried out in East Fair-field washing plant in Youngstown (Ohio) in May, 1985. The plant results indicated that total cleaning

TABLE-6

SAMPLE ANALYSIS (% IGNITED BASIS)	SEAM NO.2 W-A2	W-B2	W-C2 WEST AREA	ARITH AVERAGE	SEAM NO.1 W-A1	W-B1	W-C1	ARITH AVERAGE
SILICON DIOXIDE	37.31	33.68	45.06	38.68	38.01	32.62	47.68	39.44 (ACID)
ALUMINIUM OXIDE	20.06	19.66	20.93	20.23	20.84	20.84	19.62	20.29 (ACID)
TITANIUM DIOXIDE	2.21	2.04	2.16	2.14	2.07	2.15	1.88	2.03 (BASE)
CALCIUM OXIDE	3.52	2.64	3.88	3.35	2.80	2.88	3.06	2.94 (BASE)
POTASSIUM OXIDE	0.54	0.48	0.76	0.59	0.57	0.55	0.58	0.57 (BASE)
MAGNESIUM OXIDE	2.10	1.42	0.79	1.44	1.70	1.64	2.54	1.96 (BASE)
SODIUM OXIDE	0.74	0.65	0.48	0.62	0.58	0.64	0.32	0.51 (BASE)
FERRIC OXIDE	25.53	33.60	19.11	26.08	26.11	33.37	17.79	25.76 (BASE)
PHOSPHORUS PENTOXIDE	0.64	0.68	0.66	0.66	0.76	0.72	0.55	0.69 (BASE)
SULFUR TRIOXIDE	6.10	4.80	4.98	5.29	5.18	4.65	5.28	5.04 (ACID)
PHOSPHOURS(%DRY BASIS)	0.078	0.091	0.120	0.096	0.098	0.092	0.106	0.099
SLAG VISCOSITY(T_{250} °F)	2280	2210	2460	2317	2300	2200	2470	2323
SLAGGING INDEX	(S) 4.49	(S)5.86	(S) 3.10	(S) 4.48	(S) 4.63	(S) 6.97	(S)2.69	(S)4.70
FOULING INDEX	(M) 0.40	(M)0.46	(L) 0.18	(M) 0.34	(M) 0.30	(M) 0.45	(L)0.11	(M)0.29

MINERAL ANALYSIS OF ASH
BY FOYD

Figure 9

Slagging Index

Rs = Base/Acid x S

Slagging Classification	Slagging Factor Rs.
Low	0.6
Medium	0.6-20
High	2.0-2.6
Severe	2.6

Figure 10

Fouling Index

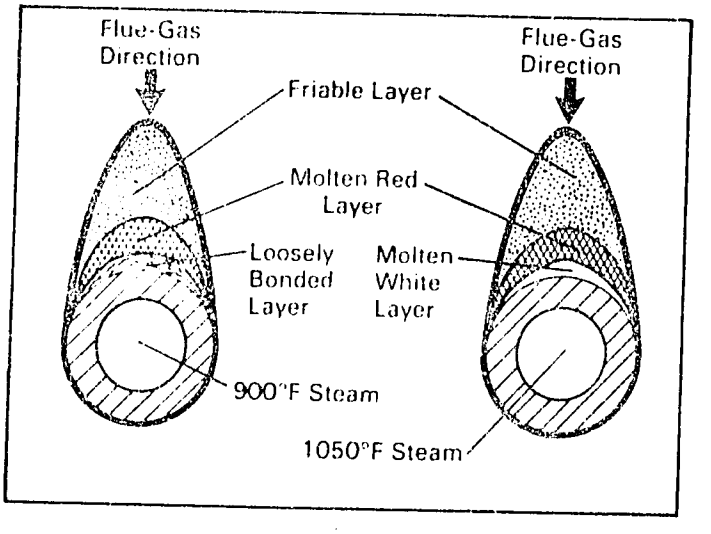
$Rf = Base/Acid \times Na_2O$

Fouling

Potential	Index Rf
Low	< 0.2
Medium	0.2-0.5
High	0.5-1.0
Severe	> 1.0

FIGURE.11

Tube Metal Temperature Effect on Deposition



through wet process at a high specific gravity of separation (1.87) can reduce the ash burden by 40 % and sulphur content by 20 %. It can also improve the heating value by 1160 BTU/pound or 644 kcal/kg. But the coal quality gets downgraded by exposure to moisture. Moreover, there is a substantial loss of coal during washing thereby resulting in reduced BTU recovery. Therefore more raw coal will be needed to produce the same energy and the benefits accruing through washing would by and large be offset.

The washed coal was also taken to the KDL laboratories of Combustion Engineering for another burn-test on the pattern of raw coal described earlier. It was seen that the slagging and fouling properties of the washed coal were worse than those of raw coal. On these considerations, the use of washed lignite in the Lakhra boilers has not been recommended for the present.

e) Capital Cost

The capital cost calculated by the consultants is as given below:-

Unit No. 1 (350 MW)

	(Million Dollars)
Local	270.252
Foreign	299.395
Custom Duty	142.205
	711.853

Unit No. 2 (350 MW)

Local	101.676
Foreign	295.410
Custom Duty	131.034
	528.121

Total Cost (700 MW)

i) Without Custom Duty	966.734
ii) With Custom Duty	1239.974

It would be absolutely in the interest of the country if the custom duty was waived to improve the financial viability of this project, which would encourage the use of an indigenous fuel on large scale in the underdeveloped district of Dadu in Sind.

The GCII also had a good look at the existing training facilities in Pakistan in general and the WAPDA's thermal power plants in particular. They have recommended a sizeable programme of training for WAPDA staff in the field of design, construction, operation and maintenance of coal-fired power plants. They have also suggested strengthening of the coal power projects department so that a proper institution could be built to install Lakhra power station and other large coal-based power plants in Pakistan.

Environmental Impact Assessment

This task was divided into two parts. The first part consisted of preliminary study of the existing pollution level and meterological conditions at Lakhra, Jamshoro and surrounding areas, design of environmental data monitoring equipment and its installation. This task was assigned to TAMS of New York, who made their initial visit

in August 1984 and completed the installation of equipment in May 1985. WAPDA staff was trained in the operation and maintenance of the computerised equipment and valuable data started getting collected on 24 hour basis. This equipment would be a permanent installation at the two sites. Several new monitoring stations will be needed in future to constantly monitor the environmental impact of the power plant after it comes into operation.

The second part consisted of an examination of the data and the impact that the mine and the power plant will have on the environment near and away from Lakhra mines and the three potential sites of the coal-fired power plant. Messrs Enviroscience Engineers (ESE) of Florida were appointed consultants in July 1985 for Environmental Impact Assessment. They started their work in August 1985 in close coordination with the mine and power plant consultants.

The inputs received by them were utilised in performing a detailed Air Modelling Screening Analysis for the Lakhra coal-fired plant comprising two units of 350 MW each. The following four cases were considered:-

Case I Two 350 MW coal units W/Single 190 M Stacks - No FGD (Flue gas Desulphurisation).

Case II Two 350 MW coal units W/Dual flue 190 M (larger diameter) stack - No FGD.

Case III Two 350 MW coal units W/Single 190 M Stacks and Partial FGD.

Case IV Two 350 MW coal units W/Dual flue 190 M (larger diameter) stack and partial FGD.

The results of the detailed screening analysis were:-

Average Time	Maximum SO_2 Impact (microgram per cum)			
	CASE I	CASE II	CASE III	CASE IV
1-hour	9971	6101	7836	4173
3-hour	3339	2034	4234	1391
24-hour	482	335	529	216
Annual	30	16	24	15

These results suggest that the maximum 24 hour SO_2 impact will not exceed the World Bank guidelines of 500 microgram per cubic meter. However, having one combined chimney of a larger diameter instead of two independent chimneys for the two power units will reduce ground level concentration by 31 %. In other words, it will not be necessary to provide equipment to remove sulphur dioxide from the flue gases, if a single stack of larger diameter is used for two units of 350 MW each. Another major source of environmental pollution can be the flyash produced by the burning of pulverised coal. To control the emission of flyash, high efficiency (99.3 %) electrostatic precipitators will be used before the chimney.

Impact on the surface and groundwater was also studied and no harmful effects were determined as the wastewater from the power plant will be discharged to on-site ponds to be developed both at Khanot and Lakhra and recycled to the process or allowed to get evaporated. Leachate through

underground areas will be able to reach the river Indus in 500 years from Khanot and 5000 years from Lakhra.

Social Soundness Studies

Dr. Professor Helweg of USA supported by two other anthropologists was appointed in late 1984 to study the social soundness of the two projects. The team visited the site of the mine and the power plant and met the labour working in the private and public mines. They also held meetings with the officials of the Provincial Government, WAPDA and other organizations. They reported that most of the labour to work in underground mines will be migratory from Swat and other areas of NWFP. The semi-skilled and skilled labour for the open-pit mines and the power plant will be available from Sind and Punjab. The project will affect very few inhabitants at Lakhra and Khanot and create better living conditions for the local population. The backward area will be developed and important infrastructure such as schools, hospitals, roads, mosques etc. will be created that could be shared by the existing and new population. In short the implementation of Lakhra project will provide Pakistan with a unique opportunity to enhance the economy and lives of its people.

Economic and Financial Analysis

M/s ICF-Inc. of Washington were appointed in April 1985 to prepare an economic and financial analysis of the integrated project of Lakhra coal mine and the coal-fired power plant. They have been working in close co-ordination with the coal mine and power plant feasibility consultants as well as the environmental specialists.

ICF adopted the following approach in the study to select the optimal Lakhra Project Configuration and evaluate its economic feasibility:-

i) Assessment of the need for a baseload coal-fired power plant.

ii) Examination of various Lakhra Project Configurations and Identification of the Optimal Choice.

iii) Comparison of Lakhra with imported coal and imported oil alternatives.

iv) Estimation of the IRR of Lakhra Project.

Internationally accepted formulas and methods were applied in the study of all the items mentioned above. Load forecasts were examined in the light of historic load growth, GDP Growth and elasticity factors were applied. Alternative projections for electricity growths were taken into account. Least Cost Generation Modelling Results of GCII were kept in view. Inputs of consultants for capital and operating costs of the mines and power plant, cost of coal per tonne, heating value and other qualities of coal, cost of coal, transportation, environmental impact etc., were factored in and a rationale for appropriate project configuration was developed. Advice of the World Bank was taken from time to time. Power Plant locations, plant characteristics, mining plans

and institutional arrangements were considered.

The issues raised by the potential donors i.e. World Bank, Asian Bank and USAID were given deep thinking.

Economic analysis of the project required that the true social costs of the project be compared with the true social benefits. Distortions in prices caused by government controls and tariffs were worked out to calculate the true social costs and benefits.

The estimated economic costs (including shadow prices) for the total bus bar costs annualised in terms of 1985 dollars for some of the alternatives of interest are as follows:-

	Levelised Bus Bar Cost	
Discount Rate(Real)	5 percent	10 percent
Lakhra (700 MW) No Scrubber	4.05	4.84
Lakhra (700 MW) W/Scrubber	4.68	5.72
Lakhra (300 MW) Underground	3.75	4.77
Imported coal	4.25	5.11
Imported oil	5.44	5.57

These estimates include the following imported fuel cost assumptions (in 1985 Dollars):

Furnace Oil:	20.50/BBL in 1990, escalating at 3 % discount.
Imported Coal:	60/tonne in 1990, escalating at 1 % discount.
Lakhra Coal:	28/Tonne at 5 percent discount rate.
	34/tonne at 10 percent discount rate.

The scrubbing alternative is 80 percent. The drag lines are new equipment.

No taxes or royalties are included in the above economic analysis.

It is concluded that the project consisting of a surface mine producing 4 million tonnes of coal per annum, a small underground mine to supply 0.3 million tonnes per annum and a power plants of 2 x 350 MW using the Lakhra coal located at site will be technically, financially and economically feasible besides being socially and environmentally sound. It will boost the economy of the country, effect savings in foreign exchange and provide great job opportunities. This project will be the fore-runner of many large-sized coal-based thermal generating units operating as base-load plants throughout the year. The reduction of generating capability at hydel projects during low water months, causing mass-scale load shedding will not be felt, the industrial production will not suffer and the domestic consumer will not face black-outs.

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APPROACHES FOR RECOVERING SULFUR FROM PAKISTANI COALS AND THE PRODUCTION OF SULFUR CONTAINING PRODUCTS

Lloyd Winsor
Dravo-Gibbs & Hill
New York, New York

INTRODUCTION

Dravo-Gibbs & Hill has been in the forefront of coal beneficiation, and has extensive involvement in coal gasifiction and flue gas desulfurization technology, the subjects discussed in this paper. Although all three technologies can be used to remove sulfur from coal, only one of these, flue gas desulfurization, can be considered cost-effective for Lakhra coals, due to their BTU content and chemical properties.

Coal beneficiation, which does reduce most of the inorganic sulfur, depending on the type of process used, yields a sulfur waste product which is too contaminated for further use. Coal gasification, which can also be used to extract sulfur, is too expensive and can only be justified in limited circumstances, especially resulting from declining oil and gas prices. Therefore, this paper will focus on flue gas desulfurization and sulfur recovery processes.

Charts I and II provide an overview of coal beneficiation and coal gasification technologies.

History and Status of Flue Gas Desulfurization (FGD)

There are approximately 120 flue gas desulfurization systems in operation in the U.S.A., about 100 in West Germany, about 50 in Japan and a few dozen in the rest of Western Europe. In the U.S.A., there are approximately 50,000 MW being "scrubbed" for SO_x reduction; an additional 12,000 MW are in construction and about 25,000 MW are in planning and engineering stages. In West Germany, there are about 30,000 MW in operation and design.

Approximately two-thirds of the U.S. operating systems are limestone throw-away, one-third lime throw-away, with a few regenerable (recovery) types in use, including those based on Wellman-Lord technology.

In West Germany, almost all the systems are lime or limestone and produce gypsum. A significant number of the U.S.A. limestone systems oxidize the product to produce gypsum.

Sulfur recovery systems, mainly those that produce a saleable product such as sulfur, sulfuric acid or gypsum, are much rarer. Of the approximately 300 systems operating or being constructed worldwide, only about 10% produce a saleable product.

History of Flue Gas Desulfurization (FDG)

During the 1930's, a few power stations in the United Kingdom used simple water scrubbing for stack gas cleanup. These were operated for several years, using the natural alkalinity in the water to react with the SO_2. Activity languished for some time due to World War II and lenient environmental laws. During the 1960's, laboratory and pilot work in the U.S.A., Japan, West Germany and other countries accellerated, and many systems were researched, both throw-away and recoverable. During the late 1960's and early

LEVELS OF COAL PREPARATION

LEVEL & BRIEF DESIGNATION	SCOPE	YIELD WEIGHT %	RECOVERY BTU %	REDUCTION POTENTIAL		WORK DONE ON RAW COAL*	TYPICAL CIRCUITS & EQUIPMENT USED	REFUSE	COMMENTS
				ASH	SULFUR				
A ABSENCE	NO PREP.	100	100	NONE		NONE - SHIP ROM COAL	NONE	NONE	NOT GENERAL PRACTICE
B BREAKING	TOP SIZE CONTROL ONLY	98-100	100	NONE TO MINOR	NONE	CRUSHING TO 4" OR LESS AND REMOVAL OF COARSE REFUSE	SCALPING SCREEN, CRUSHER, ROTARY BREAKER	DRY LUMPS AND TRASH	GENERAL PRACTICE ON ALL ROM COAL
C COARSE	COARSE BENEFICIATION	2-85	90-95	FAIR TO GOOD	NONE TO MINOR	LEVEL B FOLLOWED BY DRY SCREEN 1/8" X WET BENEFICIATE 1/8" ONLY; SHIP 1/8" AS IS.	SAME AS LEVEL B PLUS VIBRATING SCREENS, HGS, HEAVY MEDIA VESSEL OR CYCLONES, DEWATERING THICKENERS, FILTERS	1/8" DRAINED 28M DEWATERED	USED WHERE 1/8" FRACTION FAIRLY CLEAN OR MUCH ROCK PRESENT IN 1/8" FRACTION.
D DEBRIGRATE	FINE BENEFICIATION	60-80	80-90	GOOD	FAIR	LEVEL B FOLLOWED BY WET SCREEN 1/8" X WET BENEFICIATE 28M; DISCARD 28M-0	SAME AS LEVEL C PLUS CONCENTRATING TABLES OR HYDROCYCLONES, SOME THERMAL DRYING	1/8" DRAINED 28M DEWATERED 28M PONDED OR FILTERED	USED WITH COALS HAVING GOOD WASHABILITY CHARACTERISTICS.
E FLOTATION	VERY FINE BENEFICIATION	60-80	80-90	GOOD TO EXCELLENT	FAIR TO GOOD	LEVEL D PLUS WET BENEFICIATE 28M-0	SAME AS LEVEL D PLUS FLOTATION CIRCUITS, THERMAL DRYING PREVALENT	SAME AS LEVEL D EXCEPT MORE FINES.	USED WITH COALS HAVING EXCELLENT WASHABILITY CHARACTERISTICS
F FULL	FULL CLEANING	60-80	85-95	CLEAN COAL STREAM EXCELLENT MIDDLING STREAM NONE TO FAIR		LEVEL E AFTER GREATER THAN NORMAL SIZE REDUCTION AND SEPARATION INTO TWO STREAMS CLEAN COAL AND MIDDLINGS.	SAME AS LEVEL E PLUS ADDITIONAL SIZE REDUCTION.	SUBSTANTIALLY SAME AS LEVEL E	TWO OR MORE WASHED COAL PRODUCTS OF DIFFERENT QUALITIES ARE OBTAINED

*COAL SIZES SHOWN ARE TYPICAL BUT WILL VARY SOMEWHAT WITH COAL AND PROCESS SELECTED

CHART I

GASIFICATION PROCESSES

- TEXACO
- LURGI
- ALLIS CHALMERS
- COMBUSTION ENGINEERING
- BABCOX & WILCOX
- BGC SLAGGER
- WESTINGHOUSE
- KOPPERS/TOTZEK
- WINKLER

CHART II

1970's, full-scale prototypes were installed at power plants in Japan and the U.S.A. In the U.S.A., these included 400-500 MW units at Kansas Power & Light Co. and Duquesne Light Co., as well as a smaller unit at Arizona Public Service Co.

There was some reluctance by utilities to adopt this developing technology, which did have serious shortcomings, namely; scaling, fouling, corrosion and other operational problems. Early availabilities of the prototype and first generation systems were often less than 50% and equipment breakdown and failures were common. However, during the 1970's, research and development resulted in improved availability and reliability. By the late 1970's, availability increased to the 80-100% level for many systems and some second generation plants started operating.

By 1980, second generation FGD systems were operational with better than 90% availability and third generation plants were starting to come on line. Some of the throw-away systems employed magnesium compounds to enhance performance. New regenerable systems were being developed and dry scrubbers using spray dryers and wet scrubbers using forced oxidation to produce gypsum were coming on line. Currently, about 90% of the systems in Japan and West Germany are producing gypsum for either disposal or sale; there is a trend in the U.S.A. to go the same route. Figure 1 shows the historic development.

Figure 2 shows the current status of key FGD systems. not all available systems are shown, and costs are approximate, depending somewhat on the plant size. Summarizing these systems, these have been divided into regenerable (i.e., sulfur recovery systems, where a useful product is recovered for sale) and throw-away, where a currently unmarketable product is simply discarded. The case of gypsum by-product can go either way; it can be sold for cement or wallboard manufacture, or discarded as waste, assuming that the gypsum cannot be upgraded for commercial use.

REGENERABLE PROCESSES

Wellman-Lord

This process, in commercial use at several power stations, uses sodium sulfite as the reagent:

$$SO_2 + H_2O + Na_2SO_3 \rightarrow 2NaHSO_3$$

Regeneration is accomplished thermally and is the reverse of the absorption reaction. An advantage of Wellman-Lord is that it is one of the cheaper ways to recover sulfuric acid from SO_2

Chiyoda Thorobred 121

This process, in commercial use at several power stations, uses limestone to make gypsum, which can be sold or wasted.

$$CaCO_3 + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 + CO_2$$

Capital and operating costs are low and the gypsum can be dewatered to almost a dry state.

Sulf-X

This process is in the pilot development state and uses iron sulfide (pyrites) slurry to produce sulfur vapor, which is condensed. Disadvantage is that H_2S may be released during a process disturbance. A kiln is used to make sulfur with coke as the reducing agent.

AI Aqueous Carbonate

Atomics International (Rockwell) uses a spray dryer with soda ash for capture:

$$Na_2CO_3 + SO_2 \rightarrow Na_2SO_3 + CO_2$$

Crushed coal is used as the reducing agent in a step-wise regeneration process:

Reduce: $3/2C + Na_2SO_3 \rightarrow Na_2S + 3/2CO_2$
React: $2Na_2S + CO_2 + H_2O \rightarrow 2NaHS + Na_2CO_3$
React: $NaHS + CO_2 + H_2O \rightarrow NaHCO_3 - H_2S$
Product: $2H_2S + O_2 \rightarrow 2S + 2H_2O$
Regen: $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

FLUE GAS DESULFURIZATION HISTORY

1930's	-	UNITED KINGDOM - WATER SCRUBBING
1930's	-	U.S.A, JAPAN, W. GERMANY - PILOT/DEVELOPMENT
LATE 1960's EARLY 1970's	-	JAPAN - COMMERCIAL U.S.A. - FULL SCALE PROTOTYPES AT KANSAS POWER & LIGHT CO. - LAWRENCE DUQUESNE LIGHT CO. - ELRAMA & PHILLIPS ARIZONA PUBLIC SERVICE CO. - MOJAVE
1970's	-	FIRST GENERATION PLANTS COMMERCIALLY PROVEN; SECOND GENERATION PLANTS IN DEVELOPMENT
1980's	-	SECOND & THIRD GENERATION PLANT OPERATIONAL/DEVELOPMENT; THROWAWAY GYPSUM DOMINANT PROCESS CONTINUED R&D ON RECOVERABLE TECHNOLOGY

FIGURE 1

PROCESS	REAGENT	NUMBER IN USE	BY-PRODUCT RECOVERY	APPROX. CAPITAL $/kWh*	APPROX. O&M ¢/kWh*	STATUS/REMARKS
Weilman-Lord	Na_2SO_3	Several	SO_2-Sulfur	300	3	Commercial - need CH_4 for S making
Chiyoda T 121	$CaCO_3$	Several	Gypsum	150	1.5	Commercial
Sulf-X	Pyrites	0	Sulfur	350	2.2	Pilot
AI Aqueous Carbonate	Na_2CO_3	0	H_2S-S	450	3	100 MW demo. Coke used in molten salt reactor
Citrate	Sodium Citrate	A few	SO_2	450	3	Small commercial
Catalytic/IFP	NH_3	A few	Sulfur	350	2.5	CO/H_2 required
Magnesia	MgO	3	$MgSO_3$-H_2SO_4	300	2	Commercial - MgO Slaking critical; Acid plant req'd.
Lime/Limestone Wet	CaO or $CaCO_3$	200	Gypsum possible	200	2	Commercial - proven Widely used
Lime Dry	$Ca(OH)_2$	About 20	No	125	0.6**	Commercial - proven for low S coal
Dual Alkali	Caustic or Na_2SO_3	Dozen	No	175	1.6	Commercial - proven
Saarberg - Holter	$Ca(OH)_2$	21	Gypsum	175	1.8	Commercial - proven

* Includes capital charges

** For low sulfur coal

FIGURE 2

FGD SYSTEMS COMPARISON

Advantages of this process are that there is no liquid waste stream to be handled and coal is used as a reagent. A 100 MW pilot unit started up in 1983 at Niagara Mohawk Power Co. in New York State.

Citrate

Sodium citrate absorbs SO_2 and then is steam stripped to recover concentrated (95%) SO_2. Further treatment of the SO_2 is then required to produce sulfur or sulfuric acid.

Catalytic - IFP (Institut Francais du Petrole

This process uses aqueous ammonia to scrub SO_2:

$$SO_2 \ \& \ 2NH_4OH \rightarrow (NH_4)_2 SO_3 + H_2O$$

Thermal decomposition reverses the above reaction to regenerate concentrated SO_2. A reducing gas (H_2 + CO) forms H_2S:

$$3CO + SO_2 + H_2O \rightarrow H_2S + 3CO_2$$
$$3H_2 + SO_2 \rightarrow H_2S + 2H_2O$$

A Claus unit then produces sulfur:

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O$$

A disadvantage of the process is that a coal gasifier is required to produce the reducing gas (H_2 + CO). This unit generates ash, tars, oils and wastewater which must be dealt with.

Magnesia

Magnesia, MgO, in an aqueous slurry is used to scrub. This process is commercial at three units of Philadelphia Electric Co. in the U.S.A. The product is then sent to a sulfuric acid plant to thermally regenerate the SO_2 and then produce sulfuric acid:

$$MgO + SO_2 \rightarrow MgSO_3$$

A disadvantage of this process is that some $MgSO_4$ is formed, which requires coke to reduce it to $MgSO_3$, which is then calcined to produce the SO_2. An advantage is that the $MgSO_3$ can be stock-piled.

THROW-AWAY PROCESS

Most throw-away processes produce $CaSO_3$ or $CaSO_4$ as a waste product, which must be disposed of in an environmentally acceptable manner. As a rough guide, about 1 acre of land is required for each MW generated.

Lime - Limestone (Wet)

These throw-away processes were among the first developed and use low cost reagents.

Disadvantages are:

- large land area required for waste disposal;
- scaling, plugging and erosion of components;
- waste product must usually be "fixated" to be environmentally acceptable;
- liquid waste stream from first generation plants.

Second generation plants use spray towers, dual loops, closed loop water systems, magnesium and other additives an forced oxidation to gypsum to overcome some of the process disadvantages. Scaling and plugging have not been reduced to acceptable levels with a better knowledge of the process chemistry and use of additives. Some vendors claim that systems using lime can switch to cheaper limestone with adipic acid additive.

Lime (Dry)

For lower sulfur coal (< 1-1.5%S), the use of spray dryer with hydrated lime results in one of the lowest cost throw-away systems. With higher sulfur coals, high lime usage may offset the lower capital costs. The dry sludge must be fixated or otherwise handled in an environmentally acceptable manner.

Dual Alkali

Either caustic soda or sodium sulfite reagent is used; both are solutions rather than slurries, resulting in reduced erosion. Then, either limestone or lime is used to form $CaSO_3$ and $CaSO_4$.

A disadvantage is that soluble sodium salts are part of the waste sludge. An advantage is higher reliability due to significantly reduced scaling and plugging.

Saarberg Holter

A clear hydrated lime solutions scrubs SO_2 to form $CaSO_3$. Oxidation produces gypsum.

This process has been commercially proven in West Germany and is one of the lower cost processes.

Figure 3 summarises the basis for sulfur recovery in the U.S.A.

ECONOMICS

Next we turn our attention to the economics of sulfur recovery based on burning Lakhra coal in conventional power plants.

The published forecasts of future generation call for 900 MW capacity, which will required 4.6 million tons per annum of coal. This amount could yield approximately 180,000 tons/year of recoverable sulfur.

Based on U.S. sulfur prices, this tonnage could have an annual value of $27 million, given the fact that current sulfur prices in the U.S. are $150/ton. Adding shipping costs, this equates to approximately 8 mills per kWh of Lakhra coal generation which could be spent on sulfur recovrery.

This amount is not sufficient to cost-justify sulfur extraction from flue gases, which costs approximately 27 mills/kWh in the U.S.A. However, the incremental cost of sulfur recovery systems compared to throw-away systems is approximately 10 mills kWh. Therefore, if Pakistan later wanted to go to flue gas desulfurization, the additional cost of sulfur recovery could perhaps be cost-justified. Sulfur recovery economics in Pakistan could be further improved, if the lower Pakistan labor costs (compared to U.S.A.) are factored in and if the SO_2 sorbents required for the process (Na_2CO_3, $CaCO_3$, $MgCO_3$) could be obtainable locally. Manufacture of some of the desulfurization equiment,

BASIS FOR SULFUR RECOVERY IN THE U.S.A.

- HIGH REAGENT TRANSPORTATION COSTS
- LIMITED SPACE TO RECEIVE AND STORE REAGENT
- LIMITED SPACE TO DISPOSE OF WASTE PRODUCT
- SPENT REAGENT DISPOSAL COSTS ARE VERY HIGH
- AVAILABILITY OF A NEAR-BY MARKET FOR THE BY-PRODUCT

FIGURE 3

such as piping, ducts, etc. in Pakistan, could further improve economics. Typical total operating cost breakdown of recoverable flue gas desulfurization systems in the U.S.A. are:

- Capital costs for equipment - 25-35%
- Utilities, including fuel and chemicals - 30-50%
- Operating and maintenance - 25-35%

Finally, the foreign exchange savings which may be achievable by substituting sulfur recovery processes for Lakhra coal instead of imported sulfur, are an additional important consideration which would need to be included in deciding whether to adopt sulfur recovery as part of the electric generation system.

Lakhra Coal and FGD

Lakhra coal has very high ash, mosture and sulfur (3-5%) content. In addition, it is high in alkali metal oxides (4-6%).

This high alkali content, combined with the high sulfur content, could reduce capital and operating costs for throw-away FGD processes that use simultaneous scrubbing for both fly ash and SO_2 removal.

For a regenerable process, Sulf-X which uses pyrites and coal as the scrubbing and regeneration reagent, may prove more economical, due to the high pyrites content of the Lakhra coal. However, this process is still in the development stage.

CONCLUSION

As industrialization proceeds in Pakistan, so will the concerns for environmental improvement also increase. This will lead to consideration of emission controls on power plants. At that time sulfur recovery systems may provide enough overall economic benefits to justify their use.

GASIFICATION AND COMBINED CYCLE POWER GENERATION FROM HIGH SULPHUR PAKISTANI COALS

D. Walton & D. Linton
Foster Wheeler Energy Limited
Power Systems Division
Station Road
Reading, Berks. RG1 1LX

ABSTRACT

Gasification combined cycle power generation is now sufficiently demonstrated for commercial application. The paper discusses the technology status contrasting it with conventional technology, then reviews the benefits of its application with particular reference to Pakistani coals. The technology offers effective sulphur capture, reduced water requirements, efficient plant at smaller capacities and a modular more rapid construction programme.

1. INTRODUCTION

In coal gasification combined cycle power generation, coal is gasified to produce a fuel gas which after treatment is burned in a gas turbine to produce power. The exhaust gases from the turbine pass into a waste heat boiler where steam is raised. The steam passes into a steam turbine to produce additional power (see Figure 1). Advances in gas turbine design are improving the performance such that plant of this type can match the performance of conventional plant.

Some gasification processes are more flexible than boiler designs and can therefore handle a wider range of feedstocks. It is possible to treat the fuel gas to recover sulphur compounds as elemental sulphur and therefore clean combustion can be more readily achieved even from high sulphur coals. The gas turbines can burn both coal derived fuel gas and alternate fuels such as natural gas or distillate oils. The gas turbine combined cycle section of plant could be built in advance of the gasification option if alternate fuels are available, thus offering a lower capital cost and earlier availability of power.

The first plant of this type was built at Lunen in West Germany and operated during the 1970's. More recently with the development of second generation gasifiers there are a number of new pilot/demonstration plants. The most successful is the Cool Water Project at Daggett in California, this plant is rated at 90MW and came on stream in 1984. Smaller plants based on different processes are being operated/constructed by Dow, British Gas Corporation and Shell.

Gasification combined cycle (GCC) plant is now receiving serious consideration for new power generation capacity in the USA and parts of Europe. Cost, environmental and quicker construction schedules are the advantages bringing it forward. Fuel flexibility and the option to use a portion of the fuel gas in chemical processing are further assets. There is still only limited experience with the technology in its integrated form, but coal gasification and combined cycle power generation are well proven and commercial plants are expected soon.

2. COAL GASIFICATION

2.1. Gasification Processes

For efficient power generation at utility scale, oxygen blown gasifiers capable of processing a minimum of 500t/d coal and operating at pressures of about 15-20 bar are required. There are probably about 20 gasifiers at various stages of development to match this specification. These fall into three types: fixed bed, fluid bed and entrained flow. A fourth type, the molten bath gasifier is still at an early stage of development. Of these

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however only a few qualify for commercial application in the near future.

Table 1.

GASIFIERS PROVEN FOR GCC PLANT

Process	Type	Comments
Lurgi	Fixed Bed	Dry Ash
British Gas/ Lurgi	Fixed Bed	Slagging
H.T. Winkler	Fluid Bed	Developed for lignite feed
Texaco	Entrained flow	Slurry feed
Shell	Entrained flow	Dry feed
Dow	Entrained flow	Slurry feed

Table 2.

POSSIBLE GCC GASIFIERS UNDER DEVELOPMENT

Process	Type	Comments
Kilngas	Fixed Bed	Rotary Kiln
KRW	Fluid Bed	Formerly Westinghouse
U-Gas	Fluid Bed	Ash Agglomeration
Prenflo	Entrained flow	Developed from Koppers Totzek

Fixed Bed Gasifiers

The Lurgi and British Gas/Lurgi gasifiers have a high thermal efficiency and carbon conversion. They are robust in operation but require a lump coal feed and are limited in the quantity of coal fines they will accept, although the British Gas/ Lurgi has made advances in this area. Because the raw gas from a fixed bed unit exits at a fairly low temperature around 300°C-600°C (572°-1112°F) it contains quantities of hydrocarbons and condensible byproducts. These liquid byproducts, (essentially tars and oils), amount to roughly 5% of the coal feed and can be sold or recycled.

Fluid Bed Gasifiers

H.T. Winkler, Westinghouse and U-Gas gasifiers produce a clean gas at around 1000°C. They require a crushed coal feed and will tolerate fines. The H.T. Winkler gasifier operates well with reactive coals such as lignites but for hard coa techniques such as ash agglomeration must be employed to obtain an acceptable carbon conversion. Because of the relatively high temperature, the gases are essentially free of condensible by-products.

Entrained Flow Gasifiers

These gasifiers reach very high temperatures in the burner zone (up to 1900°C), and gases exit this zone at about 1400°C. The gas is then cooled by quenching, or heat exchange, or a combination of the two. The method employed will depend on the type of gasifier, the end product of the process and the requirement for steam. The gas cooling must achieve satisfactory solidification and separation of the slag droplets. Extremely high heat fluxes occur in the waste heat boilers.

Air blown gasifiers have been proposed for GCC plant however these technologies are not being developed and demonstrated to the same extent. The lower calorific value gas produced by air gasification is more difficult to combust. Simple cycle designs for gas turbines with air preheat or using diesel engines to fire the gas look interesting for low cost small plant options.

2.2. Coal Properties Affecting Gasifier Selection

There is no doubt that certain types of coal are better suited to certain gasifiers and vice-versa. The most important coal properties affecting gasifier selection are:

Size

The limitations of coal size, particularly with respect to the fixed bed gasifiers, have been mentioned already.

Reactivity

The H.T. Winkler gasifier is really only suitable for reactive feedstocks. Entrained flow gasifiers may also run into problems with low reactivity coals

because of the short residence times. Unless temperatures can be raised sufficiently, poor carbon conversion can result.

Ash

Coals with 35% ash content have been commercially run in dry bottom Lurgi gasifiers, but such high ash coals would produce low efficiency in the Texaco. High ash, high fusion point coals could show poor economics in the BGC/Lurgi Slagger if large quantities of flux are required. Coals with very high ash fusion points could be difficult to slag in entrained flow gasifiers.

Moisture

There is a thermodynamic limit to moisture content above which a gasifier will 'drown', but for many gasifiers there is a practical limit set by the coal feeding mechanism. The H.T. Winkler, U-Gas, Westinghouse and Shell gasifiers will usually require coal drying.

2.3. Fuel Gas Cleanup

To meet emission regulations, the raw gas is usually treated to reduce the sulphur content. This is achieved by removing hydrogen sulphide in a solvent acid gas removal process. In order to carry out desulphurisation the gas needs pretreatment which is different for the various types of gasifiers.

Raw gases from fixed bed gasifiers contain many byproducts such as phenols, tars, oils, naphtha, hydrogen chloride, ammonia, hydrogen cyanide, carbon disulphide and carbonyl sulphide. These could contaminate the solvent and impede the performance of the acid gas removal process. Pretreatment is therefore required for these gasifiers to reduce the byproducts to acceptable levels. The typical process sequence is quench, heat recovery and gas cooling followed by a selexol, rectisol or benzole prewash step.

Raw gases from fluid and entrained flow gasifiers are produced at much higher temperatures and thus contain negligible quantities of tars, oils, naphtha, phenols. However they do contain significant quantities of carbon and ash dust, which may be partly molten. The pretreatment therefore normally comprises high grade heat recovery, to improve the efficiency, followed by a water washing step to remove dust and other contaminants. Further pretreatment may also be necessary for some acid gas removal solvents.

There are many acid gas removal processes available. These have been developed for other processes and an evaluation is usually required to select the optimum process for GCC applications. Solvent makeup, energy requirements, selectivity and operating problems are key factors. Processes usually favoured include Benfield, Selexol, Amine/MDEA (ADIP), Rectisol or Stretford. The hydrogen sulphide from the solvent processes is then further processed to either sulphur or sulphuric acid.

Following acid gas removal the fuel gas is then prepared for combustion in a gas turbine. Typically this involves heating and saturation with water. The steam thus introduced into the fuel gas reduces the NOx produced within the turbine and also contributes thermal and mechanical energy input to the machine.

3. POWER GENERATION

3.1. Gas Turbines

Oxygen blown gasifiers produce a medium calorific value fuel gas of 9-13MJ/nm³ (240-350 Btu/scf) before saturation. These gases can be burned in modified versions of commercially available gas turbines. Only limited experience has so far been obtained but no significant problems are anticipated.

The biggest single factor affecting the overall efficiency of GCC power generation is the gas turbine inlet temperature. As inlet temperatures rise to 1200-1250°C (2192-2282°F), efficiencies approaching 40% (HHV) become achievable. These high temperatures are

achieved through continuing improvements in air cooling, materials and blade design.

Gas turbine selection should not therefore be a problem. However the gas turbine performance is critical to the GCC performance and must be evaluated in the context of the overall plant design.

3.2. Combined Cycle

GCC plant is the same in cycle configuration as gas or distillate fired combined cycle plant. The overall performance is however reduced by the efficiency of the gasification process for converting the coal to fuel gas. The reality is not as simple as this as the steam system for the gasification plant is usually integrated with the steam cycle. The gasification process both uses steam in the gasifier and raises steam in cooling the raw gases. For the fluid bed and entrained flow gasifiers considerably more steam is produced than consumed, so the combined cycle has to be designed to import steam. For the fixed bed gasifiers this is reversed.

3.3. Oxygen Plant

Oxygen blown gasification so far described requires considerable quantities of oxygen to produce the fuel gas. The oxygen plant compressors consume between 6 and 10% of the gross power output of the power station. Fixed bed gasifiers consume less oxygen than the higher temperature gasifiers. Thus the design of the oxygen plant and selection of the driver type is of considerable importance in obtaining high overall efficiency.

An alternative is to use air blown gasification. Air is extracted from the gas turbine air compressor and used as oxidant in the gasifier. The resulting low calorific value gas after treatment is burned in the gas turbine. This method may have the advantage of slightly higher overall efficiency although considerable control difficulties can be anticipated with the highly integrated system.

3.4. GCC Advantages

Whilst a GCC is a relatively unproven concept for power generation it is based on proven technology. Plants can be designed to be simple in operation and give high reliability. They will be sufficiently flexible to operate as part of an integrated distribution network whilst operating at high efficiency at both base load and part load conditions. The multiple steps in the plant lend themselves to modular construction and shorter construction times.

GCC plants can offer the following advantages when compared with conventional plant:-

* Competitive Performance
* Low environmental impact
* Reduced construction time
* Reduced capital cost
* Less than half the cooling water requirement.

These advantages together with the potential for improved performance as the technology develops should secure a future for GCC.

4. TECHNOLOGY STATUS

4.1. Cool Water

In June of 1984, the Cool Water Coal Gasification Combined Cycle Power Plant was brought on line as a coal based power generating facility, producing electricity for customers of the Southern California Edison Company. The plant represents the first commercial scale demonstration of the Gasification Combined Cycle concept for using coal in an environmentally acceptable way. The plant was finished under budget and ahead of schedule with field construction taking only 28 months.

The plant is based on an entrained flow Texaco gasifier using coal water slurry feed. High pressure saturated steam is generated in a radiant and convection cooler. The raw gas is cleaned in a water scrubber and

separated carbon recycled to the gasifier. Desulphurisation is carried out in a Selexol process with the hydrogen sulphide being converted to sulphur in a Claus unit. After reheated and water saturation the gas is fired in a General Electric gas turbine. Further power is generated in a steam turbine from steam raised from the gas turbine hot exhaust gases.

Despite several of the minor startup problems common in new plants, the overall performance during the first year of operation was highly successful. Design performance was equalled or exceeded in most areas (emission, efficiency, availability, etc). A five year programme is now underway to confirm the attractive features of the GCC concept by continuing the demonstration. A full programme of studies with various coal feedstocks including steady state, tests of dynamic response during load following, materials evaluation and environmental analysis is now underway.

For the period up to 1st August 1985 the plant operated 5480 hours, consuming 201,740 tons of coal and producing 505,133MWh of gross power. The plant has been operating at a nett heat rate of 11,500 Btu/KWh compared with a design of 11,300 Btu/KWh. Certain efficiency features have not been incorporated because of the plants relatively small scale and first of a kind nature which result in high design heat rate.

A major incentive for adopting GCC technology lies in the superior environmental aspects. Overall emissions approach or improve upon those that can be achieved with current combined cycle units fueled with natural gas. Emissions data obtained from sampling the stack are given below.

TABLE 3.

ATMOSPHERIC EMISSIONS

	lbs/million Btu coal	
	Test Results	Federal NSPS(1)
SO_2		
Utah coal, 0.5%S	0.036	0.3
Ill. No. 6 coal 3.5%	0.370(2)	1.2
NOx	0.060	0.6
Particulates	0.001	0.03

(1) New Source Performance Standards for coal fired power plants.

(2) Projected results for Ill. coal test scheduled late 1985.

4.2. Dow Syngas

The Dow Gasification Process utilises a pressurised, entrained flow, slagging, slurry fed gasifier with a continuous slag removal system. The process includes a unique heat recovery system which provides high efficiency on low rank coals.

The Dow Syngas project will be a commercial coal gasification plant that uses Dow developed coal gasification technology to convert coal into medium Btu gas for use in combined cycle gas turbines generating electricity and steam. The plant will feed about 2,400 tons per day of low rank coal and produce about 30 x 10^9KJ per day of gas. The gas output is equivalent to about 155MW net.

The project is located within Dow's existing petrochemical manufacturing site near Plaquemine, Louisiana and will be fully integrated with existing power generating units. The schedule is geared to a plant startup in early 1987.

4.3. Shell Deer Park

A Shell Coal Gasification unit (SCGP-1), currently under construction at the Deer Park Manufacturing Complex near Houston, Texas, is the first US demonstration of a technology which is

expected to be initially commercialised for electric power generation. SCGP-1 will demonstrate configurations and equipment, to be used commercially, and is a very efficient route to commercialisation of the process. The coal feed rate will range from approximately 250 tons/day on bituminous, high sulphur coal to about 400 tons/day on wet, high ash lignites.

The demonstration unit will include coal receiving and preparation facilities, a high pressure entrained flow gasifier with high temperature energy recovery, solids removal, and gas and water treating to provide both clean medium Btu gas for power generation and high valued steam. This unit, scheduled for first half 1987 start up, is the culmination of development efforts begun by Shell International Petroleum Mig., Shell Research and Deutsche Shell in 1972 and includes a 6 ton/day pilot plant (1976 start up in Amsterdam, Holland) and a 150 ton/day experimental unit (1978 start up near Hamburg, West Germany).

4.4. British Gas, Westfield

The British Gas/Lurgi Slagging Gasifier represents a commercially available fixed bed coal gasifier operating at high pressure, suitable for the production of medium calorific value gas from a variety of coals. Based on tried and proven technology.it operates at high thermal efficiency. It forms the basis of a robust gasification system which can be used to produce not only a fuel gas, but also substitute natural gas and synthesis gas for many commercially available chemical processes.

British Gas has operated commercial scale slagging gasifiers at its Westfield Development Centre in Scotland since 1975. From 1975 to 1984 a 350 ton/day unit was operated at a pressure of 350 psig. During this period over 100,000 tons of UK and USA coals was gasified in the unit and over 9,000 hours of operational experience obtained. A 90 day run was carried out confirming the reliability of the unit for prolonged commercial usage under guarantee conditions. The programme of work demonstrated that the technology can utilise graded coal with a high fines content. The recycle of hydrocarbon by-products for gasification to extinction has been demonstrated. The technology can meet the high safety and environmental criteria required for commercial usage.

The 350 ton/day unit has now been complemented by a 550 ton/day gasifier. This unit has recently been commissioned. A Rolls Royce 30MW gas turbine has been installed to demonstrate the use of the gas from the gasifier to generate electricity which will be exported to the South of Scotland Electricity Board.

A study has recently been carried out by Foster Wheeler in the UK for the Central Electricity Generating Board to investigate the design and economics of a British Gas/Lurgi slagging gasifier based power station. The study results indicated that efficiency approaching 40% (HHV) could be achieved simultaneously with over 90% sulphur removal and low particulate and NOx emissions.

4.5. Lurgi

The Sasol facilities in South Africa represent the world's largest coal gasification installation. Approximately 27 million tonnes/year of coal are gasified in Lurgi dry bottom gasifiers. The raw gas after cooling and separation of tars and oils is desulphurised in rectisol units before being converted to petrol, jet fuel, diesel and other chemicals by Fischer-Tropsch synthesis. Although dedicated to transport fuel production rather than power production Sasol represents the potential of large scale commercial coal gasification.

The Lurgi fixed bed gasification process is also used in the world's first major SNG plant which is operated by the Great Plains Gasification Associates at Beulah, North Dakota, USA. This plant came onstream in 1984 and processes 530t/h

of North Dakota lignite to produce 5800 GJ/h substitute natural gas.

It should be further noted that Lurgi dry bottom gasifiers were also used at the Luenen 170MW GCC in Germany in the 1970's. Although this plant did not use the same cycle arrangements as previously described it did prove that coal gasification could provide a suitable feedstock for combined cycle power generation.

4.6. H.T. Winkler

Rhenische Braunkohlenwerke and Uhde have been cooperating since 1975 on the development of the H.T. Winkler coal gasification process. The process is a development of the original Winkler process, but operates under elevated temperature and pressure. The pilot plant can operate at up to 10 bars pressure. The HTW process is particularly well suited for operation on highly reactive lignitic types of coals. The first commercial scale unit is currently under construction in West Germany.

4.7. Kilngas

The Kilngas commercial module is located in East Alton, Illinois Power Companies Wood River Generating Station. The plant converts high sulphur coal into clean gaseous fuel, which is burned in the Unit No. 3. steam boiler. The plant is designed to process 600 tons of coal per day. The Kilngas process produces a low Btu gas and operates at around 3 bars g.

5. PAKISTANI COALS

In order to further assess the potential for coal gasification in Pakistan it was decided to send a number of the leading gasification licensors a Pakistani coal analysis and seek their comments on the suitability of their process for the specific coal. It is recognised that a wide range of coals are available in Pakistan and that any specific project might use a different coal with a different analysis to the one selected. However the enquiry was made using an analysis of Lakhra coal, as follows:

TABLE 4.
LAKHRA COAL ANALYSIS

Proximate Analysis	
Total moisture WT%	30.6
Volatiles WT%	26.8
Fixed Carbon WT%	27.5
Ash WT%	14.9
	100.0
Heating value Btu/lb	6890
Grindability	68.5
FSI	-
Ultimate Analysis (DAF)	
Carbon WT%	71.6
Hydrogen WT%	5.7
Oxygen WT%	14.5
Nitrogen WT%	1.2
Sulphur WT%	7.0
	100.0
Calorific Value (Btu/lb)	12854
Size	78.3% Greater than 9.5mm
Ash Analysis	
AL_2O_3	20.3
CAO	2.71
FE_2O_3	21.6
MGO	2.55
P_2O_5	1.36
K_2O	0.64
SIO_2	33.1
NA_2O	2.18
SO_3	9.35
TIO_2	2.66
	96.45
Others	3.55

The responses received are given below.

5.1. Lurgi

Lurgi responded that they had experience in the early 1960's processing Pakistan (Daud Khel) sub-bituminous high sulphur coals in Lurgi dry ash gasifiers making syngas for ammonia production.

Operating experience is reported to be good.

Lurgi stated that the Lakhra coal is similar to the coal previously gasified and that they are confident that it can be gasified efficiently in Lurgi dry ash gasifiers with a steam/air or steam/oxygen gasification agent. Predrying would not be required, but fines should be reduced to 10% less than 6mm.

It was also noted that fines utilisation could be improved by use of circulating fluid bed gasification and/or CFB combustion with in-situ desulphurisation, or a combination of fixed and CFB processes.

5.2. Shell

Shell responded that they could not foresee any particular problems in gasifying the specified coal since they have processed similar coals already. However they assume that drying to 10% moisture (DAF) would be possible. They do not anticipate any difficulties with the ash or high sulphur content.

5.3. British Gas/Lurgi

British Gas responded that although they have no operating experience of this type of coal it appears that it is suitable for slagging gasification. Coals with 4% sulphur have been tested and higher sulphur coal should be manageable. The ash characteristics and analysis are acceptable and only a small addition of flux is needed.

British Gas stated that the coal size range is acceptable but recommend screening to limit the fines to the top of the gasifier to 5% less than 6mm. The undersize coal can be fed as PF with nitrogen or as a coal water slurry to the gasifier bottom, or agglomerated and supplied with the top feed.

5.4. Texaco

Texaco responded that gasification of the coal is technically feasible as demonstrated in pilot plant tests with coals of similar characteristics. The performance will, however, be poorer than than observed in existing demonstration and commercial facilities where higher grade bituminous coals are used. The higher intrinsic moisture content of the coal limits the solids concentration in the coal/water slurry, and results in an excess of water in the gasifier feed and a higher oxygen consumption. Texaco indicate two possible courses of action for gasifying the coals, depending on project economics:-

- accept a penalty on performance, using as received coal.
- include a beneficiation step, to improve slurry properties and/or ash and sulphur contents, and thus performance.

Texaco state that the other coal properties appear satisfactory. The relatively low ash fusion temperatures helping to reduce oxygen consumption.

6. APPLICATION

6.1. Phased Construction

Conventional power plant units are geared to steam turbine size. For maximum efficiency large size single units are usually employed. GCC plant is normally matched to gas turbine sizes where size does not relate so precisely to efficiency. Suitable gas turbines are available with outputs between 30 and 180MWe. The minimum economic size for GCC plant is likely to be of the order of 75MWe. Maximum size becomes a function of modular build up. Security of supply is enhanced by multiple gasifiers and multiple gas turbines and the typical commercial plant configuration is likely to follow this route.

EPRI have been studying phased plant construction using gas turbine units firing natural gas or distillate in open cycle mode for the first two phases then adding the coal gasification step and the heat recovery/steam turbine for combined cycle as the third phase. This enables closer matching of capacity with electricity requirements and leads to lower overall power generation costs

and staging of the capital expenditure. An approach of this type could suit the Pakistani situation with the advantage that the initial gas fired open cycle units supply power within 2 years. The coal gasification and combined cycle units being added as retrofits at a future date. This phased approach can be easily accommodated so long as adequate provisions are made in the initial planning.

6.2. Coproduction

A coproduction process is defined as one in whcih the feed (coal) is converted into an intermediate product (gas), part of which is converted into power via some combustion process (combined cycle), and part can be converted into another product (coproduct) which has a sale value in its own right.

A GCC power plant has many possibilities of being converted into a coproduction plant because gas comprises valuable intermediate products H_2, CO, CO_2 etc. An example of the process is a scheme where part of the gas is to be burned in gas turbines to perform a peak shaving function. The proportion of the gas that is sent to the methanol plant directly affects its size, and the relative proportions of power and methanol that are produced (Figure 2). A complex of this type has a number of advantages.

- The gasifier operates at 100% for most of the time.
- Peak loading is achieved by peak shaving with methanol firing in the gas turbines. This reduces the size of the gasifier, oxygen plant etc.
- Low load operation can be achieved with reduced gasifier turndown.
- Short term load fluctuations can be handled without upsetting steady stage operation of the gasifier.
- Unscheduled outages in gasifer and ancilliary equipment can be handled with 100% methanol firing if necessary.

6.3. Future Developments

The technology and applications discussed earlier in the paper are based on proven building blocks in relatively novel configurations. The economic and technical feasibility of plants designed to these criteria is now being accepted, and the next decade will see the establishment of GCC as a new route for power generation. As with all new products, improvements will emerge and be introduced for this technology. Since it is only just being introduced the scope for improvement is much greater and we should expect more rapid change than with conventional power generation plant. Areas for development include:-

* Increased fuel flexibility.
* More efficient gasification processes.
* Air blown designs eliminating oxygen production.
* Hot fuel gas clean up.
* Higher combustion temperatures in gas turbines.
* Design optimisation including coproduction.

The benefits of GCC are significant and should secure its future. Many of these advantages suit the Pakistani situation and it could have a key role in future power generation strategy for the country.

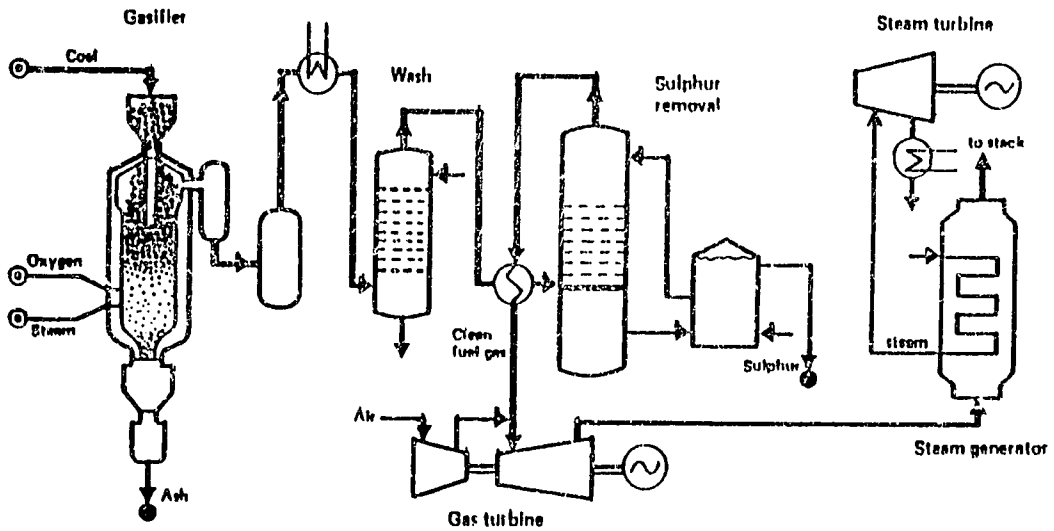

FIGURE 1. FLOW SCHEME OF COAL GASIFICATION COMBINED CYCLE PLANT

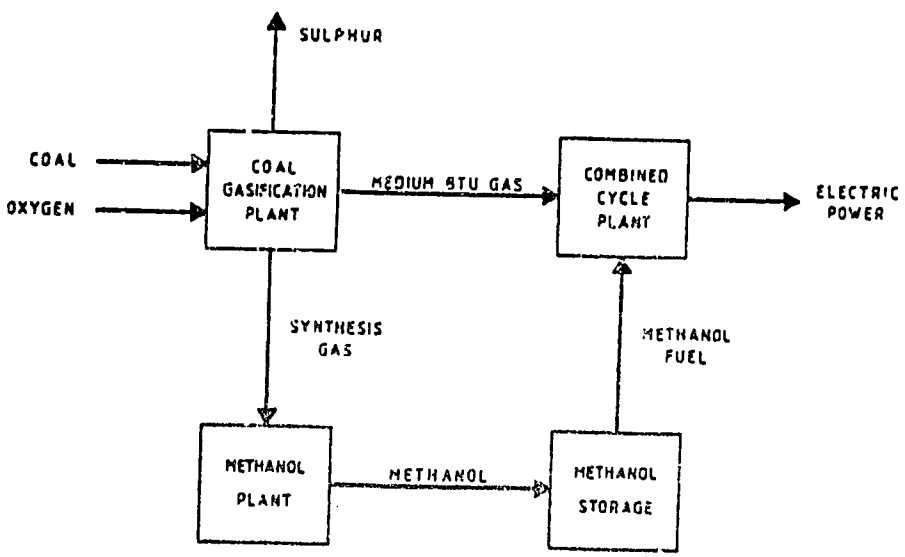

FIGURE 2. COAL GASIFICATION COMBINED CYCLE WITH METHANOL PEAK SHAVING

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USE OF PAKISTAN COALS IN INDUSTRY

Dr. Ahmad Shah Nawaz
Managing Director
Chemical Consultants (Pak) Ltd.
P.O.Box. 126
Lahore, Pakistan

ABSTRACT

The paper considers the potential for use of Pakistani coals in industry; both in current plants and for the future. Since the Karachi Steel Plant represents special problems of its own, it is not included in the discussion.

Chemical Consultants(CHEMCON) undertook a detailed study on the reserves and quality of Pakistani Coals, for use in Industry in 1983-84, for the Government of Pakistan. The paper first summarises the results of this survey.

The survey indicated that recoverable results of all the major coalfields in Pakistan (excluding Chamalang which could not be visited) are around 770 million tons, (of which as much as 520 million tons are inferred) including all the drilled Lakhra area. The quality of representative samples from all the fields, as analysed overseas is given, and variation in the samples collected from representative fields is also given. The Pakistani coals are Characterised by high Sulphur and a high and variable ash content.

The use of coal/coke and petroleum products have been largely confined to direct use in the brick, cement and other industries. Of large scale consumers in 1982-83, as much as 83.2% of such fuels were consumed by the Fertilizer and Cement Industry.

The paper finds that there are no inherent difficulties in installing new boilers using Pakistani coals. Some difficulties could arise in combined bagasse-coal boilers for the Sugar Industry due to lack of lump coals.

In the case of the Cement Industry mixtures of imported coal (or low sulphur furnace oil) and local coal could be used, with local coal content of 40-60%. This could be possible for both old wet process plants and new dry process plants.

Some difficulties would be encountered with current dry Cement plants which have no by-passes.

In the case of the fertilizer industry the use of coal as a raw material would require plants which are 20-25% more expensive, and the economics do not justify the use of coal as a raw material, but Pakistani coal could be used in the boilers.

The use of beneficiation and the economics of conversion of gas for use through existing pipeline systems is also discussed.

1.Historical

Following the formation of Pakistan in 1947, the only fuel resources available were the coal deposits of Baluchistan and NWFP. At this time all boilers in the country used Indian coal and attempts were used to convert to the Pakistani coals. Unfortunately the majority of boilers were designed to use lump coal and hence difficulties arose in this conversion. Since from 1948, imported coal was available this was used.

However for new projects it was decided to try and use Pakistani coals. The most important projects at that time were the PIDC projects and the Fertilizer and Cement Plants at Daud Khel were in close proximity to the coal deposits at Makerwal. It was decided to use Pakistani coal both as a raw material for the fertilizer industry and as fuel for both industries. The plants were brought into operation in 1957-58 and operated successfully until 1971 (Fertilizer Plant) when the extension of the natural gas line to Daud Khel made them more economical on gas. It should be emphasised that a 20,000 KW power station, and both fertilizer and cement factories were run successfully for many years on Pakistani coals. Problems were faced but these were all easily overcome.

The availability of natural gas and Furnace oil (from 1954 onwards) meant that all industry, shifted over to natural gas or furnace oil. It is only recently that interest in Pakistani coal has grown.

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2. Availability and Production of Pakistani Coals.

Pakistan Coalfields exist mainly in Southern Sind, in the areas near to and east of Quetta in Baluchistan, and in the Salt Range of the Punjab on both sides of the Indus, extending into the NWFP. The location of these fields has been given in Fig.2.1.

While there indications of semi-anthracitic coals in Azad Kashmir, there are small and nearly all the coals in Pakistan are semi-bituminous or lignitic coals. In addition the coal seams are small, with the result that the coals contain high ash and since there are pyritic intrusions, they are also characterised as high Sulphur coals.

Geologically the coals are of approximately the same age (Paleocene to Eocene).

The main differences in the coals are in the moisture and ash contents.

The moisture contents are dependant upon the geological environment under which they have been deposited. Thus the Lakhra coals have deposited from a marine environment and are located at depth, and hence contain much more moisture: 20-25% in freshly mined samples, which rapidly reduce to 10% when air dried. The marine nature of these deposits is also seen by the Chloride (Cl) content which is as high as 0.28% in the Southern Lakhra fields. Thus the Lakhra coals, although basically the same as the other coals, when mined have a lower heating value.

The ash contents of the coal is partly inherent in the coal itself, but is also dependant upon the mining methods. Thus samples carefully collected by the Consultants from various mines at the face, and in run of mine samples, gave the following ash content varying from 10% to 60%.

	Ash Content Face Sample %	Ash Content R.O.M. Sample %
Baluchistan		
- Deghari	6.35-8.29	10.52-29.24*
- Sor Range	8.23-9.34	8.50-13.64*
- Sharigh	19.36	27.04*
Punjab		
- Ratucha(East)	39.02	53:86-55.21**
- Central Salt Range.	17.57	29.72-95.55**
- Makerwal	26.93	18.21-41.73*
Sind		
- Lakhra(North)	32.53	33.93*
- Lakhra(South)	38.76	34.64**
- Jhimpir-Meting	28.22	32.15-37.95**

* PMDC Mines.
** Private Mines.

It was noticed, that with the exception of Lakhra where high ash content was almost inherent, the ash content of private mines is much higher that the face samples, particularly in the Punjab. The PMDC mines have a smaller range in Baluchistan, between face samples and R.O.M. samples.

The production of coal in Pakistan for the last few years is given in Table 2.1.

Table-2.1

Coal Production in Pakistan

(Thousand Tons)

	Punjab	Sind	NWFP	Baluchistan	Total
1974-75	378	153	18	765	1314
1977-78	409	186	42	642	1279
1978-79	371	152	42	696	1261
1979-80	461	158	45	841	1505
1980-81	424	288	55	830	1597
1981-82	-	-	-	-	1765
1982-83	-	-	-	-	1855
1983-84	-	-	-	-	1437
1984-85	-	-	-	-	1587

Source: Pakistan Statistical yearbook 1985.

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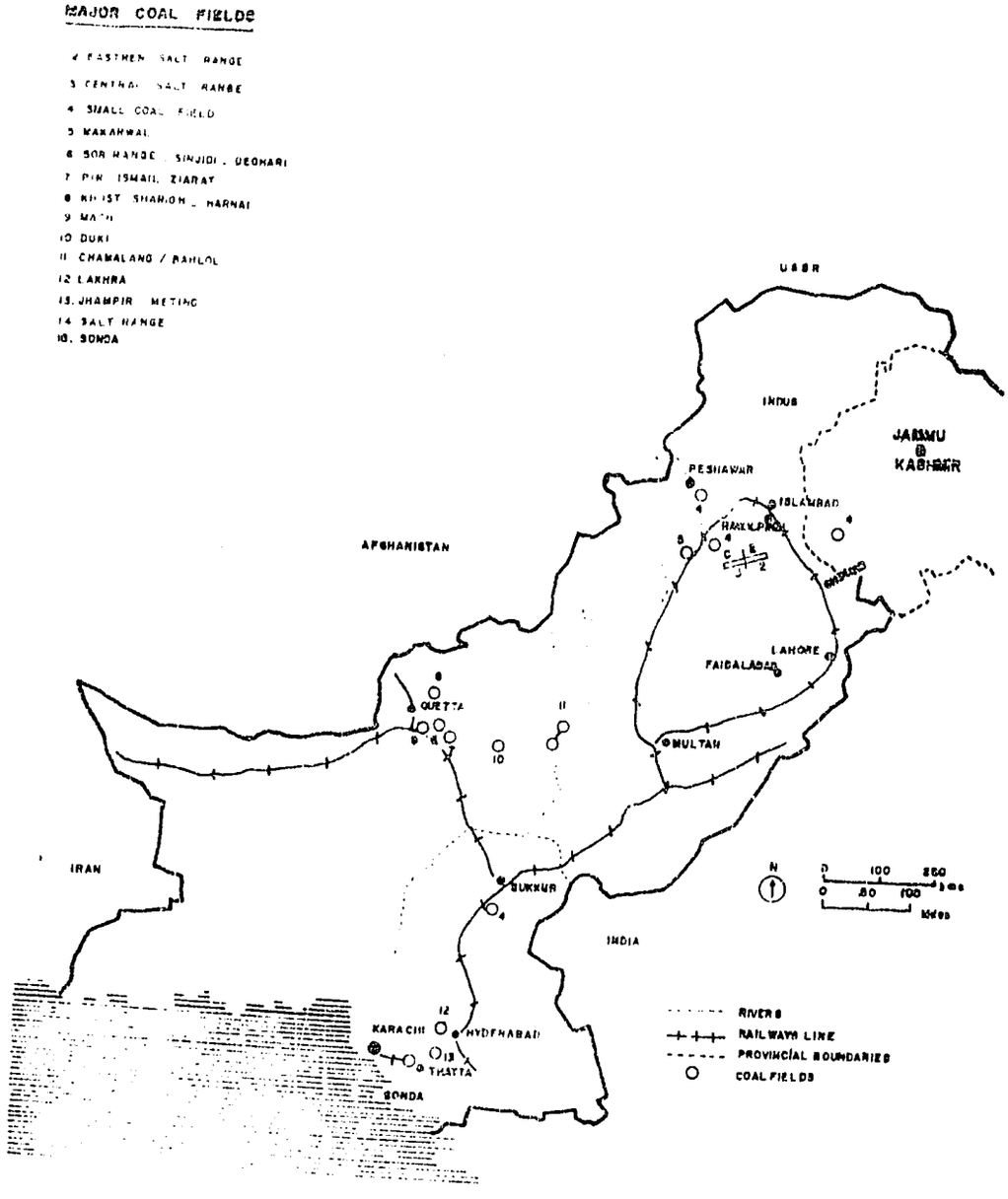
MAP SHOWING COAL FIELDS OF PAKISTAN.

Fig: 2.1



It will be seen that the production in Baluchistan and Punjab is now steady, whereas the production from the newer fields in Sind is rising. This trend is likely to continue. The increase in NWFP is really an increase in the Makerwal-Gulla Khel zone which extends to the NWFP.

3. Reserves.

Chemical Consultants (CHEMCON) in a recent report for the Ministry of Petroleum and Natural Resources carefully examined all available data upto end 1984 and arrived at the estimates of recoverable coal reserves given in Table 3.1.

It will be seen that the total Current Recoverable Reserves, as estimated by CHEMCON are 770 million tons, of which about 120 tons are in the subsidiary area (Northern Area) of Lakhra which are basically inferred reserves.

Table - 3.1

SUMMARY OF COAL RESERVES

(Current Recoverable Reserves) (Million tons)

	Major Coalfield	Measured	Indicated	Inferred	Total
Punjab/ NWFP.	Makerwal - Main	3.0	7.0	2.0	12.0
	- New Seam	-	-	5.0	5.0
	Gullakhel	-	-	2.6	2.6
	Eastern & Central Salt Range.	4.0	36.0	13.0	53.0
	Western Salt Range	-	-	0.36	0.36
	Misc. Cherat.	-	-	0.04	0.04
Balu-chistan.	Sor Range-Sinjidi-Deghari.	7.6	22.9	-	30.5
	Khost Shahrigh-Nakus-Harnai.	0.3	8.3	19.4	28.0
	Mach.	0.5	5.5	7.5	13.5
	Abegum	0.1	2.4	6.5	9.0
	Pir Ismail Ziarat.	0.1	1.7	2.7	4.5
	Duki (Private)	0.1	2.0	3.9	6.0
	Duki (Public)	-	-	2.6	2.6
	Chamalang.	-	-	6.0	6.0
Sind.	Lakhra- Main Area.	62.0	44.0	274.0	380.0
	- Subsidiary Area.	-	-	118.0	118.0
	Jhimpir/Meting.	5.0	10.0	25.0	40.0
	Sonda.	6.0	19.0	32.0	57.0
	Total:-	88.7	158.8	520.6	768.1
	Rounded-off:	90	160	520	770

The main reserves (more than 50% of the reserves in Pakistan) are in the main area (Central Area) of Lakhra, and this area represents the best area for exploitation from the point of view of reserves.

Reserves are not available for the Chamalang Field and for only part of the Sonda Field. The Chamalang Field is of particular importance due to its location and high potential.

4. Quality of Coal and Variation in Analyses.

CHEMCON undertook over 200 analyses of carefully collected samples of Pakistani coals, from all the major fields. In addition representative samples were sent overseas for analyses. The analyses of samples of coal sent overseas for analyses are given in Table 4.1

However the variation within each field was very substantial. Variation of the analyses from some important fields are given in Table 4.2

It will be seen that there are very substantial variations in the Run of Mine (ROM) coals. Face samples showed better results in almost all cases indicating that mining is not well controlled.

5. Petrography

All the coals were petrographically analysed at the University of the Punjab. The results of a few samples from different areas are given in Table 5.1.

Table - 4.1

Representative Analysis of Pakistani Coals

Field	Proximate Analyses				Ultimate Analyses %				Calorific Value Kcals/Kgm		Analysed by
	Moisture	VCM	Ash	FC	C	H	Sulphur	Chlorine	Gross	Net	
Sor Range	14.7	36.4	7.1	41.8	51.2	4.1	5.0	0.02	5534	5235	(A1)
Sinjidi.	10.6	35.9	19.8	33.7	51.2	3.9	4.0	0.01	4865	4602	(A1)
Deghari	12.1	35.5	18.0	34.4	50.9	4.2	2.2	0.02	4907	4622	(A1)
Pir Ismail Ziarat	10.7	38.1	8.1	43.1	60.2	4.5	4.1	0.02	5865	5571	(A1)
Duki	6.2	33.4	17.6	42.9	57.6	4.2	6.0	0.03	5571	5316	(A1)
Makerwal	3.6	37.6	20.8	38.0	-	-	6.11	0.08	5587	-	(A2)
Padhrar	4.2	33.5	21.8	38.7	-	-	9.96	0.04	5519	-	(A2)
Katha	5.2	31.8	32.0	31.0	-	-	5.64	0.06	4454	-	(A2)
Nali	3.5	25.0	47.0	24.5	-	-	5.26	0.05	3398	-	(A2)
Ratucha	3.9	23.2	50.0	22.9	-	-	7.82	0.07	2857	-	(A2)
Lakhra (North)	26.9	25.9	24.3	22.9	34.4	2.9	4.3	0.15	3222	2915	(A1)
Lakhra (Central)	24.9	30.3	17.4	27.5	41.4	3.2	4.2	0.11	3926	3617	(A1)
Lakhra (South)	22.7	32.0	14.2	31.2	45.1	3.3	6.1	0.28	4292	3991	(A1)
Jhimpir-Meting	12.25	33.98	31.23	22.54	-	-	-	-	3961	-	(A3)
Sonda	13.4	30.3	27.5	26.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	GSP
Lakhra(high VCM)	6.5	49.5	12.5	31.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	(A4)

Analysed by (A1) - Holderbank A.G. Switzerland

Analysed by (A2) - N.C.B. Yorkshire Regional Laboratory U.K.

Analysed by (A3) - PCSIR Lahore.

Analysed by (A4) - L & C Steinmuller G.m.b.H, Germany.

Table - 4.2

Variation of the Coal analyses from some important coal fields

	Sor Range	Pir Ismail Ziarat	Dandot	Lakhra
Moisture.	8.64-16.40	5.23-10.04	4.37- 8.77	13.01-20.12
VCM.	30.39-46.70	27.08-41.56	26.65-35.96	17.49-42.80
Ash	5.52-23.67	13.36-43.47	22.64-45.12	28.82-37.27
FC	31.51-43.14	21.96-37.22	21.83-34.66	12.68-31.07
Sulphur	0.75- 3.80	2.6 - 4.87	2.34- 4.21	3.80- 8.56
Calorific Value (Gross Kcals/Kgm)	4937-6507	4437-6063	3245-5445	3408-5012

Table - 5.1

Petrographic Analysis

Mineral composition of gangue of Pakistani Coal Samples

Area	Rock Type	Coaly matter %	Clay %	Quartz %	Pyrite %	Iron Oxide %	Sulphur %	Carbo-nate %	Gypsum %
Shahrigh	Coal	88	6	1.5	0.5	-	-	0.5	-
Sor Range	Coal	90	7	-	0.5	-	-	2.5	-
Deghari.	Coal	93	5.5	0.5	0.3	-	Traces	0.7	-
Punjab (Ratucha)	Coal	62	20	8	10	-	-	-	-
Dandot	Coal	82	15	2	-	0.5	0.5	-	-
Phadrar	Coal	88	8	1	3	-	-	-	-
Makerwal	Coal	81	12	1.5	5	0.5	-	-	-
Lakhra	Coal	74	14	2	3	6.5	0.5	-	-
Lakhra	Coal	82	8	1	5.5	3.5	-	-	-
Lakhra	Coal	60	30	-	6.5	3	0.5	-	-
Meting.	Coal	66	25	2	3.5	3.5	-	-	-

6. Utilisation of Fuels by Industry.

Until 1981-82, virtually all industries along the gas lines were using natural gas, and the rest of the industries, except brick kilns, were using furnace oil. Table 6.1 shows the use of energy by different industries at that time, and the percentage useage by coal/coke.

It should be pointed out that this was the estimated consumption of all industries.

Table - 6.1

INDUSTRIAL CONSUMPTION OF ENERGY 1980-81

	Energy Consumption (%)	Coal Consumption (As % of Energy Consumed)
- Iron & Steel	10.4	58.4
- Brick.	19.6	95.2
- Cement.	13.4	0.5
- Fertilizer.	17.0	Nil
- Textile.	9.2	0.5
- Others.	30.4	8.0

Source: Planning Commission Report. includes coke consumption.

In 1982-83, CHEMCON undertook a study of fuel consumption of all large industries i.e. those using over 1 million cu.ft./day gas or 9000 tons furnace oil/year. The percentage use of energy in large scale industries is given in Table 6.2.

Table - 6.2

ENERGY CONSUMPTION- MAJOR INDUSTRIES 1982-83

	%
- Sugar	4.4
- Textile	1.3
- Fertilizer	66.0
- Cement	17.2
- Others	11.2

Source: CHEMCON.

It will be noticed that as far as large-scale industry is concerned, it is dominated by Fertilizer and Cement industries, which both use the fuel for the process as well as for energy.

The next most important is Sugar but normally this industry is self-sufficient using the by-product bagasse for full, and it is only where bagasse is being used for other purposes (e.g. for paper) that the Sugar Industry requires fuel. The Sugar Industry must be capable of using bagasse and fuel, and any discussion of the use of coal for this industry must take this into account.

Virtually all the other industries use fuel for generating steam, and for these industries, the utilisation of Pakistani coals in steam boilers should be discussed.

In the case of brick kilns, the industry almost universally uses circular kilns and tunnel kilns are not generally used. The circular kilns can be fired from the top with local coals (the size is not important) and the brick kilns use Pakistani coals without any problems, and hence this industry need not be considered further, although it is an important one.

The utilisation of coal in the Metallurgical industry is normally in the form of metallurgical coke. Unfortunately Pakistani coals are generally non-caking with some Baluchistan coals showing light caking characteristics. An acceptable briquetted coal could possible be produced from most Baluchistan coals after low temperature distillation, and subsequent briquetting of the remaining char. Experiments of this type were conducted by a German company in the fifties and sixties and showed positive results. But where coke is required, the use of the Coke ovens of the steel plant still represent the best approach, and the conventional production and utilisation of metallurgical coke in the steel industry still remains the best answer, although the Karachi Steel Plant should consider partial use of Baluchistan coals, and they are fully conscious of this aspect of the use of local coals.

This discussion leads, therefore, to the fact that the use of Pakistani coals needs to be discussed for:-

(a) Fertilizer Industry.
(b) Cement Industry.
(c) Other Direct Firing Industries.
(d) Sugar Industry boilers.
(e) Other Industrial boilers.

7. Fertilizer Industry.

All nitrogenous or complex fertilizer manufacturing units use natural gas as feed stock for their ammonia plants. In addition, natural gas is used in the reformer furnace of ammonia plant as fuel to maintain the reforming

temperatures at desired level, since the steam/methane reforming reaction is endothermic. The fuel requirements of reforming furnace are met either through natural gas or naptha. Direct coal fired reforming furnaces have not been designed so far.

Fertilizer plants are basically plants producing Nitrogen(N) and mixed Nitrogen- Phosphate(NP) fertilizer or plain Phosphatic fertilizers.

In the former case, all the plants first produce Ammonia before converting it to fertilizer (Urea, Ammonium Sulphate, Nitric Acid, Ammonium Nitrate, Nitrophosphates).

In the case of plants producing only phosphatic nutrients, the heat of reaction combined with extra heat generated in making Sulphuric Acid from Sulphur requires very little external heat. Hence these plants are not considered for conversion to coal.

A generalised flow sheet for an ammonia plant is shown in Figure 6.1. This flow sheet is a simplified one. In actual practice, the heat streams, particularly the steam-generation utilisation process is more complicated.

The natural gas is used in all the existing Ammonia Plants at the following points:-

(a) As feedstock to the Reforming Section, for the reforming of the methane contained in the natural gas with steam to produce hydrogen (as well as carbon monoxide).

(b) As a fuel in the reformer furnace.

(c) As a fuel for generating steam which is used throughout the fertilizer plant, not only for the production of Ammonia, but even more important for the production of Fertilizer.

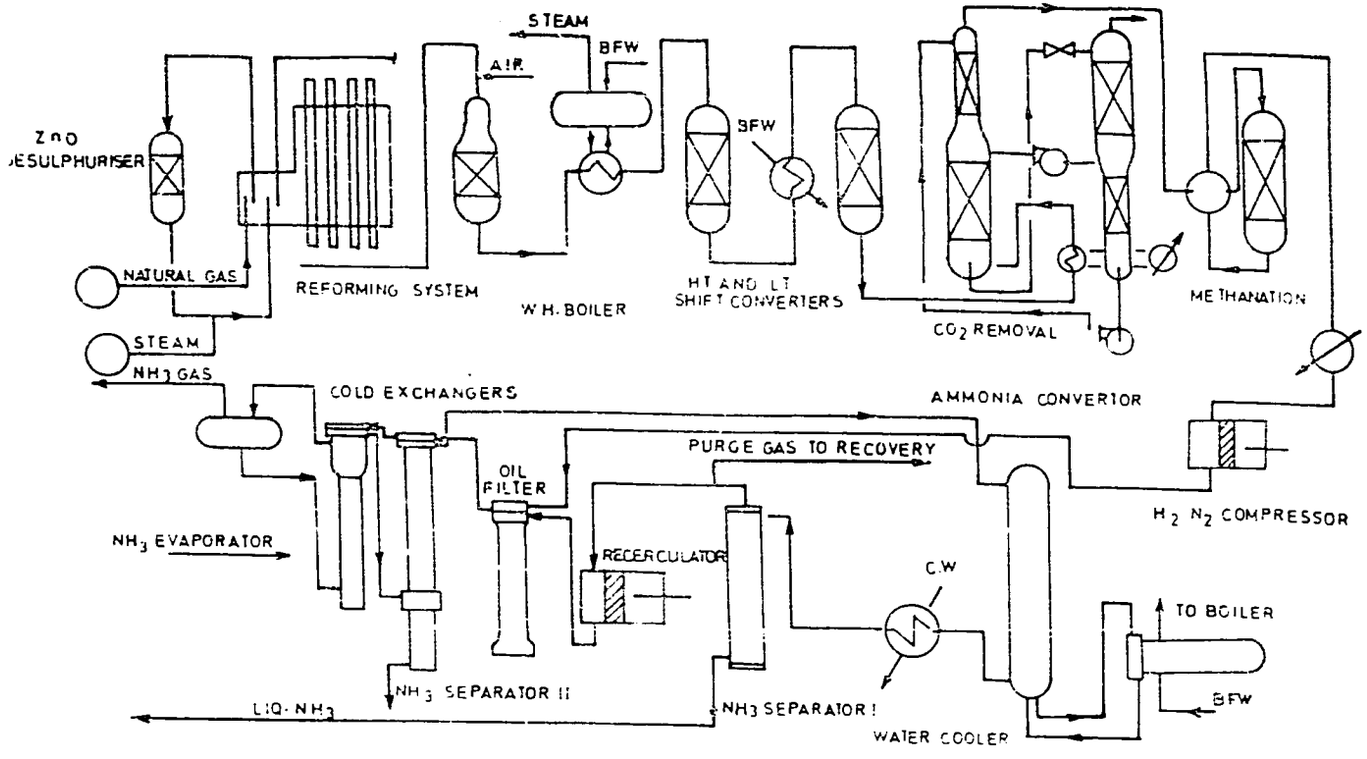
As a feedstock, coal or coal gases cannot be substituted for existing reformers of the Ammonia Plants. In general in coal based Ammonia Plants, a special gasifier is used and not only does this require oxygen to operate, but it also produces a host of by-products which must be removed (oil, tar, phenolic wastes etc.). In addition, the plant is very expensive, and the subsequent sections of the fertilizer plant also need changes due to the inherently different composition of the gas from coal gasifiers, otherwise production would drop by 15-25%.

The reformer tubes need fuel gas as a heating medium, but this gas must be Sulphur-free (a few ppm only) otherwise severe corrosion results. Even Pakistani Furnace Oil cannot be used for this purpose and coal is out of the question.

In fertilizer plants, therefore, coal can only be considered for steam raising.

About 27-30% of the total natural gas requirements of an ammonia plant are utilised as fuel, the rest being consumed as feedstock.

All the existing fertilizer plants except Pak-China Fertilizers, also generate power for their internal requirements. In addition, steam is generated to meet the requirements of fertilizer production units. The Exxon and Fauji Plants are generating power utilizing direct gas turbines, the other Plants have installed steam driven (thermal) power turbines and the boiler capacities are designed to meet the fertilizer producing units steam requirements.



FLOW SHEET FOR STANDARD AMMONIA PLANT

FIG : 6.1

The existing plants boilers can be changed without too much difficulty to the use of either powdered coal or Coal-Liquid mixtures - the latter would be preferable because the actual burning would be easier.

Turning now to new Fertilizer Plants, coal based plants are certainly possible. A 54 tons/day Ammonia Plant was operated at Daud Khel based upon Makerwal coal over the period 1957-71 and all the bugs removed. More recently in India three 1000 tons/day coal-based Ammonia Plants have been operated.

Actual working data of these plants shows that, not only are they 25-30% more expensive in capital costs, but their operating costs are high. This is due to the much higher volumes of gas to be handled when the raw material is pure Carbon (C) in coal as compared to Methane (CH_4) at pressure in natural gas. In addition the waste disposal problems of coal-based plants, particularly the Phenolic liqours pose serious problems.

It is universally recognised, therefore, that using coal as a raw material for fertilizers is not only uneconomical when compared to natural gas, but is also much more complicated. Thus in the future, if coal is to be used it should be confined to boilers (which are discussed below) in the Fertilizer Industry.

8. Cement Industry.

The use of coal in the Cement Industry has had a chequered history.

When the Cement Plants were based on the Wet Process or the long dry process kiln, and there was no Suspension Preheater, the use of coal all over the world was common place. Even in Pakistan the pre-partition plants (Wah, Rohri, Dandot) used coal as the fuel. The first plant built after partition (Daud Khel) also used coal as fuel.

As soon as the Suspension Preheater was developed and a true Dry Process developed, which substantially reduced the fuel consumption, the early dry process plants developed in the 1950's all gave trouble, when operating on coal. Different methods were adopted by different countries in the period 1955-1970 and these were:-

1) In the United States where the use of coal is a maximum, virtually no true Dry Process Plants were set up for 14 years (two small one were set up of which one closed down). The troubles were not all due to the problems associated with coal but also those associated with MgO, and Chlorine.

2) In Germany where the Dry Process was developed by 1975, virtually all the plants were working on oil and gas, and this was to avoid the problems created by coal. At this time SP kilns represented over 50% of the German Industry.

3) In Japan, where the subsequent development of the Precalciner (PC) was undertaken in 1973-74, nearly all the plants had changed to oil.

It will be noticed that until the oil crisis of 1974, there was a considerable reluctance to build coal-based dry process plants. The price of oil internationally was also lower than coal.

After the dramatic increase in oil prices from 1974 onwards, the problems associated with use of coal have mostly been overcome and yet the sensitivity of the Dry Process Plants to variations in both the feed and the ash and sulphur in the coal remain.

Thus the Cement Industry normally represents the largest potential for conversion to coal. In fact with

current world prices of coal, there is a world-wide movement for the Cement Industry to convert to coal. Thus, while in 1974, all the German and Japanese plants were using furnace oil or gas, by 1983, 100% of the Japanese, and 60% of the German Plants had converted to coal.

However, these plants, particularly the Japanese plants use low sulphur coals. World-wide guarantees for sulphur content and heat value from the main exporting countries are given in Table 8.1. It will be seen that the guarantees from major exporters (Australia, South Africa) of coal are generally below 1% sulphur, with heat value around 12,000 Btu/lb. equivalent to about 6,700 Kcals/Kgm coal. In practice coals, such as Australia coals, with around 0.4% sulphur can be obtained (Table 8.2).

In contrast Pakistani coals have high sulphur contents (generally around 5-6%) and in the main fields considered have low heating values as well as high and variable ash content. Thus Pakistani coals represent problems to the Cement Industry.

The problems of the use of Pakistani coals must be separately reviewed for the type of Cement process being used. Basically the two processes are the wet and dry process; the dry process using suspension preheaters (SP) with (SP-PC) or without a precalciner.

8.1. Wet Process Plants

In the case of the wet process, the raw materials enter the Cement kiln as a slurry and at low temperature, with the result that the only major problem is to ensure that the total sulphur content in the clinker is within acceptable limits. The BSS specifications used in Pakistan require 3.0% Sulphur (as SO_3) and since gypsum ($CaSO_4$) is used to control the setting time, the SO_3 should not go higher than 2.5% to 2.7% in the clinker.

Table- 8.1

Specifications of Internationally Traded Coal (International Guarantees)

Coal	Sulphur %	Ash %	Gross H.V. Kcals/Kgm.	Price FOB $/ton
USA (Norfolk)	below 1	10.0	7,220	50.0
	1.0	10.0	6,945	44.0
Poland (Gdansk)	1.0	13.5	6,390	31.0
S.Africa (R.Bay)	1.0	16.0	6,000	34.0
Mozambique (Maputo)	1.0	18.0	5,900	33.0
Australia	below 1	14.0	6,670	45.0

(Basis: January 1984)

Table - 8.2

Normal Characteristics Australian Energy Coals.

	Sulphur %	Ash %	Proximate Analysis Moisture	VCM	FC
A.	0.6	15	8	30	47
B.	0.5	15-20	10	32	38-43
C.	1.0	5	16	30	49
D.	0.5	12	-	22	-
E.	0.5	5	8	36.8	50.2

(Source: Mining Engineering, February, 1980)

From available data, it appears that 70% of the Sulphur fed to the kiln (either as Sulphates in the raw materials or as Sulphur in the fuel) appears in the clinker. It is therefore a simple material and heat balance calculation to work out the anticipated SO_3 in the Clinker. CHEMCON made extensive calculations for wet process plants for the SCCP, and found the results given in Table 8.3.

Table - 8.3

Source of Coal	Plant	Kiln No.	SO_3 in Clinker
Lakhra	Rohri	1	4.67
(Central)	Hyderabad	Avg.(6)	5.29
Pir Ismail Ziarat.	Rohri	1	2.63
	Wah.	3-5	1.97-2.30
Makerwal.	Daud Khel.	Avg.(2)	2.76
Sor Range.	Rohri.	1	2.10

It will be noticed that in the wet process plants near Lakhra, the use of 100% Lakhra coal would not be possible, and blending either with Australian coal, or with low Sulphur furnace oil (dual burner) would be necessary. The general range for use of Lakhra coal is a 50:50 blend with Australian coal.

The other problem is the ash. The petrographic analyses shows a considerable variation in the type of products present in ash.

It follows, therefore, that the ash in Pakistani coals will vary very significantly. No doubt some order can be and must be maintained at the mines to keep the ash down. But the ash varies from point to point and seam to seam and hence control may be impossible.

The only possible method of control would be by blending the coals, using stacking and reclaiming arrangements. For a 1000 tons/day wet process plant, the use of Lakhra coal would involve a pile of 12,000 tons coal for 30 days operation. For a dry process plant, the coal requirements would be halved. It is essential, therefore, to consider blending arrangement for the coal and this is even more necessary if Australian coals are blended.

There are virtually no electrostatic precipators in Pakistani Wet process plants. Therefore no difficulties are likely to arise from SO_x emissions to the stack.

8.2. Dry Process Plants.

Apart from the problems encountered in wet process plants, the following additional problems can be encountered:

(a) The presence of Chlorides in coal. Until the CHEMCON report Pakistani Coals had not been analysed for chlorides. It will be seen that Lakhra coals contain chlorides and in some cases as much as 0.28% Cl. These coals would give trouble in dry process plants which do not have by-passes. Normally without a by-pass chlorides of only 0.02% can be handled, but with by-passes considerably more chlorides can be handled but with a loss of heat. If SP-PC (with precalciner) plants are considered, the gases from the kiln can have a 100% loss in heat efficiency. The chloride containing coals are then burnt only in the precalciner.

Where Sulphur is present either in the raw materials, or in the fuel, as in the case of Pakistani coals, the problem is complicated further as the presence of Sulphur results in the choking of preheaters, just as do the chlorides.

The quantity of Sulphur which can be tolerated in the preheaters has been the result of much study. One method suggested has been (H.M.Gavrett, Mining Engineering, Feb.1980 p.188-189) that the Sulphur: alkali ratio should be such that the value of K in the equation:

$$K = \frac{\text{Total } SO_3}{1.29\ (Na_2O + 0.658\ K_2O}$$

should be between 1 and 1.2.

If this method is used, and even the low Sulphur Sor Range coals are used, calculations for low SO_3 raw material plants, show that the value of K is higher(Cherat Cement 1.89%, FECTO Cement 1.98%) than anticipated thus requiring blending with Australian Coals.

Another method is to limit the SO_3 to 3% at the not meal point, and to designing a by-pass in such a manner that any excess SO_3 is removed through the by-pass. Calculations made by Dyckerhoff Engineering for Zeal-Pak and Rohri Plants show that for Zeal-Pak, the use of all Lakhra coal would require a over 100% by-pass and hence is impossible. Even with Australian coal, due to SO_3 in the feed their calculations show a 17% by-pass. This is, of course, after conversion to dry process.

In the case of conversion of the Rohri Plant to dry process, the use of all Lakhra coal requires a 88% by-pass (using 6% Sulphur in coal, which is high) and no by-pass with Australian coal. In any case it is clear that with an appropriate by-pass the Rohri Plant can use a mixture of Lakhra: Australian Coal, possibly in the ratio of 50:50.

In view of the difficulty of pre-heater choking by the use of local coals in dry process plants, and the necessity of substantial by-pass (not available in existing plant) it is suggested that one plant: the Rohri Plant should be immediately converted to the use of coal (mixtures of Lakhra and other coals) and problems of wet process plants immediately worked out. The plant is thereafter scheduled for conversion to a 1600-2000 tons/day dry process plant, and this should also be designed for coal usage, with appropriate by-pass and a precalciner. After the initial problems have been worked out, the conversion of other dry process plants to coal will be easy.

An important development in the North has been the discovery of substantial oil deposits containing only 0.2% Sulphur at Dhurnal (Salt Range). The result is that Furnace oil in the North is now less than 1% Sulphur. Therefore in the north this could be used in special oil-powdered local coal burners, instead of blending local coals with imported low Sulphur coals. It is suggested that this should be considered for the proposed conversion to dry process of the Wah Plant.

The other problem is that of ash. The range of ash in the PMDC are of the Lakhra field is given in Table 8.4, along with the analysis of a representative sample.

The ash must, of course, be ragarded as a raw material for the Cement Industry and treated as such. For this purpose it must be homogenized by blending either at the field, or at the Cement plant.

Table - 8.4

Lakhra - Range of Ash Analyses

	Range (1)	Representative Sample (2)
SiO_2	8.1 - 44.4	38.97
TiO_2	N.A.	2.21
Al_2O_3	9.5 - 28.7	29.15
Fe_2O_3	17.3 - 70.8	18.87
MgO	0.9 - 7.0	3.24
CaO	1.3 - 12.5	4.17
Na_2O	0.4 - 3.2	1.44
K_2O	0.3 - 2.0	0.56
MnO	N.A.	0.11
P_2O_5	N.A.	0.10
SO_3	1.9 - 16.9	5.4

(1) Core Samples, JICA.
(2) Mined sample by Dyckerhoff Engineering.

Since there is a large variation is in the core samples itself, the variation in the case of Lakhra is not all due to mining.

An alternate method is the gravity separation of the ash, to beneficiate the ash. Work doen by the PCSIR,

Lahore for CHEMCON indicates that different samples can be beneficiated by a wet separation to a fairly steady 14%-19% with a recovery of around 70-75%. This represents another method for controlling the ash. A comparison of economics between the alternative methods indicates that at the level of one plant, homogenisation would be acceptable. For large scale consumption, beneficiation at the field could be considered.

9. Other Industries.

9.1. General.

Where other industries using fuel are concerned, these can broken up into three basic types:-

(a) Coke consuming industries.
(b) Direct fuel firing industries.
(c) Industries using boilers.

9.2. Coke and Low Temperature Distillation.

Pakistani coals are not suitable for making metallurgical coal. They have very low Fixed Carbon, and practically no caking characteristics. The only coals with some caking characteristics are the Shahrigh Coals, and the potential of blending these coals with imported metallurgical coal may exist. Even then, the percentage use of Pakistani coals would be limited.

The possibility does exist of the low temperature distillation of Pakistani coals. Extensive tests were carried out in Germany in the early 1960s and WPIDC projected a plant at that time.However, the high costs of Baluchistan coals at present and the low quality of the finished coke breeze, would not make this economical at present. Briquettes of the fine coke,however,could be used.

9.3. Direct Firing Industries.

Apart from the Fertilizer and Cement industries, there are few industries (apart from coke or charcoal consuming industries) which could use coal directly.

Some chemical industries e.g. Sodium Sulphide, use coal as a direct reducing medium in preference to coke, because of the high rate of reaction of coal. But in such cases, a high Fixed Carbon and low ash is required and Pakistani coals are seldom satisfactory for this purpose. Attempts to use Baluchistan Coals in a Sodium Sulphide Plant in 1964 were not successful although semi-anthracitic coals from Azad Kashmir could be used. Unfortunately a regular supply of such coals could not be arranged, and the coal as-mined contained much more ash than the original samples.

The use of Pakistani coals in Industries using boilers is considered in the next section.

10. Use of Coal in Boilers.

10.1. General.

Most of the industry like fertilizer, petroleum, refineries, petrochemicals, industrial chemicals, pharmaceuticals, sugar, textile,dairy, food and plastics & synthetic fibres install boilers to generate steam for use in process or heating. The Industrial boilers can be designed to fire any type of fuel including coal, gas, oil and even organic matter like bagasse and industrial/organic wastes.

In Pakistan, earlier boilers were installed with coal as fuel. Later on with availability of low period natural gas all boilers were converted gas and all new installation were also based on gas. In mid-seventies with the constrain on natural gas availability most of new installation was designed for dual oil/gas firing or only oil firing. Any size or type of

industrial boiler can be designed for direct or indirect coal firing.

It will not be economical to install boiler of capacities less than 1 MW using run-of-mine coal because of heavy investment in coal handling and crushing/pulverizing equipment. Smaller size boiler can be designed to use directly supplied pulverized coal or coal-liquid mixtures provided they are supplied at reasonable prices and in good quality.

10.2. Lump Coal.

Run-of-mine solid or lump coal can be used in grate or stoker type boilers. Modern stokers for water-tube boilers are highly efficient and very flexible, and can accept a wide range of coals. Strong caking coals with ash of low fusing point should be avoided for mechanical firing, Pakistani coals being friable semi-bituminous coals are not generally "lumpy". Thus, except for some areas in Baluchistan, lump coals are not easily available. The low sulphur lump coal available from Deghari and Sor Range is being used by WAPDA and Army, and Shahrigh coal may be utilized by Pakistan Steel Ltd. Some lump coal could be available from Pir Ismail Ziarat mines.

The bagasse fired boilers of existing sugar industry can be converted to use of lump coal. This is possible only in case of those sugar plants which are selling bagasse to paper industry and will need alternate fuel at prices less than equivalent prices of bagasse sold.

10.3. Pulverised Coal.

There are two ways of firing pulverised coal, direct and indirect.

Practically any fuel, higher or low in either ash or volatile matter, can be successfully fired in powdered form. High-volatile coals, however, on account of their greater ease of ignition and lower cost of pulverization, are better than low-volatile coals or coke. The amount of moisture in the coal is of utmost importance, particularly if driers are not installed. With properly designed equipment, the quality of fuel used may be changed almost at will.

The chief advantages of powdered coal lie in the great flex lity, the high efficiencies that are possible to maintain, and the wide range of fuels which may be used successfully. Coal of all types, from the low-grade fuels, such as lignite or high-ash graphitic anthracitic, to the high rank, high quality bituminous coals have been successfully adapted for powdered-coal firing.

It will not be possible to convert all existing gas/oil fired boilers to coal without ensuring heavy investment in conversion like installation of soot and ashing handling equipment, increase in furnace sizes, coal handling/crushing equipment etc. It is economical to install a new boiler to fire coal.

10.4. Conversion of Existing Industrial Boilers to Coal.

The Sugar Industry had switched over to gas-firing because of convenience and low cost of gas utilization. The Sugar Plants that were releasing bagasse to Paper Industry had changed to alternate fuel but since 1982-83, because of gas curtailment, they have switched back to bagasse and surplus bagasse is being supplied to Paper Mills. The Sugar Industry need not use any alternate fuel (even coal) if they don't have to supply bagasse to Paper Mills.

Those Sugar Plants, which have to supply bagasse to Paper Mills from

their requirements of bagasse as fuel, can convert to coal. The additional cost of using alternate fuel will be passed on to bagasse buyers.

The existing boilers of remaining industries cannot use coal in any form other than Coal-Liquid-Mixture (CLM). CLM is a new technology and is still in infancy stage. Research is being carried out in Europe, USA, Japan and China in the field of CLM preparation, handling, transportation and firing. The present technology is available for use in Pakistan from various process licensors.

The problem of utilization of Pakistan coals in the form of CLM relates only to the low quality of coal. The high ash/high sulphur coals would need extensive investigations to beneficiate these materials to acceptable quality for CLM utilization of the boilers already operating on gas or designed for gas or oil-firing.

Beneficiation processes have been developed in the context of CLM preparation. These proprietory processes may be suitable for Pakistan coal beneficiation.

CONVERTING CEMENT ROTARY KILNS TO COAL FIRING

BY

DR. PAUL HUSKA
TECHNICAL DIRECTOR - FULLER INTERNATIONAL EUROPE S.A.
FIESA-SPAIN

AND

SURINDER K. KAPOOR
VICE PRESIDENT - SALES - FULLER INTERNATIONAL INC.
BETHLEHEM, U.S.A.

PRESENTED AT

THE FIRST PAKISTAN NATIONAL COAL CONFERENCE

SHERATON KARACHI
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OVERVIEW

In a dry process cement plant, the cost of fuel accounts for over 20% of the total cost of manufacturing of clinker. Obviously, the choice of fuel in the cement manufacturing process is an important consideration and makes a significant impact in the cost of production.

After the oil embargo of 1974, coal emerged as the dominant fuel in the cement industry and has continued its leading position since then as the most economical choice of fuel in the cement industry.

Today, over 95% of the 125 cement plants in U.S.A. are operating with coal.

Figure 17 shows the trend of coal use about two to three years ago (1982-83) in the U.S.A., West Germany and the ASEAN countries. In spite of the additional handling and storage costs, the industry has chosen coal as its primary fuel due to its tremendous cost advantage over other fuels. By 1983, 60% of the German plants had converted to coal and almost the entire Japanese Cement Industry had also switched to coal as well.

In Pakistan most of the cement plants currently use oil rather than the indigenous coal mainly due to the high sulfur content of the local coal. Introduction of a significant quantity of sulfur into the kiln system from the coal is not desirable for several reasons, including the operating problems which could be experienced. However, a relatively much higher sulfur content in the coal can be tolerated by designing a suitable sulfur bypass system for the kiln area.

The size of the bypass system will depend upon the total sulfur content in the system from the raw materials and the proposed coal. Most importantly the SO_3 level in the clinker must not be allowed to exceed the permissible level. If the sulfur content of the raw materials does not permit use of (high sulfur) 100% indigenous coal, then a blending of local coal with imported coal or its use in conjunction with oil may be the most viable alternative.

It is not an uncommon practice to blend one, two or three different qualities of coal for firing in the kiln. In some cases depending on the raw materials and other factors it may be desirable to use only imported coal.

Table 7 considers the use of oil, imported coal, local coal or a mixture of the two. Projected savings in each case as compared to the currently used oil is shown. Considerations include:

A. Oil (presently used)
B. 100% imported coal
C. 100% indigenous coal
D. Split [25% import/75% local]
E. Split [50% import/50% local]

As indicated in Table 7, the projected savings based on blending 25% and 50% imported coal with the indigenous coal are also significant. Thus providing an attractive return on investment.

In our opinion it is technically feasible, and socially and economically desirable to convert the cement industry in Pakistan from oil to indigenous coal.

Besides the cost advantages, there are many important national considerations as follows:

- The use of nation's natural resource (coal).
- Development of nation's coal mining industry including additional employment.
- Less Dependence on Imported Fuel.
- Opportunities for service and support industries in the country, relating to the mining, transport and handling of coal.
- Savings in foreign exchange - a valuable national asset.

Currently, the production of cement in Pakistan is approximately five million (5,000,000) tons per annum, and almost all of it is produced using oil as fuel.

Assuming that 75% of the oil used is

imported (25% indigenous oil) further assuming that it takes an average of 1,000 Kcal to produce 1 kg of clinker, the total fuel needed is about 500,000 tons of oil per year, of which 375,000 tons of oil is imported. At a price of about $157/ton for imported oil, the annual outlay in foreign exchange is $59 million. A significant saving when replaced with local coal.

On a direct price comparison basis, even use of total imported coal offers a savings of $19 million in foreign exchange.

The cost of converting to coal firing will vary with the required capacity and the type of system employed, that is, direct, semi-direct or indirect for a particular plant.

While the comparison above does not take into account the cost of the coal system, the net savings in the operating cost will more than justify this investment.

The choice of coal system in each plant will be determined by factors such as coal moisture, the type of pyroprocessing system, heat source, plant layout and safety considerations. In a multiple kiln plant, a single grinding mill using an indirect firing system with multiple firing points may be more cost effective.

The simplest system is the direct fired type which involves the least amount of equipment (no dust collector), simple layout and obviously lowest initial cost. However, in some instances, it is more desirable to use semi-direct or indirect system.

Fuller has been intimately involved with coal for many decades now. As a matter of interest, the first Fuller Kinyon Pump used to convey coal to a coal fired boiler was installed in as early as 1926. Hundreds of F.K. Pumps in the coal firing systems are successfully operating today.

The first precalciner in the world using coal firing was supplied by Fuller in 1974 to National Cement Company in Ragland, Alabama. Since then, Fuller has furnished numerous coal drying, grinding and firing systems for all types of pyroprocessing plants.

These systems are operating successfully in the U.S. Cement Industry and many other countries around the world.

The systems use lignite in Turkey, high ash (35%-38%) low grade coals in India, coke in Canada & U.S.A. and locally available coals in Taiwan, Korea, Canada, Australia, Spain and other countries.

Fuller has the expertise it takes to study, analyze and then develop the most optimum and economical system approach compatible with the overall plant operation.

For the cement industry, coal is no doubt the fuel of today. Fuller is pleased to share the experience gained in this important area and stands committed to be partners in progress with Pakistan's Cement Industry.

PORTLAND CEMENT

Portland cement is primarily composed of a mixture of silicates and aluminates of calcium. The principle compound, present as approximately 50-70%, is tricalcium silicate, $3CaO.SiO_2$, and referred to as C_3S in the industry. This compound reacts readily with water yielding hydration products which give concrete most of its properties, especially the rapid development of high compressive strength.

The next most important cement compound is dicalcium silicate, $2CaO.SiO_2$, or C_2S in the industry notation. This compound, present in cement in the range of 20-40% contributes only to the long term strength of cement, since it reacts slowly with water. This compound continues to react with available water for many years.

The remaining two important compounds are tricalcium aluminate, $3\ CaO\text{-}Al_2O_3$ (or C_3A), found in the range of 3-17%, and tetra-calcium-alumino-ferrite, $4\ CaO.Al_2O_3.Fe_2O_3$, (or C_4AF), which is normally in the range of 5-15%. These two compounds make only minor contributions to the strength characteristics of concrete. However they do aid as fluxing agents during the high temperature reactions necessary to form C_3S and C_2S. Also, C_3A contributes to early strength, and generates considerable heat of reaction. Its content is strictly limited when low heat and/or sulphate resistance properties are desired.

CEMENT MANUFACTURING PROCESS

OVERVIEW

The raw materials for the manufacture of Portland Cement must provide the oxides of calcium, silicon, aluminum and iron. Almost all cement plants use limestone as the source of calcium. Clays or shales normally provide a combination of aluminum and silicon, which can be adjusted by the addition of silica sand or bauxite. Finally, iron ore is the usual source of iron.

These raw material components are precisely proportioned based on chemical composition and then ground to a fine powder, usually 80% passing 200 mesh. After blending to ensure the necessary homogeneity, the powder is fed to a high temperature rotary kiln in which all of the chemical reactions take place which provide the final portland cement product.

The nodules of hot cement product from the kiln, called clinker, are quenched by forced air cooling. This hard dense clinker, normally gray in color, is ground, along with about 3-5% gypsum, to a fineness of approximately 90% passing 325 mesh. This final gray powder is the Portland Cement product of commerce.

PYROPROCESSING

In this sequence of cement manufacturing steps, the pyroprocessing step which is carried out in a rotary kiln, is the key one, since here, the relatively inert and common raw material components undergo a complex series of chemical reactions and phase transformations to yield the desired final cement compounds.

The rotary kiln is a long steel cylinder, lined with special high temperature refractory brick. The kiln is mounted in a nearly horizontal position, but with a few degrees of slope. During operation, the kiln rotates slowly about its axis. This rotation, combined with its slight slope causes the raw material to pass through the length of the kiln, from the higher feed end, to the lower product discharge end.

Fuel is burned within the kiln, near the discharge end, in the form of an intense, free-standing flame, located near the central axis of the kiln, and directed longitudinally toward the opposite end of the kiln. This flame heats the raw materials up to a temperature of approximately 1450°C, supplies all of the endothermic heat of reaction, and produces a sufficient quantity of liquid phase

necessary for the completion of the final chemical reactions.

The hot gases leaving the combustion zone pass through the length of the rotary kiln, normally drawn by an induced draft fan. These hot gases move in a direction opposite to that of the incoming raw material reactants, thereby transferring a large amount of their heat to the reactants by counter-current heat transfer.

This heat transfer process was made significantly more efficient in the early 1950's by using a much shorter kiln, preceeded by a suspension preheater. Here, the powdered raw material is dispersed in the upward moving hot gas from the kiln as shown in Fig. 1. This intimate contact transfers heat at a very high rate. The gas and raw material then enter a cyclone for the separation of the now heated particles from the gas stream. A series of four or five of these heat transfer stages are normally used.

The current state-of-the-art design of equipment for this pyroprocessing step employs a cyclonic furnace (precalciner) interposed between the rotary kiln and the suspension preheater shown in Figures 2 and 3. After being preheated with hot waste kiln gases in the preheater, the powdered raw material enters the precalciner where fuel is burned with hot air from the clinker cooler to complete the major endothermic chemical reaction called calcination (thermal decomposition of the calcium carbonate).

$$CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)} \uparrow$$

After this, the hot and decarbonated raw material particles enter the kiln where the sintering and final chemical reactions take place.

Therefore, the fuel is burned both in the kiln and the precalciner. Normally, up to 60% of the required total fuel is burned in the precalciner, while the remaining 40% is burned in the kiln. For this reason, the size of the kiln, especially the diameter, can be made significantly smaller than that for a preheater-kiln system alone, without changing the production rate. Table 1 compares the volume loading or unit volume production rates for a rotary kiln as applied to these three major configurations. It is evident that an existing preheater equipped kiln can be converted to a precalciner system, with the addition of a second parallel preheater, and realize an increase in production capacity of 100%.

An additional important advantage of the precalciner is that practically any type of fuel can be successfully burned in it, since the combustion is essentially a flameless, low temperature form which takes place at approximately 900°C. Consequently any low grade fuel with low calorific value and a high inert or ash content can be easily used.

FUEL

OVERVIEW

Today, Portland Cement kilns systems are successfully being fired with gas, oil, and coal of all types, with high quality clinker being produced with all of these different fuels. If fuel price and availability were the same for all of these fuels, then the fuels of choice would be gas and oil.

GAS

Gas requires only a pipeline and pressure reducing station. There is no fuel handling or storage. Gas has no ash, and consequently its combustion in the kiln adds no contaminants altering the highly specific chemical composition requirements of the clinker product.

OIL

With oil it is necessary to store a sufficiently large quantity in a local tank, and to provide a pumping and distribution pipeline system to the firing points. Normally number 6, or heavy oil is used (since is the lowest cost) and

consequently a heating system is provided for the storage tank and piping system to warm the oil to a temperature where its viscosity becomes sufficiently low to permit satisfactory pumping. The ash content is so low as to produce no contamination of the cement clinker. Sulphur in oil will partly combine with clinker as SO_3.

COAL

The use of coal necessitates the handling and storage, drying and grinding of a solid fuel prone to self heating and spontaneous combustion, and which can form explosive mixtures with air, after it is ground sufficiently fine for burning in a cement kiln. In addition it always contains a significant quantity of non-combustible minerals (ash) which contaminate the clinker. This must therefore be corrected by adjustments to the kiln feed material composition.

Coal also contains some sulfur. This can produce problems in the quality of the cement as well as encrustations or build-ups of sticky solid material coatings within the preheater resulting in operating problems. The sulfur and nitrogen content of coal can both contribute to increased emissions of SO_x and NO_x to the atmosphere. However there are means to reduce these emissions to a reasonable level so as to minimize potential hazards and problems thereby permitting coal to be used for cement manufacture in a safe and environmentally acceptable way.

COAL

DEFINITION

Coal is a fossilized form of hydrocarbon material which was formed by the chemical and physical transformation of extensive deposits of decaying vegetable matter which accumulated over a considerable period of time in swampy areas. Chemically therefore, coal is chiefly composed of carbon, hydrogen, oxygen, nitrogen, sulfur and mineral matter (ash).

ORIGIN

The first phase of this transformation is the slow decomposition of the accumulated plant matter into peat. This is dependant upon such factors as the rate of growth of the plant material, ambient temperature, the exposure of the original material to air and the filling or drainage of the swampy area. Considerable shrinkage takes place in the peat beds due to decomposition and consolidation under the increasing weight of the superposed layers of new growth accumulating on top of the peat bed.

The second phase of the coal formation begins when the peat becomes buried under accumulating sediments, such as clay or silt which later may become shale or rock formations. This phase is characterized by further densification of these peat beds due to the greatly increased mass of the overlying sediments.

During this process, the oxygen and hydrogen contained in the peat begin to slowly combine chemically This gradual combustion progressively lowers the hydrogen and oxygen content of the transforming peat, and simultaneously increases the carbon content. This aging process reduces the volatile content of the coal while increasing the fixed carbon content. The oldest coals have extremely high fixed carbon with low volatile and oxygen contents.

The transformation or aging process of coal is extremely slow. Although coal can be found with widely differing chemical and physical characteristics, they all represent different stages of the aging process. There are no sharp dividing lines between the stages or ranks of coal. Instead, all of the actual chemical and physical characteristics fall on a continuum of these properties. Nevertheless, it is possible to classify coals by their characteristics, as for example those in Table 2 as done by the

American Society for Testing Materials (ASTM). This table lists various coals found in the United States according to their age or rank.

PROXIMATE ANALYSIS

The most commonly used coal analysis is termed the proximate analysis. This analysis gives the heating value, volatile matter, moisture and ash contents. In addition, the fixed carbon is a value which can be obtained from these other values.

The volatile matter does not actually exist in coal as such, but represents the gases and vapors which escape from the coal as it is heated. Generally these gases result from a thermal decomposition of the complex hydrocarbon chains which constitute coal.

In the laboratory analysis, the volatile matter content is determined by heating the coal sample to 950°C for seven minutes in a reducing atmosphere. The volatile matter consists mainly of hydrogen, carbon monoxide, carbon dioxide, tar vapors and water vapor, plus minor amounts of methane and other hydrocarbons.

The ash is the inorganic residue which remains after a sample of the coal has been burned in a furnace at a final temperature between 700 and 750°C under a specified control of time, temperature and atmosphere.

Coal moisture consists of two types: surface or free moisture, and inherent moisture. Surface moisture is simply liquid water which exists on the surface of coal particles, and consequently is easily removed by heating. Inherent moisture however is chemically bound to the molecules in the coal. This form of moisture is more difficult to remove by drying.

The fixed carbon content is obtained by subtracting from 100% the sum of the percentage of volatile matter, ash, and moisture.

COALS IN PAKISTAN

The coals in Pakistan primarily range from lignites to sub-bituminous ranks, which are characterized by high volatile matter, low fixed carbon, high sulfur and ash content, and relatively low calorific value.

According to available information, Table 3 presents the approximate range of composition of representative coals from Pakistan.

CONVERSION OF CEMENT KILN TO COAL FIRING

During the past decade the world's Portland Cement industry has been converting its manufacturing facilities from oil and gas fuels to the use of coal. Each year many millions of tons of coal are received at cement plants, and safely used as the sole fuel for producing Portland Cement.

The key considerations which must be addressed when converting a cement rotary kiln from oil or gas fuels to coal firing are:

- Storage of large quantities of coarse coal, as received from the mine.
- Blending of more than one type of coal for cement quality control purposes.
- Drying
- Grinding
- Storage of pulverized coal
- Effect of coal ash and sulfur upon the chemical composition and quality of the finished cement product.
- Effect of coal sulfur upon the operation of the rotary kiln and its related pyroprocessing equipment.

All of these considerations fall into the following three general areas:

- Prevention and control of fires and explosions caused by the nature of coal itself.
- Control of quality of finished cement product.
- Avoidance of operating problems in the pyroprocessing system and equipment.

These topics are discussed in the following sections.

STORAGE OF COAL

The quantities of coal used by a typical cement plant are quite large. For example, a modern plant equipped with a single precalciner kiln system of 3000 tons per day of clinker production would require approximately 200,000 tons of coal per year. In order to ensure uninterrupted kiln operation, cement plants normally store several months supply of coal at their plant. The plant in this example would therefore store a quantity of coal equal to approximately 30,000-50,000 tons.

Normally this coal is stored outside, either with or without a protective roof or side walls, depending upon the local climate and amount of precipitation.

One of the most important characteristics of coal, from a safety standpoint, is its self-heating tendency. If this is allowed to occur at a sufficient rate, the temperature within the stored coal can reach the ignition temperature, resulting in a fire.

This self-heating or spontaneous combustion is caused principally by two phenomena:

- Heat of oxidation
- Heat of wetting

Either one of these phenomena can cause a coal to heat up to its ignition point and begin to burn. When both of these act together the time required to reach the ignition temperature of the coal is significantly reduced.

It is generally believed that the low temperature stage of coal oxidation produces coal-oxygen complexes, such as carbonic and carboxyl compounds, which upon further heating, liberate CO and CO_2. Also the mineral pyrite, present in most coals (a major contributor of sulfur to coals), oxidizes in the presence of air and moisture, also generating heat.

All of these exothermic reactions increase in rate exponentially with temperature. Typically, chemical reactions double their rate with each 10 centigrade degrees of temperature rise. Consequently a 90°C temperature rise within a coal storage pile due to self-heating will result in the rate of these reactions and also the rate of heat generation increasing 1000 times.

All coals are subject to self-heating. The rate of heat generation is a function of:

- Rank of coal
- Particle size or specific surface area
- Length of time exposed to air
- Temperature
- Petrographic constituents
- Quantity of pyrite present
- Particle size distribution of pyrite
- Moisture

Coals of lower rank, containing a higher quantity of volatile matter and sulfur usually experience self-heating at a higher rate than other coals.

The volatile content of a coal usually provides the best indication of its probable ignition temperature. Results of a study by the US Bureau of Mines (REF. 1) shows the relationship between the volatile content of coals and the ignition temperature of pulverized coal, in the form of a layer, or packed bed, and suspended in air as a coal dust cloud.

From this data, a layer of powdered lignite or sub-bituminous coal with a volatile matter content, in the range of 25-50% (representative of Pakistani coals) when exposed to air would be expected to ignite at the following temperature:

Volatile Content (%)	Ignition Temperature (°C)
25	230
50	190

The rate of temperature rise due to spontaneous heating of coal is clearly illustrated in Fig. 4. This data is from experiments conducted by the U.S. Bureau of

Mines (REF. 1). Samples of wet coal were exposed to dry air. The rate of heating was accelerated by conducting these experiments in a sealed, insulated vessel. In an open pile of coarse coal, the heating would be much slower.

When coal has been dried, and then is exposed to moist air, the rate of spontaneous heating is much higher than for that same coal which has not been predried. This is shown on Fig. 5 (REF. 1).

There are two approaches used for building a storage pile of coal depending upon the size distribution of the coal received:

- Graded size coals - Since all of the particles are approximately the same size, and will be fairly coarse, promote good ventilation through the pile. The air flow through the pile will remove the heat generated by self-heating. Also, the rate of heat generation will be low due to the low surface area of the coarse sized coal particles.
- Mixed size coals - Prevent the flow of air through the bed of coal to keep the rate of self-heating sufficiently low that ignition temperatures are not reached.

The coals used by cement plants are normally received as mixed sizes. Therefore a compacted storage pile should be employed. This is built in horizontal layers, with each new layer being compacted before depositing the next layer. The maximum thickness of each layer should not exceed 0.5 meters. Compacting can be done by driving a front-end loader or bull dozer across the top of each new layer. The reclaiming should be done vertically from the side of the pile in order to minimize the newly formed surface. This also accomplishes some blending of the various coals contained which is very desirable for establishing uniform kiln burning conditions and cement clinker quality.

BLENDING OF COAL

Fluctuations in the characteristics of the coal being fired to the kiln are undesirable at least, and can be totally unacceptable depending upon the coal property which fluctuates, and the magnitude and frequency of this fluctuation.

Coal ash normally consists of inorganic minerals rich in oxides of silicon, aluminum, iron, and sometimes calcium. All of the ash residue which remains after the coal is burned in the pyroprocessing system becomes physically and chemically combined with the original raw material components. All of these ash elements are the very ones of which cement clinker is made. Therefore, the coal ash becomes an additional raw material component in the process.

Consequently, the chemical composition and quantity of the coal ash being added to the primary clinkering raw materials must be known in order to suitably adjust the primary raw material composition to permit this coal ash addition, and still permit the production of the desired cement clinker.

In addition, changes in the calorific value of the coal are reflected in changes in the burning zone temperature of the kiln (the highest temperature zone) with resultant changes in the quality of the clinker produced. High ash, low heating value coals usually exhibit the largest variations in these characteristics.

If the blending produced by horizontal layering and vertical reclaiming by front-end loader is not sufficient, a highly effective blending bed system, incorporating a mechanized stacker-reclaimer can be employed.

It is desirable to select a stockpiling method that reduces the segregation of coal sizes at the exposed edges of the pile. The Chevron method of stacking produces segregation, however the windrow method minimizes segregation.

The best type of reclaiming method employs a bridge-type scraper-reclaimer. This device cuts across the end of the

pile, recovering all layers simultaneously and equally.

DRYING, GRINDING AND FIRING

OVERVIEW

The drying, grinding, and firing of coal represent three different processes. However, these are often grouped together since they can be accomplished in a single system. Nearly all the coal systems in operation today rely on an airswept mill system for simultaneous drying and grinding. The term airswept refers to the fact that the fine coal produced is carried or swept out of the mill by air or combustion gas. In general these mills use a high gas to coal ratio and drying is accomplished by the hot gas as it passes through the mill. The degree of drying which is needed in a given mill system depends on the inlet moisture of the coal as well as the desired product moisture.

To predict mill performance with any degree of accuracy for a specific coal, a grindability test must be performed.

This is generally done by pulverizing a small sample of properly prepared coal. The results of this type of test are used to predict the operating characteristics of the full sized mill.

Firing is accomplished in some systems by using the hot air or gases leaving the coal mill to convey the pulverized coal directly into the coal burner. In other systems the pulverized coal is separated from the hot gas stream and stored in a special silo from where it is pneumatically conveyed to all firing points.

MILL TYPES

Today, there are two principal and quite different mills used by the cement industry for grinding and drying coal:

- Roller mill
- Ball mill

ROLLER MILL

In the roller mill system coal is dropped onto the center of a spinning table. The coal is transported outwards due to centrifugal force developed by the table. The grinding is accomplished between two surfaces, one rolling over the other. Fine coal is carried out and over the edge of the table. Hot air or gas enters the bottom of the mill and passes up and around the table. The fine coal that passes out from under the rollers and over the edge of the table is picked up and dried by the incoming gas. Fine dry coal is then carried out of the top of the mill system.

A dynamic classifier located in the top of the mill body separates the coarse coal particles from the air stream and returns them to the table where they combine with the feed stream of fresh coal to be further ground.

BALL MILL

The ball mill is very similar to those used for cement raw material preparation only smaller. It consists of a cylinder filled with alloy steel balls of graded sizes. The mill is rotated continuously while being fed wet coarse coal in one end. The grinding is accomplished by the force transferred to the coal from the falling balls or from compaction between balls. The hot air or gas is introduced with the coal and drys the coal as it passes through the mill system. Fine dry coal is picked up by the air and carried out the other end of the mill.

Roller mills normally require a lower capital investment and also less electrical power for grinding than do ball mills. The coal fed to a roller mill can have a much larger maximum size (75 mm) than that fed to a ball mill (20 mm). Also, the amount of drying air or gases which can be passed through a roller mill is much larger than through a ball mill, so normally the roller mill can successfully grind and dry a wetter coal than can a ball mill. However, because of this greater air flow, roller

mills usually have a higher pressure drop than a ball mill, requiring the expenditure of more electrical power for the mill system fan.

FIRING SYSTEMS

The success of the combustion process in the kiln is very much dependant upon the performance of the mill circuit. Coal fineness, moisture content, and primary air rate and temperature have marked effects on the combustion reactions. As mentioned earlier, the amount of free moisture in the coal as fired and primary combustion air affects the amount of useful heat that can be generated.

Increasing the amount of primary air required affects the system heat consumption by reducing the amount of hot secondary combustion air that can be utilized from the clinker cooler.

There are three different firing methods employed by the cement industry today. Each has its own particular advantages and disadvantages with respect to safety, effectiveness of utilization of coal fuel value, flexibility and cost.

These firing systems are:

- Direct fired system
- Semi-direct fired system
- Indirect fired system

DIRECT FIRED SYSTEM

In the direct fired system the coal from the mill and/or classifier goes directly to the prime mover, system fan, before being blown directly into the fired equipment. A schematic flow diagram for this system is shown on Fig. 6.

This is the safest of the three systems since there is no storage of the pulverized coal. The system is fairly simple to operate and many of these systems have been installed and are operating.

The major disadvantage of the system is that all the drying air and evaporated water from the coal is passed into the process equipment adding to the heat consumption and fan power. This system can only utilize hot air from the cooler. Only one piece of equipment or location can be fired at controlled rates since the mill exit gas is passed directly into the burner. One system can supply coal to all four burners of a flash furnace system but not to a kiln and flash furnace.

SEMI-DIRECT SYSTEM

In a semi-direct system, mostly used with airswept ball mills, the coal stream goes to a cyclone which discharges the coal through an airlock to the primary air duct after the fan. The fan intake is connected to the top of the cyclone, so the difference between the direct and semi-direct systems is the movement of the coal and the dust load to the primary air fan. In this circuit the mill must operate in conjunction with the kiln system. Fig. 7 shows a schematic flow diagram for this system.

The semi-direct system has some of the advantages and disadvantages of the direct fired system. The quantity of primary air is reduced by the amount that is recirculated in the system thus heat consumption and power losses will be lower. The system can supply coal to more than one point at controlled rates. The system does have a greater fire and explosion hazard and care must be taken in the operation of the system. The increased duct work and the cyclone collector increases the potential area for coal build-ups and the duct concentration leaving the cyclone may be in the explosion hazard range. The system must use hot air for drying since part of the air is used as primary air. The system fan will see a lower dust loading and less wear of the fan blades should be expected. However, all of the coal moisture removed from the coal during the drying process still enters the kiln (or precalciner) since none of the recirculated air is ever vented to the atmosphere.

INDIRECT SYSTEM

In the indirect fired coal system the

dried and ground coal is conveyed to a storage bin from where the coal is withdrawn at a controlled rate. In this circuit the mill does not have to operate in conjunction with the kiln system. Primary air may or may not be drawn from the system. See Fig. 8.

Since it can have controlled firing of several pieces of equipment, it has definite advantages when it is desirable to convert several pieces of equipment in the same plant. The system is also more suitable for combination firing such as, natural gas and coal or oil and coal. The coal mill system can use either hot air from a clinker cooler or hot combustion gas from a kiln exhaust. The system has infinite turn-down capability only if operated intermittantly, and the primary air requirement can be held at a minimum. The system disadvantages are that it requires more expensive and extensive equipment including a specially designed dust collector and coal distribution system. The fire hazard of storing dry pulverized coal in a holding bin is of course of primary concern and appropriate safety precautions must be used.

CONTROL OF COAL FIRING

An example of a simplified automatic control diagram for a coal firing system is shown in Figures 9 and 10. The pyroprocessing system used in this example is a precalciner kiln. A semi-direct system was selected to permit a single coal mill to provide firing to both the kiln and precalciner.

CEMENT PRODUCT AND PROCESS EFFECTS

ASH

In a modern coal-fired suspension preheater equipped cement kiln, with or without precalcination, essentially all the coal ash is captured by the pyroprocessing system. The ash becomes mixed with the reactants in the system, ultimately becoming chemically reacted with the clinkering raw materials to actually form part of the final Portland Cement product. Since the coal ash minerals actually are chemically transformed into cement clinker, the ash is truly an additional raw material component.

Typically, coal ash has a chemical composition which is quite different from Portland Cement clinker. It is necessary therefore to adjust the proportions of the principal raw material components to compensate for the change in chemical composition of the clinker which results from the coal ash addition.

Uniform and unvarying chemical composition of the prepared raw material entering the kiln is necessary in order to:

- Provide the desired quality of cement clinker
- Avoid operating problems in the rotary kiln

No matter how uniform the chemical composition of the raw material is that is fed to the pyroprocessing system, the composition of the clinker product, as well as the necessary stable operating conditions of the rotary kiln can be upset significantly by variations in the quantity and chemical composition of coal ash. Consequently, the coal must be blended, prior to firing in the pyroprocessing system. Also, representative samples must be taken from appropriate points located between the receiving station and the feed to the coal grinding system, to give the plant chemist the analyses, and the lead time to adjust the composition of the raw material feed to the kiln to compensate for variations in the coal ash.

SULFUR: EFFECT ON CEMENT

Today's modern cement kiln system captures essentially all of the sulfur introduced to it by both the coal fuel as well as the raw material reactants. During the combustion process, the sulfur contained in the coal is converted to gaseous sulfur oxides which subsequently chemically combine with the calcium oxide

contained in the reacting raw material, which is present as an intermediate reaction product. A portion of the sulfur also combines with the potassium and sodium oxides, present in most raw materials, to form their respective sulfates.

Finished cement is produced by intergrinding cement clinker with gypsum, in order to control the setting time of the concrete. Since gypsum is the di-hydrate of calcium sulfate, it contains 47% sulfur expressed as SO_3. The amount of gypsum added to clinker is typically in the range of 3-5%. The sulfur content of the finished cement product comes from two sources:

- Clinker sulfur
- Gypsum sulfur

Standards for Portland Cement all contain a maximum level for sulfur. This ranges from approximately 2.3-4.0%, depending upon the specific country and also the type of cement being considered. In Pakistan, the standards specify:

- 2.5% SO_3 (when $C_3A \leq 7\%$)
- 3.0% SO_3 (when $C_3A > 7\%$)

Typically, high sulfur coals produce high sulfur clinker. The higher the sulfur content of the clinker, the less gypsum can be added, to produce a finished cement with a total sulfur content within the specified maximum level. However, in all cases, there will be an optimum amount of gypsum required to produce the best physical characteristics of the cement. This is determined by laboratory testing. If the clinker sulfur content is too high, then this optimum amount of gypsum cannot be used, and consequently, the cement quality suffers.

SULFUR: EFFECT ON PROCESS

OVERVIEW

Within the high temperature burning zone of the rotary kiln, the elements sulfur, chlorine, potassium and sodium form compounds with sufficiently high vapor pressures to permit them to volatilize. These vapors are carried by the hot combustion gases out of the highest temperature zone of the kiln.

Within the normal range of oxidizing conditions and temperatures which exist in the pyroprocessing system, the thermodynamically most favored compounds formed are potassium and sodium chlorides and sulfates. In the case of high sulfur fuels, there usually is an excess of sulfur over that required to form these alkali sulfates; this excess forms calcium sulfate.

CYCLICAL PROCESSES

These gases and vapors subsequently cool as they transfer their heat to the incoming lower temperature reactants in the kiln.

As the hot combustion gases pass through the rotary kiln, precalciner, and lower, cyclonic stages of the preheater, the alkali sulfates and chlorides condense out of the gases. Calcium sulfate forms from any excess sulfur oxides present in the gas stream. These compounds condense upon, the incoming, cooler raw material reactant particles, thereby enriching their content of these volatile elements. This now enriched raw material passes through the burning zone of the kiln, where the volatilization of both the original raw material and fuel volatile element occurs, plus that of the recycled volatile compounds.

This results in a cyclical process of volatilization and condensation of the volatile elements. The continued input of additional volatile elements from the fuel and raw material progressively increases the recirculating load of these compounds.

The condensation temperatures of these compounds are within the range of temperatures typical of the feed end of the kiln, and the lower stages of the preheater. Therefore these volatile compounds are liquid or sticky, which promotes the deposition and growth of

build-ups of solid reactant particles on the inner surfaces of the kiln, and within the ducts and cyclone vessels of the preheater. As these build-ups grow, the cross-sectional area of the kiln or preheater duct is progressively reduced, which correspondingly increases the pressure drop of the combustion gases drawn through that zone by the main system fan. When the fan rating is exceeded, the gas rate begins to decrease, with a direct reduction in fuel burning capability, and hence also in production rate.

BY-PASS SYSTEM

The cyclical process of internal recycle of volatile constituents can be controlled by withdrawing some of the kiln exit gases and wasting their heat. This by-passing of the preheater provides an outlet for these volatile compounds from a region where they exist in a high concentration relative to the combustion gases that carry them, and also to the raw material reactant dust particles suspended in that gas stream. This is illustrated in Figure 11.

After withdrawal from the kiln exit, the preheater by-pass gas stream is mixed with a stream of cold ambient air within a specially designed quenching chamber, in which the volatile compounds are completely condensed and solidified before they can contact the inner surface of that chamber or its outlet ducting. This prevents any solid build-up problems in this by-pass system. After this air quenching, the dust containing the alkalies, chlorine and sulfur is removed by means of a dust collector and discarded. The cooled, clean gases are then vented to the atmosphere.

PREHEATER WITH BY-PASS

The use of such a by-pass with a suspension preheater equipped kiln is limited to the by-passing of only a small amount of kiln exit gases, normally less than 30%. The more gas withdrawn through the by-pass, the less gas there is to pass up through the preheater. With too much by-pass, there is insufficient gas remaining to permit proper functioning of the preheater.

For proper preheater operation, it is necessary to maintain a minimum velocity in the preheater ducting of approximately 10 m/sec. Lower velocities permit the solid feed particles to drop by gravity directly through the preheater without being suspended in the hot gas stream and therefore without being heated by the gases.

A suspension preheater equipped kiln with a by-pass of up to 30% can operate well with raw materials which contain some chloride. This will serve to eliminate the build-up problems caused by the chlorides present.

PRECALCINER WITH BY-PASS

A preheater equipped with precalciner permits by-passing any amount of kiln exit gas; up to 100% if necessary. Normally, approximately 40% of the total system fuel is burned in the kiln. Therefore the concentration of volatile constituents in the kiln exit gas is much higher than in a prehoater kiln system only, which enhances the effect of the by-pass. Also, since the precalciner burns fuel with hot air taken from the clinker cooler, and not from the kiln exit gases, the effects of reduced kiln exit gases (during by-pass operation) can to a large extent be compensated for by increasing the hot air and fuel inputs to the precalciner.

In a precalciner system with a separate precalciner tertiary air duct, the value of gas from the precalciner to the preheater only decreases 19% with an increase in by-pass from 0-100%. This modest decrease in value has little or no effect on the operation of the preheater.

The use of a precalciner system with by-pass can be very effective in removing large quantities of sulfur from the pyroprocessing system, while still conserving a reasonably high level of thermal efficiency, along with the

elimination of potential operating problems coming from high sulfur content build-ups within the kiln and preheater vessels.

PREDICTING BY-PASS EFFECTIVENESS

Fuller has developed a means of predicting the performance of a by-pass system on a suspension preheater equipped rotary kiln, with or without a precalciner. This methodology employs:

- Overall material balance for all volatile constituents entering with raw materials and fuel, incorporating an expression for the volatility of each element for initial volatilization (e.g. from original mineral components) and secondary volatilization (e.g. from recycled form of compound).
- Laboratory procedure for determining the primary and secondary volatilities for each volatile element.
- Correlation of operating performance of actual full scale pyroprocessing systems over a wide range of by-pass operation and volatile element content in both fuel and raw material components.

This methodology permits predicting both the amount of each volatile element eliminated by any specified by-pass level, and also permits the prediction of potential kiln system operating problems due to build-ups caused by volatile constituents.

ACTUAL BY-PASS PERFORMANCE

Three modern coal-fired cement rotary kiln systems, equipped with precalciners and by-pass systems, supplied by Fuller, have been selected to illustrate the performance of the by-pass in interrupting the internal recycle process involving the volatile elements. These examples have been selected specifically to show the effectiveness of the by-pass in eliminating sulfur from the kiln system, as introduced by the coal fuel and the raw material reactants.

Two of these pyroprocessing systems, plant A and C, are current state-of-the-art rotary kilns equipped with precalciners and four stage suspension preheaters. Their nominal production capabilities are 2000 and 4000 metric tons per day of Portland cement clinker. Their by-pass systems are capable of a wide range of operation, with a maximum of 100% possible for plant A.

Plant B is a special installation of a rotary kiln equipped with a precalciner followed by a single cyclonic stage, used only for recovery of the precalcined raw material. This installation is equivalent to having no preheater. The principal objective of this configuration is to burn kerogens out of the raw material in the precalciner, to correct a prior air pollution problem caused by these hydrocarbons being vaporized (but not burned) in the cooler feed end of the kiln. This system has a nominal production capacity of 1150 metric tons per day of clinker. The by-pass operates nominally at 40% in this installation.

Table 4 presents the actual chemical analysis of the raw material feed to each of these pyroprocessing systems along with the clinker produced by the kiln from that raw material. For plants A and B, two sets of data are shown, representing samples taken on two different days, using different raw material chemistry and/or different amounts of by-pass. The principal equipment parameters are also included in this table.

The expected clinker SO_3 content, with 0% by-pass is calculated by adding all of the sulfur contained in the fuel and raw material, and expressing it as weight percent SO_3 in the clinker. A suspension preheater kiln system operating with no by-pass is found to perform exactly this way; that is, all of the sulfur (and other volatile constituents) from the fuel and raw material is found in the clinker.

By comparing the SO_3 content of the clinker actually produced, with this calculated maximum SO_3 content, at 0%

by-pass, the percentage of sulfur eliminated by the by-pass can be determined.

There is no direct correlation between the percent by-pass used and the percent of sulfur which is eliminated from these three systems. The reason for this is that the volatility of sulfur differs among all of these various raw materials used. However, the laboratory determination of these volatilities which are then employed in the correct by-pass simulation, which has been adjusted by extensive full-scale performance data does provide a good correlation among these parameters.

PREDICTED PERFORMANCE OF BY-PASS WITH TYPICAL PAKISTANI COALS AND RAW MATERIALS

The key question to be answered regarding the use of high sulfur Pakistani coals in the manufacture of Portland Cement is: "what is the maximum sulfur content in Pakistani coals used for the cement process which will not produce a final cement clinker with too high a sulfur content, nor cause operating problems in the operation of the cement pyroprocessing rotary kiln system".

This has been addressed by using available raw materials data in our by-pass model, and carrying out a parametric analysis.

During the past years, Fuller has investigated numerous cement making raw materials from Pakistan, these studies have included complete chemical analysis, raw mix design, and burnability and volatility tests. Table 5 presents a raw mix design for the kiln feed material, based upon analyses of Pakistani raw materials, and representative of the raw materials from other investigations. Figure 12 shows the results of our laboratory's volatility test for the kiln feed analysis shown in Table 5. This test was performed on a raw mix prepared from samples of the individual raw material components from Pakistan.

This volatility data for potassium, sodium, chlorine and sulfur was used, along with a typical analysis for a Pakistani coal. An analysis for coal from the Central Lakhra area was selected, and is shown in Table 6. This data was used in our by-pass simulation. The sulfur level in this coal analysis was varied over the range of 3% - 10%, to represent the full range of possible sulfur levels in Pakistani coals.

The most important results obtained from performing this by-pass simulation are:

- Percent sulfur in clinker vs. percent by-pass.
- Percent calcium sulfate in preheater stage 4 solids product vs. percent by-pass.

The clinker sulfur content can be compared directly with the maximum sulfur allowable in the applicable cement standards. The predicted calcium sulfate content in preheater stage 4 product should not exceed 5% in order to ensure trouble-free operation of the pyroprocessing system, with no solid build-up problems. Figure 13 shows the sulfur content of clinker produced from the typical Pakistani raw materials and coal, with a coal sulfur content of 4% (expressed as S). Figure 14 presents the predicted level of calcium sulfate for the same raw materials and coal. This figure shows that operation with 35% by-pass will produce a stage 4 solid product containing 5% calcium sulfate.

The coal sulfur content was varied over the range of 3-10% in order to explore the entire range of the expected sulfur content of Pakistani coals. The amount of by-pass necessary to hold the stage 4 calcium sulfate content to 5% was selected from each run of this model. This result is shown in Figure 15. This curve represents the predicted minimum amount of by-pass necessary to permit safe and build-up free operation of the pyroprocessing system for coal sulfur levels from 3-10%. The sulfur level in the clinker produced over the range of coal sulfur levels and by-pass amounts is expected to be, in all cases,

less than 0.7% SO_3.

This prediction of pyroprocessing system operation with typical Pakistani raw materials and coal, was compared with the actual full-scale operating data from Table 5 by reducing the raw feed sulfur level in each actual case to 0.10% SO_3, to be equivalent to the Pakistani raw material used, and by adding the difference in raw feed sulfur to the actual coal used in each case. This maintains the total amount of sulfur unchanged, but redistributes it between the raw material and fuel. The resulting data points were plotted on the original Figure 15, and are shown together on Figure 16.

This final figure shows the prediction of successful use of coals with an equivalent sulfur level from 2-7% (for a raw feed typical of that in Pakistan), using a suspension preheater rotary kiln equipped with a precalciner and by-pass system.

BY-PASS BENEFITS WITH EXISTING PLANTS

It is not necessary to build an entirely new pyroprocessing line to have the benefits of a sulfur by-pass system, which will permit the successful use of high sulfur indigenous coals. It is standard practice today to modify an existing long dry or wet kiln, or suspension preheater kiln. At an existing multi-kiln plant, typically one kiln is suitably modified, and one or more of the remaining ones are shut down to compensate for the large increase in capacity of the modified kiln.

For example, an existing 4 stage suspension type preheater kiln would be modified by the addition of a precalciner, a second preheater constructed adjacent to, and operating in parallel with the existing preheater, a by-pass system and a larger modified or new clinker cooler. This modification will result in approximately a doubling of the original kiln's production capacity.

REFERENCES

1. J. Kuchta, V. Rowe, D. Burgess, "Spontaneous Combustion Susceptibility of U.S. Coals." U.S. Bureau of Mines Report 8474.

TABLE 1

UNIT VOLUME PRODUCTION CAPACITY OF PRINCIPAL CEMENT PYRO-PROCESSING SYSTEMS

PYRO-PROCESSING SYSTEM	UNIT VOLUME PRODUCTION CAPACITY ($MTPD/M^3$ KILN VOLUME)
Long Dry Kiln	0.50 - 0.75
Preheater - 4 Stage	1.5 - 2.0
Precalciner - 4 Stage	3.0 - 4.0

TABLE 2

COALS OF THE USA/PROGRESSIVE STAGES OF TRANSFORMATION OF VEGETAL MATTER INTO COAL

FUEL CLASSIFICATION	STATE	H_2O	V.M.	F.C.	ASH	S	H	C	N	O	HHV KCAL/KG
Wood		46.9	78.1	20.4	1.5	0.0	6.0	51.4	0.1	41.0	4911
Peat	MN	64.3	67.3	22.7	10.0	0.4	5.3	52.2	1.8	30.3	5033
Lignite	ND	36.0	49.8	38.1	12.1	1.8	4.0	64.7	1.9	15.5	6133
Lignite	TX	33.7	44.1	44.9	11.0	0.8	4.6	64.1	1.2	18.3	6156
Subbituminous C	WY	22.3	40.4	44.7	14.9	3.4	4.1	61.7	1.3	14.6	5889
Subbituminous B	WY	15.3	39.7	53.6	6.7	2.7	5.2	67.3	1.9	16.2	6722
Subbituminous A	WY	12.8	39.0	55.2	5.8	0.4	5.2	73.1	0.9	14.6	7167
Bituminous Hi-Vol C	CO	12.0	38.9	53.9	7.2	0.6	5.0	73.1	1.5	12.6	7256
Bituminous Hi-Vol B	IL	8.6	35.4	56.2	8.4	1.8	4.8	74.6	1.5	8.9	7439
Bituminous Hi-Vol A	PA	1.4	34.3	59.2	6.5	1.3	5.2	79.5	1.4	6.1	8000
Bituminous Med-Vol	WV	3.4	22.2	74.9	2.9	0.6	4.9	86.4	1.6	3.6	8433
Bituminous Low-Vol	WV	3.6	16.0	79.1	4.9	0.8	4.8	85.4	1.5	2.6	8333
Semi-Anthracite	AK	5.2	11.0	74.2	14.8	2.2	3.4	76.4	0.5	2.7	7300
Anthracite	PA	5.4	7.4	75.9	16.7	0.8	2.6	76.8	0.8	2.3	7078
Meta-Anthracite	RI	4.5	3.2	82.4	14.4	0.9	0.5	82.4	0.1	1.7	6456

TABLE 3

PAKISTANI COALS - REPRESENTATIVE RANGE OF COMPOSITION

Moisture	5-25%
VCM	25-50%
Ash	7-50%
FC	23-43%
Sulfur	2-10%
Chlorine	0.01 - 0.30%
HHV (Gross)	2800 - 5900 kcal/kg
LHV (Net)	2500 - 5600 kcal/kg

TABLE 4

EFFICIENCY OF A BY-PASS IN REDUCING SULFUR FROM PRECALCINER TYPE PYRO-PROCESSING SYSTEMS

	A1		A2		B1		B2		C	
	RAW FEED	CLINKER	RAW FEED	CLINKER	RAW FEED	CLINKER	RAW FEED	CLINKER	KILN FEED	CLINKER
	13/05/80	13/05/80	30/10/80	30/10/80	09/10/80	09/08/80	15/08/80	15/08/80	04/76	04/76
SiO_2	12.80	21.42	13.76	22.22	13.28	21.04	13.14	20.98	14.05	21.52
Al_2O_3	3.54	5.80	3.29	5.12	3.33	5.14	3.28	5.12	3.56	5.70
Fe_2O_3	1.41	2.53	1.32	2.36	3.27	5.17	3.14	5.25	1.52	2.14
CaO	41.67	63.31	41.52	63.51	42.75	64.38	42.42	64.61	13.03	65.60
MgO	2.92	3.96	2.08	3.23	0.57	0.98	0.67	1.01	1.98	3.10
K_2O	1.00	1.16	1.04	1.48	0.56	0.73	0.53	0.60	0.82	0.59
Na_2O	0.10	0.15	0.13	0.18	0.14	0.25	0.13	0.25	0.16	0.13
SO_3	1.05	0.93	0.77	1.38	1.60	1.36	1.24	0.90	0.71	0.19
P_2O_5	0.0	0.08	0.20	0.01	0.14	0.23	0.13	0.19	-	-
TiO_2	0.15	0.24	0.15	0.24	0.11	0.16	0.11	0.17	-	-
Mn_2O_3	0.07	0.04	0.05	0.05	0.10	0.15	0.10	0.15	-	-
LOI	35.40	0.45	35.41	0.39	33.85	0.45	35.22	0.61	34.88	1.02
Total	100.11	100.07	99.72	100.17	99.70	100.04	100.11	99.84	100.71	99.99
Approximate % Bypass		95%		55%		40%		40%		30%
Expected Clinker SO_3 with 0% Bypass		2.59		2.07		2.66		2.15		1.09
Percent Reduction in Sulfur through Bypass		64%		33%		49%		58%		83%
Heat Consumption (kcal/kg)		910		830		1010		1010		
% $CaSO_4$ in Stage IV Material					5.84%		5.04%			
Pyro Processing System Description										
Preheater	SF 1.41				cc 1.35 with pre-cleaning cyclone				SF 132	
Kiln (meters)	5.6 x 43.5/4.6/5.2 x 58.7				4.3 x 74.7				4.1 x 99.1	
Capacity (MTPD)	4000				1140				2000	
Coal Sulfur (%S)	2.55				0.57					

TABLE 5

TYPICAL CEMENT RAW FEED FOR PAKISTAN

	WEIGHT %
S_1O_2	14.23
Al_2O_3	3.60
FE_2O_3	1.88
CaO	42.99
MgO	1.08
K_2O	0.51
Na_2O	0.13
SO_3	0.12
Cl	0.01
Loss	35.45
Total	100.00

TABLE 6

PROXIMATE ANALYSIS FOR COAL
FROM CENTRAL LAKHRA REGION, PAKISTAN

	WEIGHT %
Moisture	24.9
Volatile	30.3
Ash	17.4
Fixed Carbon	27.5
Sulfur	4.3
HHV	3926 KCAL/KG
LHV	3617 KCAL/KG

TABLE 7

COMPARISON OF FUEL COSTS FOR
PAKISTAN CEMENT INDUSTRY

	PRICE PER METRIC TON	FUEL HEATING VALUE KCAL/KG	FUEL PRICE PRICE PER MILLION KCAL
Oil	RS. 1740	10300 kcal/kg	RS. 169
Imported Coal	RS. 900	7778 kcal/kg	RS. 115
Local Coal	RS. 250	3600 kcal/kg	RS. 69

FUEL COSTS PER METRIC TON OF CLINKER

	SP/SF PROCESS	LONG DRY PROCESS	WET PROCESS	PERCENT SAVINGS COMPARED TO OIL
Oil	RS. 136	RS. 220	RS. 254	0.0
Imported Coal	RS. 92	RS. 150	RS. 172	32.0
Local Coal	RS. 56	RS. 90	RS. 104	59.0
25% Imported Coal 75% Local Coal	RS. 65	RS. 116	RS. 122	52.0
50% Imported Coal 50% Local Coal	RS. 74	RS. 124	RS. 140	46.0

Note: Above values based on the following typical heat consumptions:

SP/SF Process Fuel Consumption	800 kcal/kg (0% Bypass)
Long Dry Process Fuel Consumption	1300 kcal/kg
Wet Process Fuel Consumption	1500 kcal/kg

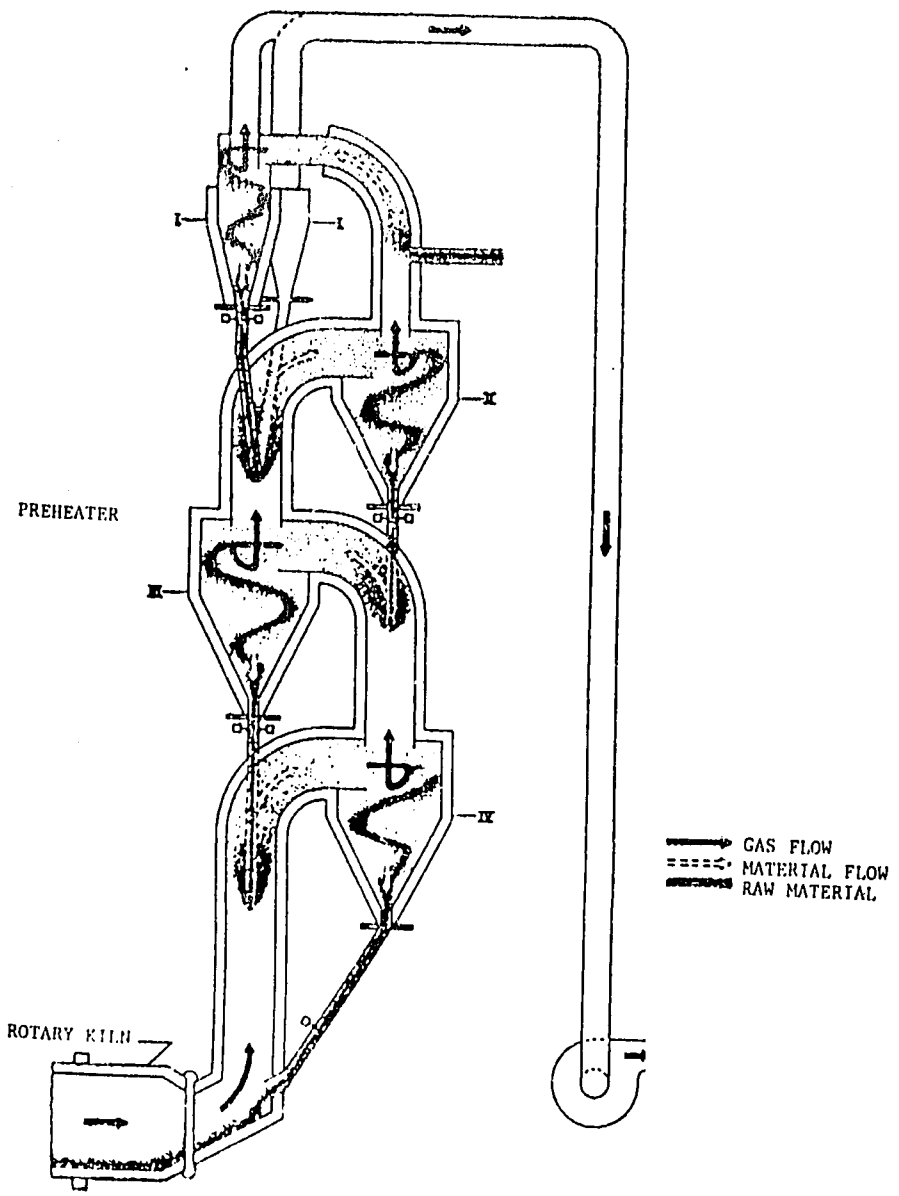


FIGURE 1

PREHEATER OPERATION

content within the specified maximum level. However, in all cases, there will be an optimum amount of gypsum required to produce the best physical characteristics of the cement. This is determined by laboratory testing. If the clinker sulfur content is too high, then this optimum amount of gypsum cannot be used, and consequently, the cement quality suffers.

SULFUR: EFFECT ON PROCESS

OVERVIEW

Within the high temperature burning zone of the rotary kiln, the elements sulfur, chlorine, potassium and sodium form compounds with sufficiently high vapor pressures to permit them

volatilization of both the original raw material and fuel volatile element occurs, plus that of the recycled volatile compounds.

This results in a cyclical process of volatilization and condensation of the volatile elements. The continued input of additional volatile elements from the fuel and raw material progressively increases the recirculating load of these compounds.

The condensation temperatures of these compounds are within the range of temperatures typical of the feed end of the kiln, and the lower stages of the preheater. Therefore these volatile compounds are liquid or sticky, which promotes the deposition and growth of

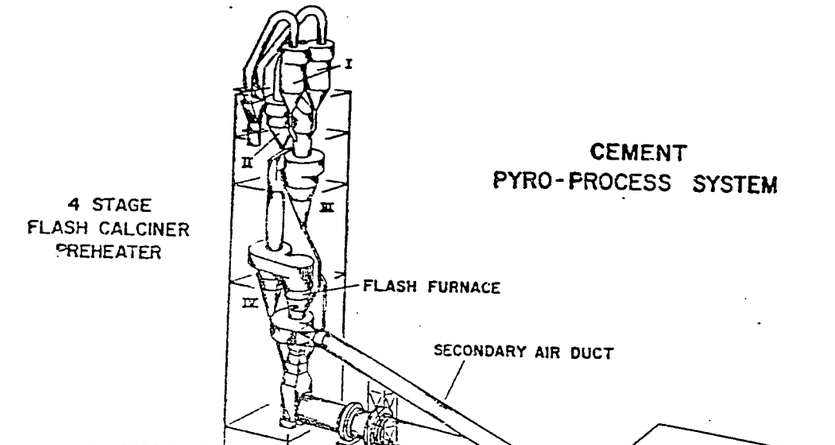


FIGURE 2

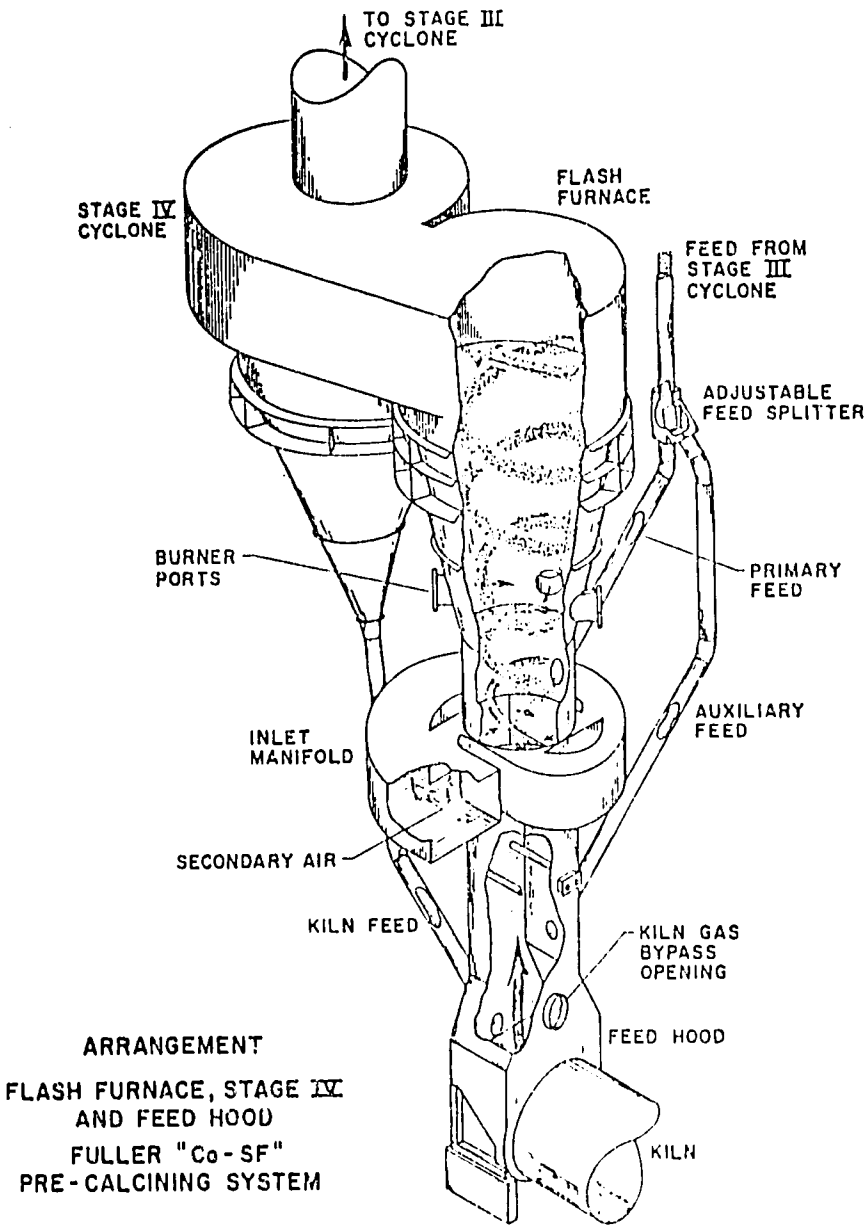

TO STAGE III CYCLONE
FLASH FURNACE
STAGE IV CYCLONE
FEED FROM STAGE III CYCLONE
ADJUSTABLE FEED SPLITTER
BURNER PORTS
PRIMARY FEED
AUXILIARY FEED
INLET MANIFOLD
SECONDARY AIR
KILN FEED
KILN GAS BYPASS OPENING
FEED HOOD
KILN
ARRANGEMENT
FLASH FURNACE, STAGE IV AND FEED HOOD
FULLER "Co-SF" PRE-CALCINING SYSTEM

FIGURE 3

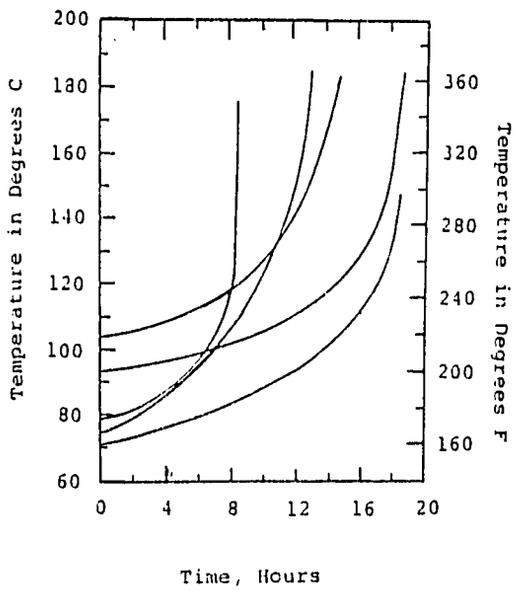


FIGURE 4 - Rate of spontaneous heating of 100 to 200 mesh samples of undried coal

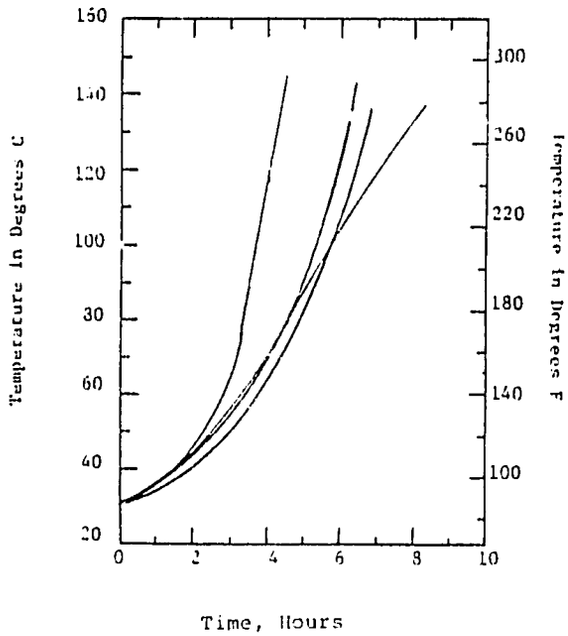


FIGURE 5 - Rate of spontaneous heating of 100 to 200 mesh samples of dried coal.

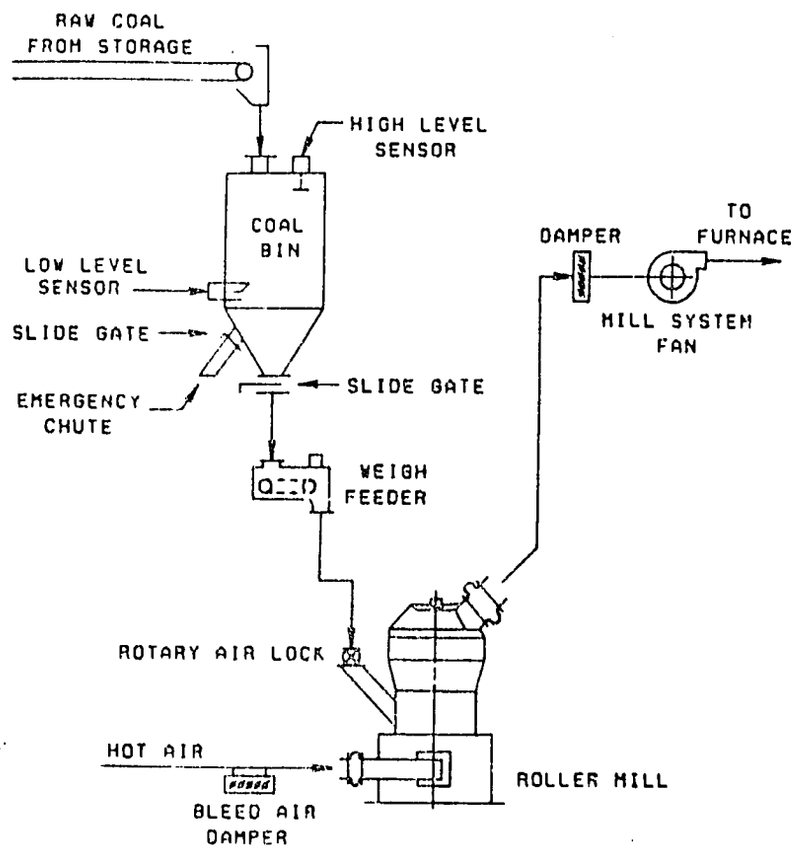


FIGURE 6

DIRECT FIRED SYSTEM

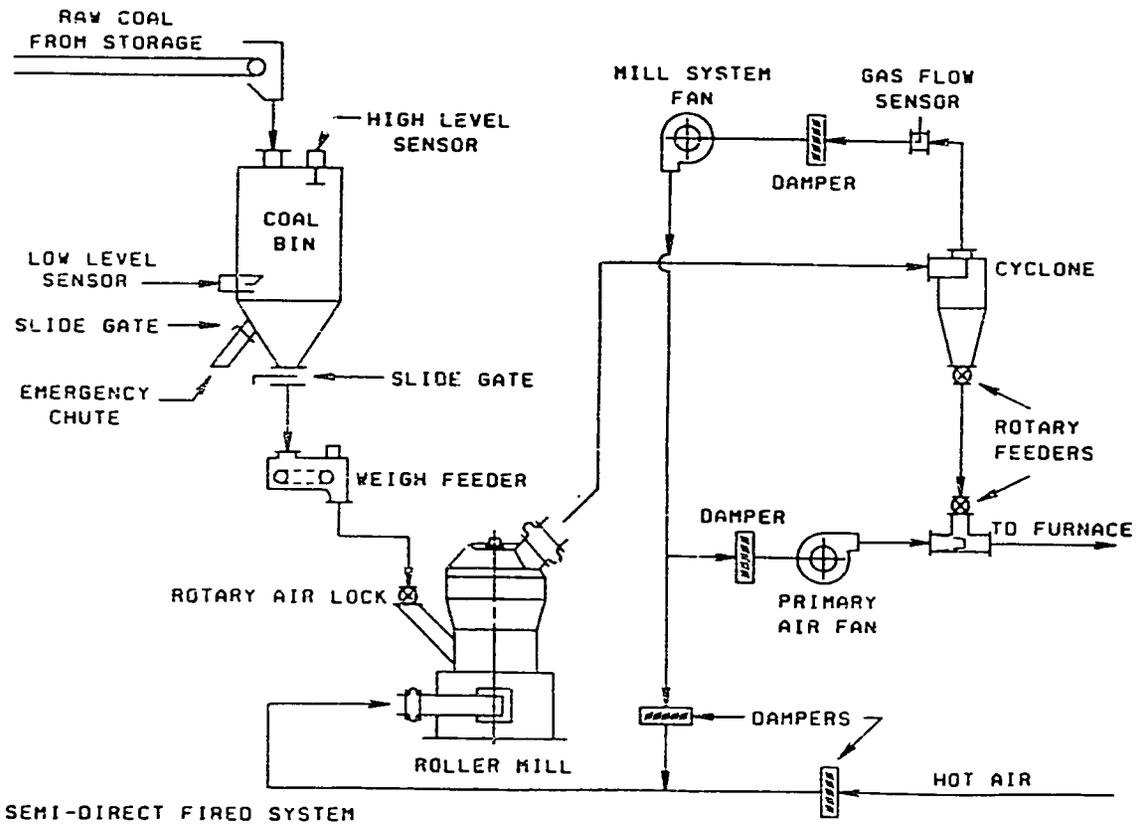
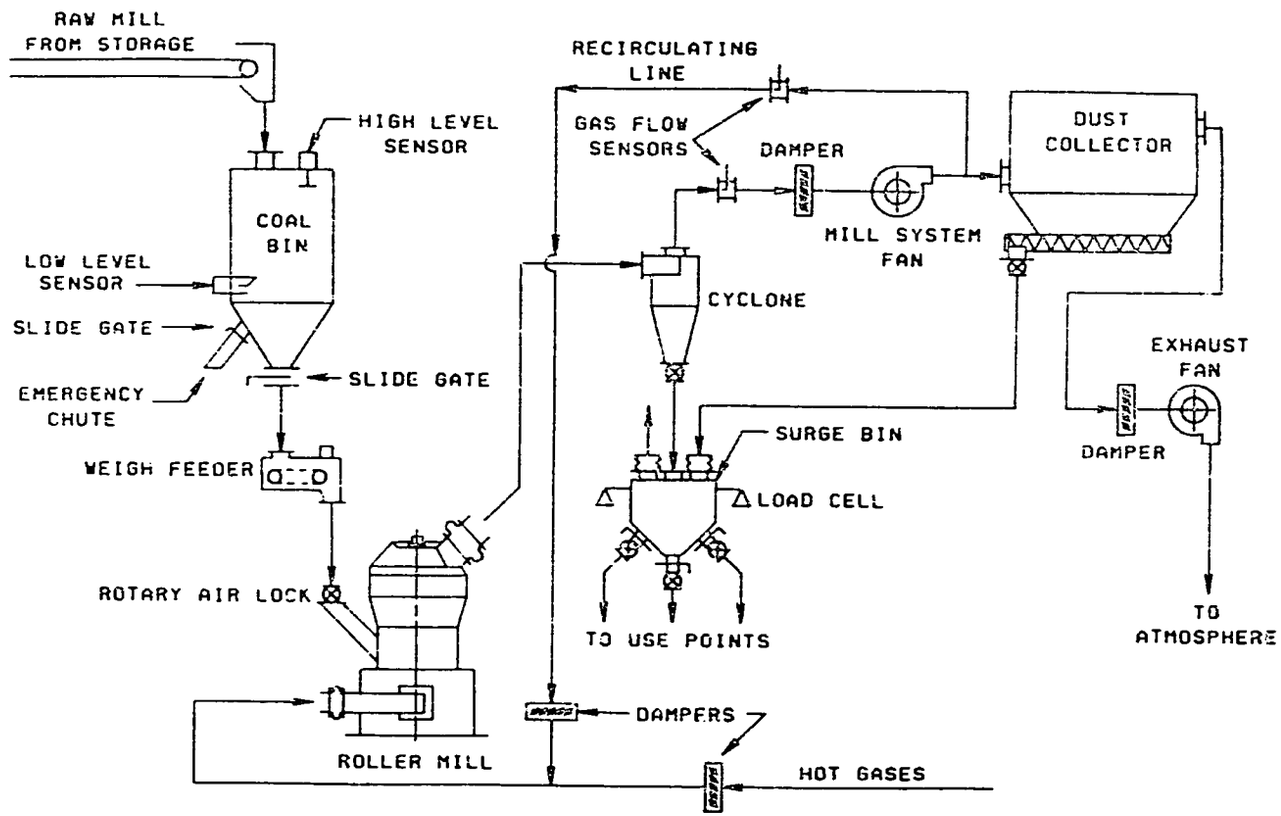
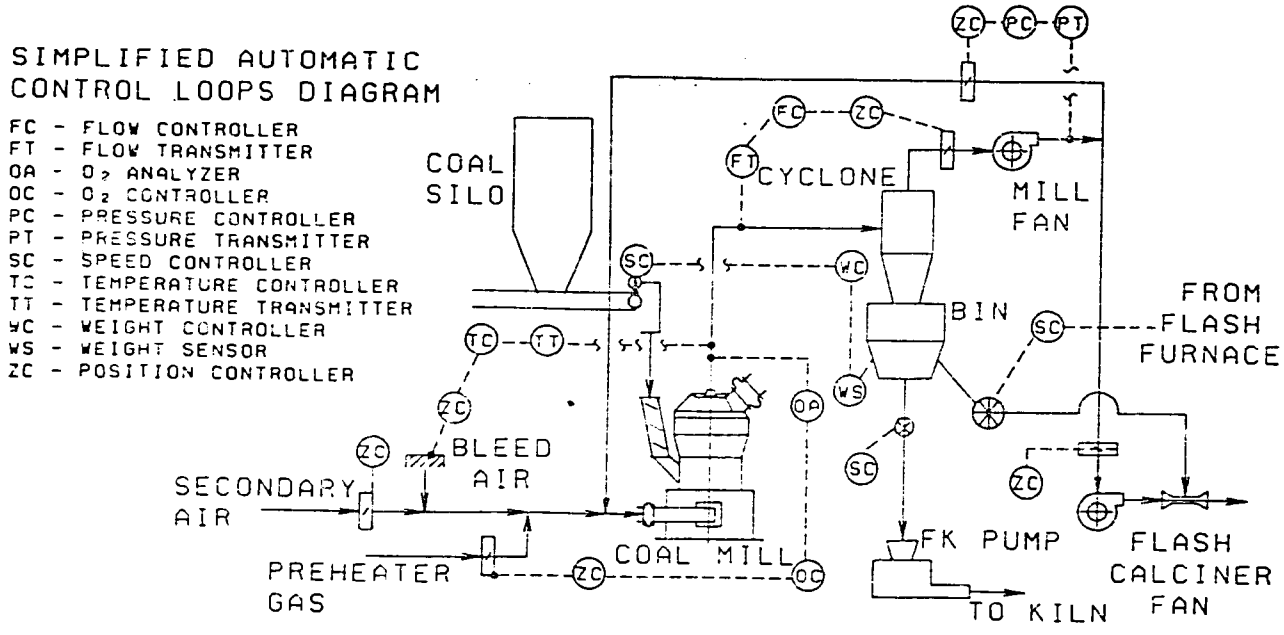

RAW COAL
FROM STORAGE
HIGH LEVEL
SENSOR
COAL
BIN
LOW LEVEL
SENSOR
SLIDE GATE
EMERGENCY
CHUTE
SLIDE GATE
WEIGH FEEDER
ROTARY AIR LOCK
ROLLER MILL
MILL SYSTEM
FAN
GAS FLOW
SENSOR
DAMPER
CYCLONE
ROTARY
FEEDERS
DAMPER
TO FURNACE
PRIMARY
AIR FAN
DAMPERS
HOT AIR
SEMI-DIRECT FIRED SYSTEM

FIGURE 7



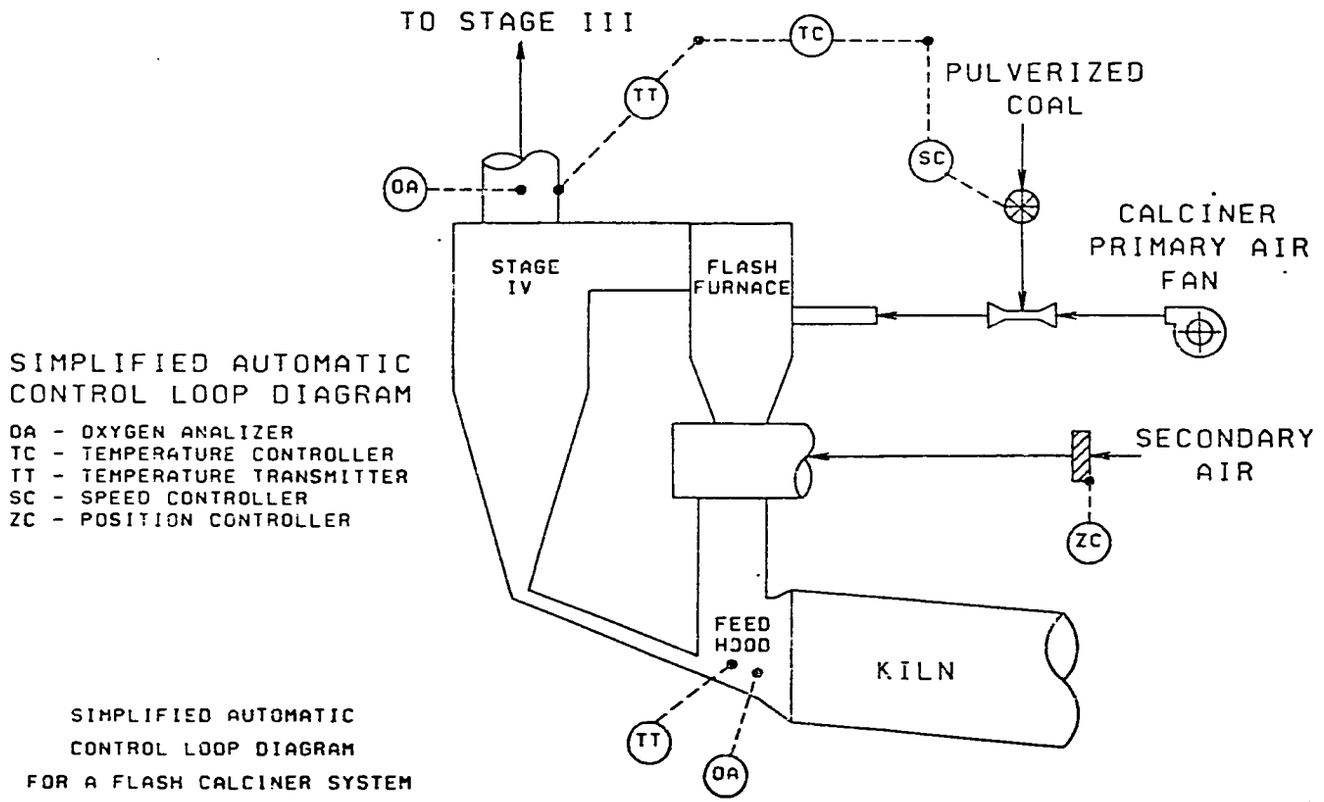
INDIRECT FIRED SYSTEM

FIGURE 8



SIMPLIFIED AUTOMATIC CONTROL LOOP DIAGRAM
FOR A SEMIDIRECT-FIRED COAL SYSTEM

FIGURE 9



SIMPLIFIED AUTOMATIC CONTROL LOOP DIAGRAM

OA - OXYGEN ANALIZER
TC - TEMPERATURE CONTROLLER
TT - TEMPERATURE TRANSMITTER
SC - SPEED CONTROLLER
ZC - POSITION CONTROLLER

SIMPLIFIED AUTOMATIC CONTROL LOOP DIAGRAM FOR A FLASH CALCINER SYSTEM

FIGURE 10

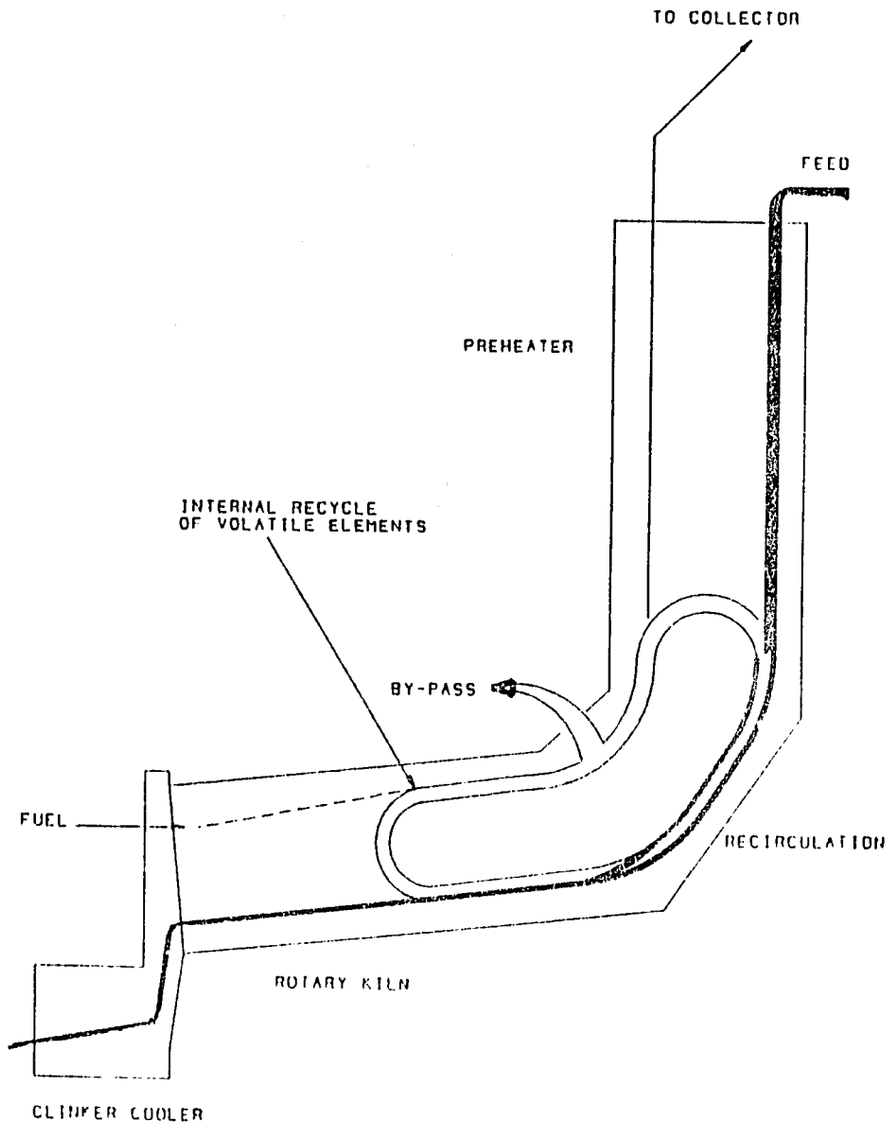


FIGURE 11 - EFFECT OF BY-PASS ON THE INTERNAL RECYCLE OF VOLATILE ELEMENTS

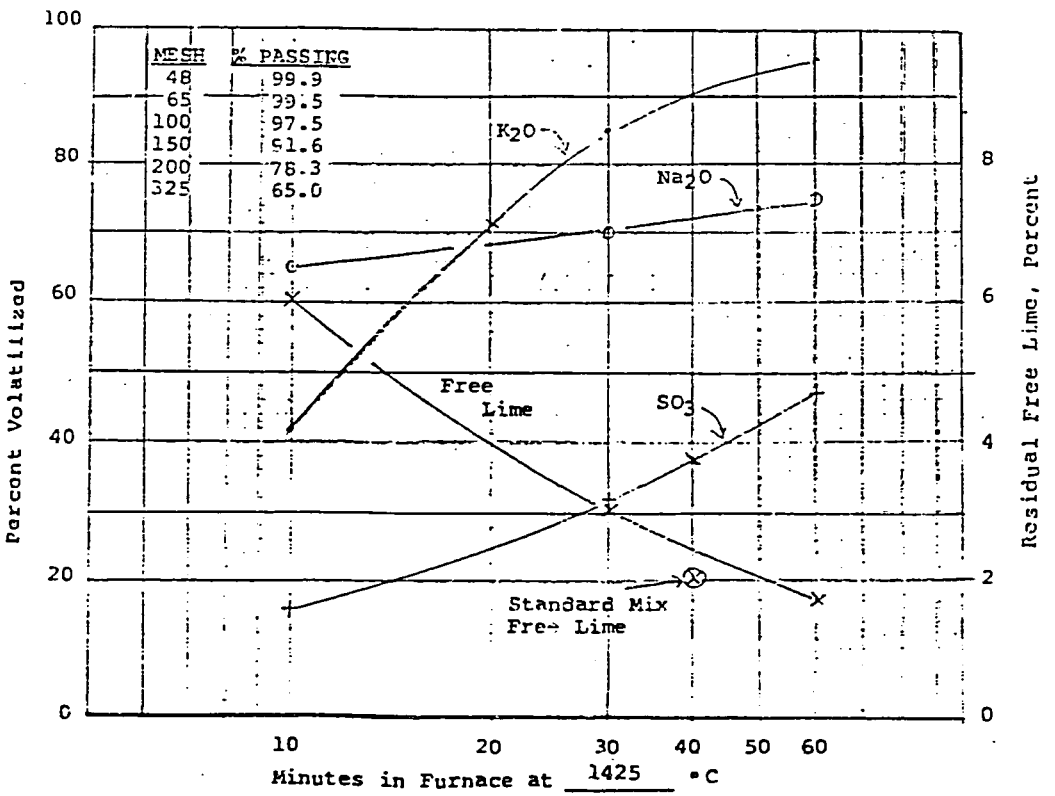


FIGURE 12 - FULLER VOLATILITY TEST
TYPICAL RAW FEED FROM PAKISTAN

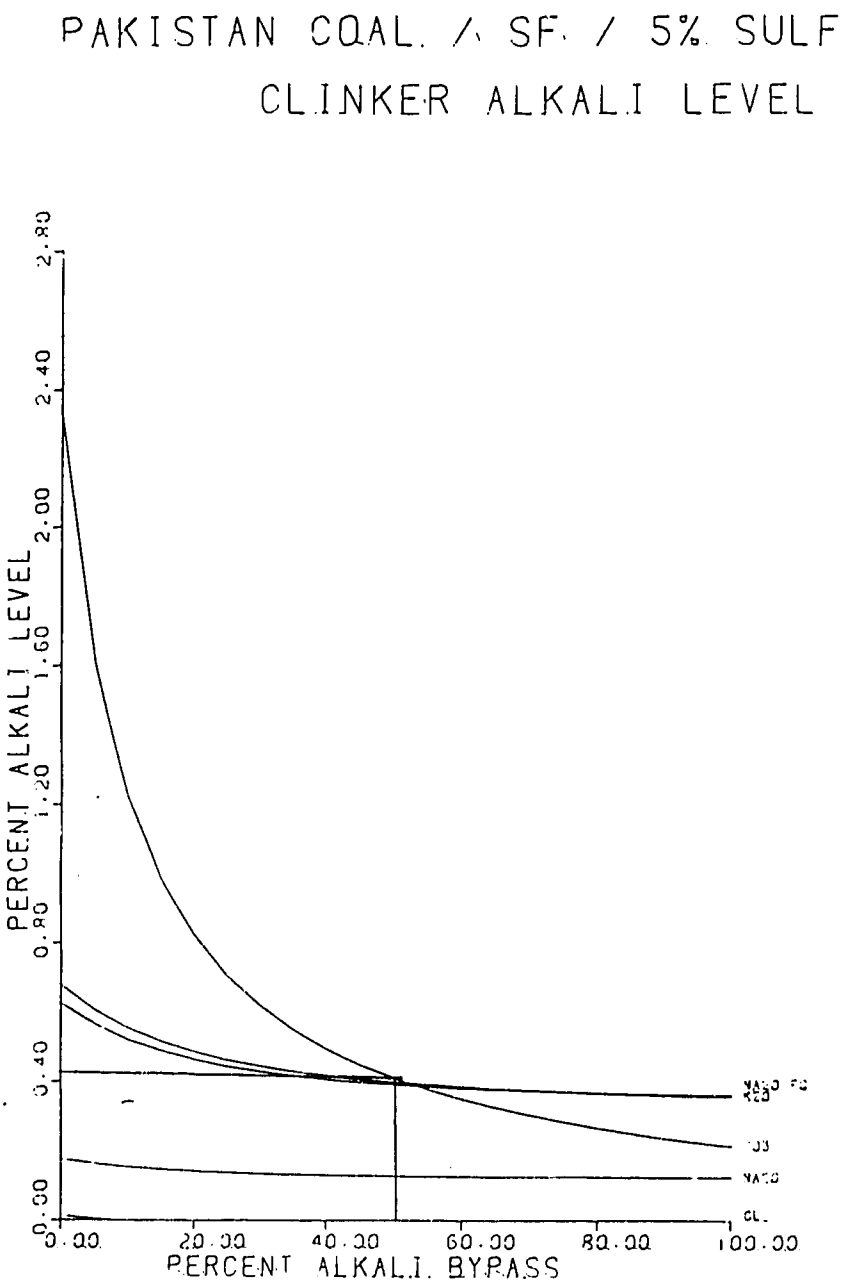


FIGURE 13 - CLINKER SULFUR LEVEL AS A FUNCTION OF PERCENT BYPASS

PAKISTAN COAL / SF / 5% SULFU
STAGE 4 ALKALI LEVEL

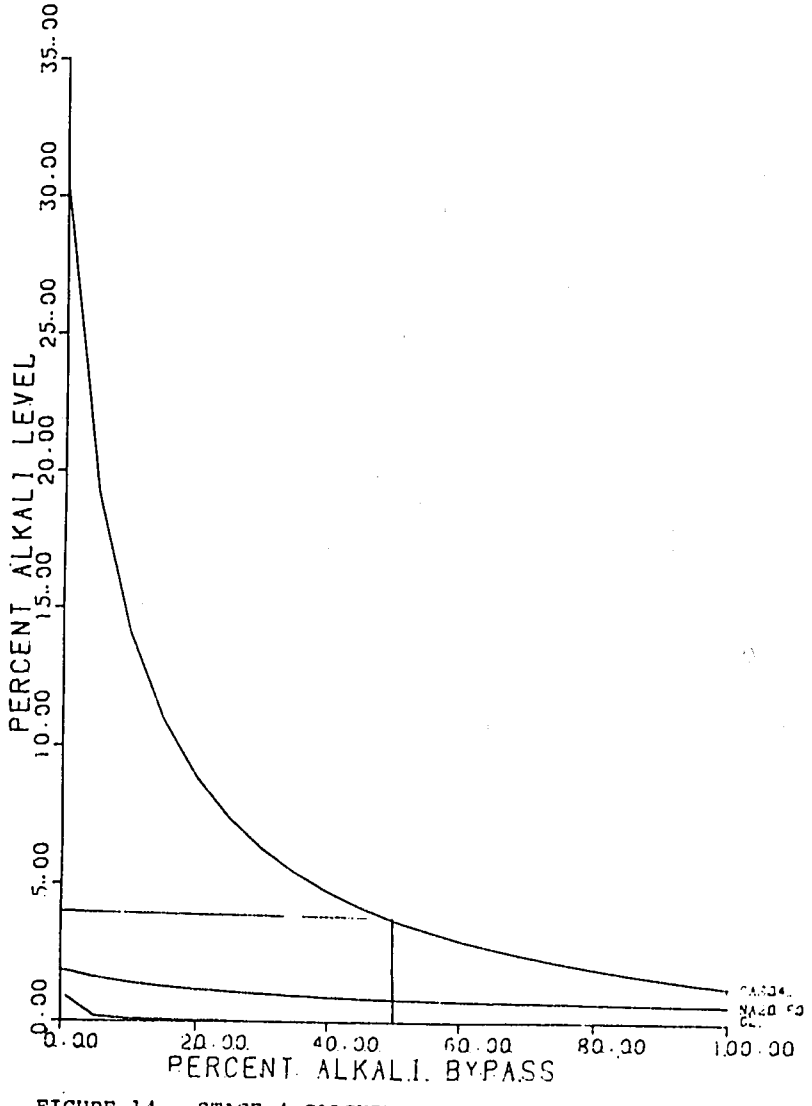


FIGURE 14 - STAGE 4 CALCUIM SULFATE LEVELS AS A FUNCTION OF PERCENT BYPASS

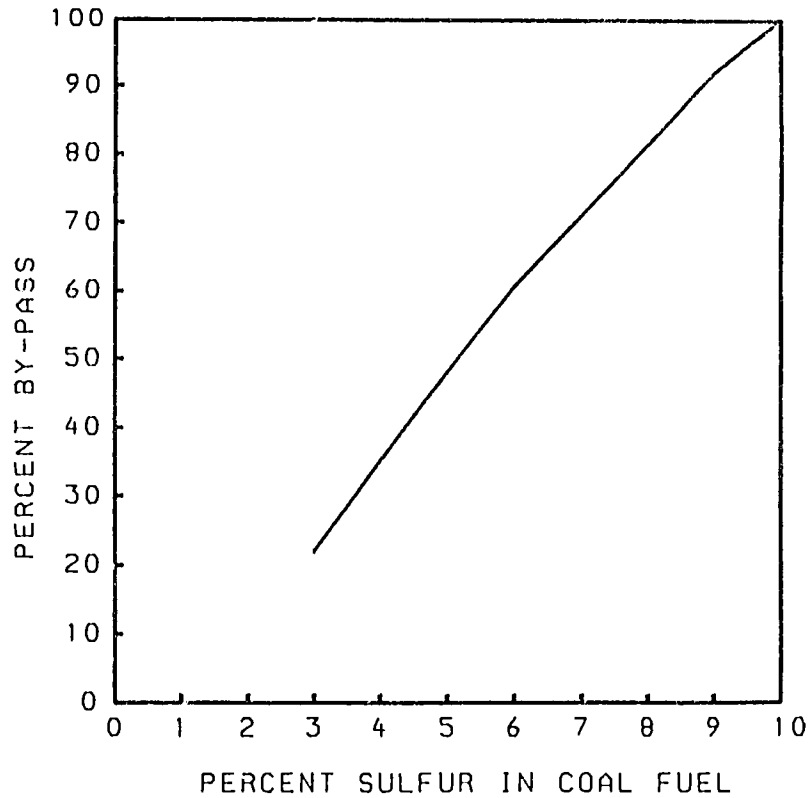


FIGURE 15 - PREDICTED AMOUNT OF BY-PASS NECESSARY WITH TYPICAL PAKISTANI RAW MATERIAL AND COAL.

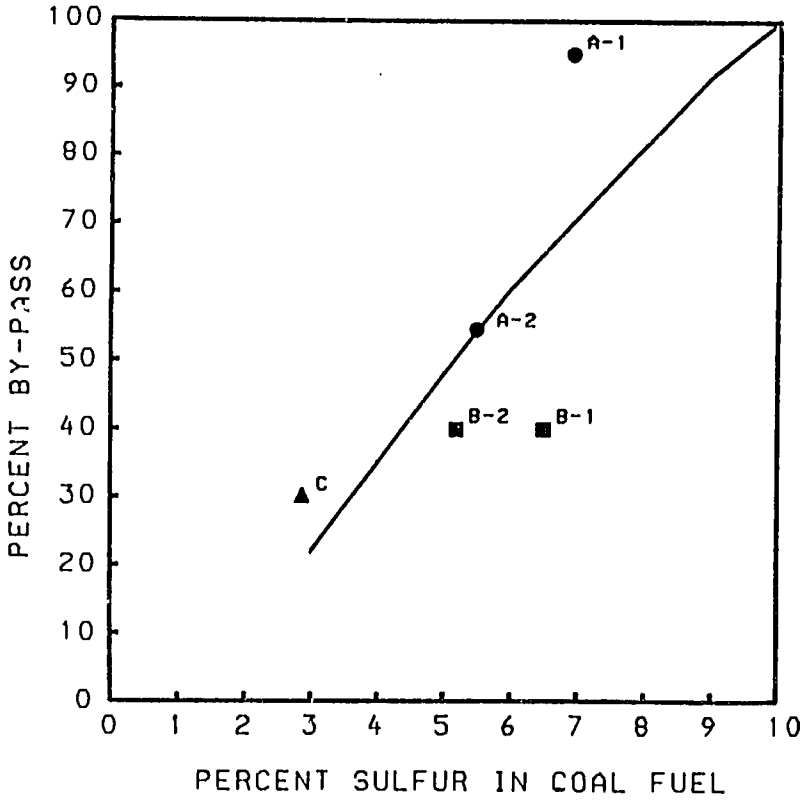


FIGURE 16 - FULL SCALE BY-PASS OPERATING DATA ADJUSTED TO EQUIVALENT PAKISTANI RAW MATERIAL AND COAL.

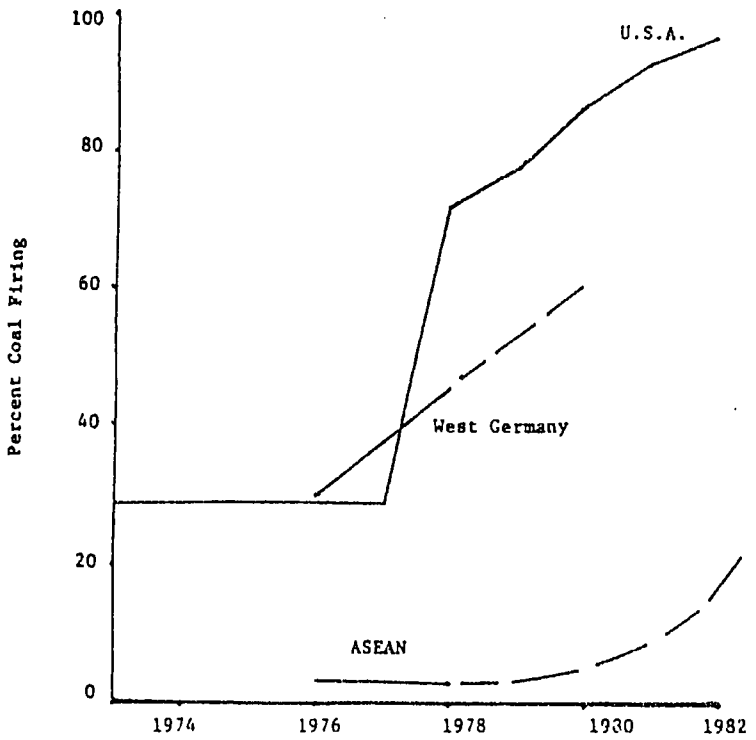


FIGURE 17 - PERCENT COAL FIRED CEMENT PRODUCTION CAPACITY - ASEAN AND OTHER COUNTRIES

FULLER COMPANY

ALKALI BYPASS REFERENCE LIST

175-80-4-1704
SHEET 1 OF 2

NO.	CUSTOMER	COUNTRY	CAPACITY (MTPD)	REASON	PRE-HEATER SIZE	DATE
1.	ST.LAWRENCE CEMENT CO. CLARKSON	CANADA	2450	OPERATIONAL CHLORIDE	SP2.27H	1965
2.	MONARCH CEMENT CO. HUMBOLDT,KANSAS	U.S.A.	766	QUALITY ALKALIS	SP1.23H	1971
3.	SOUTHWESTERN P.C. CO. FAIRBORN,OHIO	U.S.A.	1630	OPERATIONAL CHLORIDE	SP1.30H	1972
4.	UNIVERSAL ATLAS CEMENT BUFFINGTON,INDIANA	U.S.A.	770	OPERATIONAL SULFUR	SP1.22H	1972
5.	UNIVERSAL ATLAS CEMENT BUFFINGTON,INDIANA	U.S.A.	770	OPERATIONAL SULFUR	SP1.22H	1972
6.	MONARCH CEMENT CO. HUMBOLDT,KANSAS	U.S.A.	750	QUALITY ALKALIS	SP1.23H	1973
7.	TONG YANG CEMENT SEOUL	KOREA	2200	QUALITY ALKALIS	SP2.25H	1973
8.	UNIVERSAL ATLAS CEMENT LEEDS,ALABAMA	U.S.A.	1623	QUALITY ALKALIS	SP1.30H	1973
9.	SOUTH DAKOTA STATE RAPID CITY,S.DAKOTA	U.S.A.	1500	OPERATIONAL ALKALIS & CHLORIDE	SP1.29H	1974
10.	NATIONAL CEMENT RAGLAND,ALABAMA	U.S.A.	2000	QUALITY ALKALIS	SF1.32	1974
11.	LOUISVILLE CEMENT SPEED,INDIANA	U.S.A.	1815	QUALITY ALKALIS	SP1.30	1975
12.	CEMENTOS HIDALGO MONTERREY	MEXICO	1000		SP1.27H	1975
13.	STATE CEMENT CORP. JAVEDAN	PAKISTAN	1000	OPERATIONAL CHLORIDE	SP1.25	1975
14.	IDEAL CEMENT KNOXVILLE,TENNESSEE	U.S.A.	1550	QUALITY ALKALIS	SF1.30	1976
15.	SOUTHWESTERN P.C. CO. ODESSA,TEXAS	U.S.A.	770	OPERATIONAL SULFUR	SP1.22	1977

FULLER COMPANY

ALKALI BYPASS REFERENCE LIST

175-80-4-1704
SHEET 2 OF 2

NO.	CUSTOMER	COUNTRY	CAPACITY (MTPD)	REASON	PRE-HEATER SIZE	DATE
16.	MEDUSA CEMENT CHARLEVOIX, MICHIGAN	U.S.A.	4000	OPERATIONAL SULFUR	SF1.41	1977
17.	SUEZ CEMENT CAIRO	EGYPT	3300	OPERATIONAL CHLORIDE	SF1.41	1977
18.	GIZAN SOUTHERN PROVINCE GIZAN	SAUDI ARABIA	2500	OPERATIONAL CHLORIDE	SF1.35	1977
19.	GIZAN SOUTHERN PROVINCE GIZAN	SAUDI ARABIA	2500	OPERATIONAL CHLORIDE	SF1.35	1977
20.	CALIFORNIA P.C. CO. MOJAVE, CALIFORNIA	U.S.A.	2840	OPERATIONAL SULFUR	SF1.41	1978
21.	MARTIN MARIETTA LYONS, COLORADO	U.S.A.	1140	OPERATIONAL SULFUR	CC1.35	1978
22.	ST.LAWRENCE CEMENT CLARKSON, ONTARIO	CANADA	4500	OPERATIONAL CHLORIDE	SF2.27	1979
23.	MARTIN MARIETTA LEAMINGTON, UTAH	U.S.A.	1630	QUALITY ALKALIS	SF1.30	1979
24.	CEMENTOS PORTLAND OLAZAGUTIA	SPAIN	1200	OPERATIONAL	SF1.30	1980
25.	TEXAS CEMENT BUDA, TEXAS	U.S.A.	1250	OPERATIONAL CHLORIDE	SP1.25H	1980
26.	CAPITOL AGGREGATES SAN ANTONIO, TEXAS	U.S.A.	1370	OPERATIONAL SULFUR	SF1.26	1982
27.	BOX-CROW CEMENT DALLAS, TEXAS	U.S.A.	2800	OPERATIONAL SULFUR	SF1.37	1985

STATUS OF CONVERTING CEMENT PLANTS TO COAL FIRING

G.A.Qureshi
Director (R&D)
Cement Research Institute
State Cement Corporation
of Pakistan (PVT) Ltd
Lahore - PAKISTAN

Z.H.Rizvi
Dy.General Manager
(Coal Coordination Cell)
State Cement Corporation
of Pakistan (PVT)Ltd
Lahore - PAKISTAN

ABSTRACT

There is a general awakeness to substitute coal for the liquid/gaseous fuels after the 1973 Oil crisis. The latest innovations in cement technology advocate plant operation at a lower thermal load and making use of poor quality fuels to a maximum level. In Pakistan, the cement plants built prior to nationalization were mostly Wet process kilns. All SP-dry process which are more energy efficient were installed after nationalization in public and private sectors. The technology improvements have laid constraints on the suitability of raw materials and fuel. Cement being a consumable commodity should be manufactured at an economical cost. It is apprehended that coal conversion would raise the production cost merely because of higher fuel cost and additional cost of coal equipment. Before embarking on coal conversion the following options are of imperative consideration:-

i) Re-assessment of local coal reserves supplemented by detailed Geo-studies and assuring supply of atleast 20 years.

ii) Rationalization of local coal prices to make them competitive with imported fuel.

iii) Government consideration on relaxation of duties, surcharges etc, on the import of coal/coal equipment and an incentive policy decision to offset the impact of increase in cost due to coal-firing in cement industry.

RATIONALE

Until the middle of this century, coal was the primary source of energy used all over the world. However, in the decade beginning 1960's, Oil then relatively cheap and abundant began to replace coal and there was a gradual contraction of the coal industry. The rapid rise in cost of liquid and gaseous fuel following the middle east crisis and restrictions in supply by the OPEC countries in 1973 has brought about a resurgence of world wide interest in the use of coal in cement industry.

A great many cement manufacturers have converted their Oil/gas fired installations to Coal-fired units. At the same time older units are being phased out and many thermally efficient coal systems are being built to replace them. A key factor in the use of coal is the ability to absorb Ash in the clinkering process where it behaves as a raw material. This can be advantageous when it replaces the argilleceous component. However to produce good quality cement clinker the ash level in the coal needs to be rational and constant. Besides, the coal should be finely ground. In Pakistan the situation was different. The kilns of Maple Leaf Cement Co. had operated on local coals available from Makerwal collieries, till the middle of 1972.
The quality of coal was poor and variable which resulted in operational difficulties. We had also accidents due to explosion in the coal mill and fine coal hopper resulting in one fatal accident. After conversion to gas firing in 1972, the production and quality of cement improved considerably and so was the profitability. The small kilns of A.C. (Wah) and Rohri were also fired with imported and indigenous coal mixtures. They were

converted to oil/gas firing in mid 1950's. They faced the same problems and their quality, production and profitability also improved after conversion to gas/oil firing. At present all the cement plants are oil fired.

The depleting resources of the natural gas and rising share of furnace oil in import bill have focussed the Government's attention for maximum utilization of the indigenous coal resources to supplement the energy requirement. The cement sector is also required to substitute oil/gas with indigenous coal as far as possible in the light of qualitative constraints of the coal.

The State Cement Corporation of Pakistan have 15 cement plants under its control with an overall installed capacity of 5.841 million tonnes per year. This include the projected production of the cement plants under construction at D.G.Khan and Iskanderabad. About 63.5% of the total production is produced from 26 kilns running on wet process. The remaining 36.5% would be achieved with 6 kilns on SP-dry process. In Pakistan per capita cement production is about 61 kgs. Some of the cement plants have come in production under the private sector whereas others are under completion stages of construction. It is anticipated that by the end of 6th Five Year Plan total OPC production @90% efficiency would collate to 7.188 million tonnes. The production ratio of SCCP and private sector would thus be around 73:27.

SCCP has a variety of plants dating from new SP-dry process plants to about 64 years old wet process plants. However, majority of the wet process plants have already outlived their effective life. To make these units energy efficient they would need RMR/Process conversion from wet to semi-dry or dry process.

The contents of chloride, sulphur, alkalies in raw materials used in manufacture of cement would also influence the process conversion. It is experienced that raw-materials of the southern cement plants indicate prevalence of increased percentage of chloride contents as compared to the raw materials used at the northern units. Therefore, in south the SP-dry process plants mostly require by-pass provision to offset these impurities.

FUEL CONVERSION

The fuel used for burning also influence chemistry of the clinker if it contains high percentage of the undesired components. In our wet process kilns the collective effect of total chloride, alkalies and sulphur imparted through raw materials and fuel is lesser, as they escape the system through stack which works like a "natural" by-pass. In dry process preheater kilns the operational disturbance and blockages of cyclones etc are usually caused by higher concentration of the above components in volatile form which condense on the walls of cyclones and ducts or, more frequently in the relatively cooler raw-meal particles in which they are carried back into the Kiln. There they evaporate again and a close circuit develops. In cases where higher concentration of the volatiles are experienced, the withdrawal through a BY-PASS of some of the gas coming from the kiln prior to entry into the preheater is a useful step to interrupt the closed circuit and to eliminate some of the volatile components together with the dust of the by-pass gas. The furnace oil being used has about 3.5% sulphur and 9750 Kcal/kg heating value. As sulphur content in the raw meal is mostly below 1.0%, the oil-firing is imparting no deteriorating effect on the quality of cement.

QUALITATIVE CHARACTERISTICS OF COAL FIRING

The coal has from its geographical and geological origin and age relatively wide range of variation in its composition. All coals except anthracite are used for clinker burning, however, anthracite coal is being used in verticle shaft with Black meal Process. Suitability of coal in cement manufacture is governed by the following characteristics:-

Effect of Calorific Value

From an economic point of view the coal with a calorific value of 6,000 - 7,000 K.cal/kg is commonly used in kiln firing globally in cement industry. In principle it is advantageous to use coal with calorific value as high as possible in kiln firing in order to obtain a high temperature in the kiln burning zone while maintaining heat consumption as low as possible. In consideration to practical operation or economics a net calorific value of 5000 K.cal/Kg is supposed to be the lower limit.

Effect of Volatile matter

The content of volatile matter is important for the rating of coals. The loss

in weight as the result of carbonization of coal under exclusion of air, represents the total of volatile matter.

Coal from younger geological formation contain more parts of Oxygen, Hydrogen and Nitrogen than coal from older geological formation. During combustion these elements and their compounds generate more volatile matter than coal from older geological formation.

When burning coal on the fire grate the length of the flame depends on the contents of volatile matter. Coals which are high in volatile matter generate a long flame on the fire grate and are called long-flaming coals. Whereas coals containing little VM produce short flame and are therefore designated as short-flaming coals.

However, coals behave differently by burning them as pulverized coal into the rotary kiln. Long flaming coals injected as pulverized coal into the hot rotary kiln decomposes with high speed. The gasified volatile matter burns off immediately and the segregated coke particles are highly porous, this allows for a quick and complete access of oxygen, thus enabling a fast combustion of the coke. These circumstances promote fast combustion limited to a short section of the rotary kiln thus generating a short flame. Short flaming coals contain little volatile matter and decompose only slowly when burning in the rotary kiln as pulverized coal flame. The low contents of volatile matter causes slow combustion along an extended kiln section and the more dense coke has a low combustion velocity. As a result the so-called short flaming coals when burned as pulverized coal in a rotary kiln generate long flame. The standard contents of volatile matter for coal used in the combustion of pulverized coal is about 18-22%. The coals having volatile matter more than 32% are liable to self-ignition on storage.

Effect of Ash Content

The ash content in coal causes a decrease in calorific value of coal, at the same time it remains in the clinker during clinkerization. Therefore, the ratio of Ash in coal need to be constant so that raw meal proportioning can be maintained at a known composition. If the ash content becomes higher, the lime content in the raw mix should in principle be higher. With an ash content of more than 20% pure limestone may be required.

Effect of Sulphur Content

The maximum permissible SO_3 contents of cement is classified as 3% or 2.5% depending upon the C_3A content as specified in the BSS-12/1958 or 232/1962 Pakistan Cement Standards. Therefore, quantity of coal to be used in kiln-firing will be dependent upon its sulphur content and sulphur content in the raw materials. In general, the range is 3 to 5% by weight in the 100% coal firing.

Effect of Chloride Content

The chloride contents of the coal ash in combination with chloride contents imparted from the raw-materials may increase the permissible limit specified for SP-dry process i.e. over 0.015%. In such case by-pass is required to operate the plant properly.

INDIGENOUS COAL

The availability of quantitative and qualitative coal resources is a pre-requisite to embark upon coal conversion. The reserve estimates of the indigenous coal ascertained by various agencies and latest compilation by M/S CHEMCON - 1985 collates to 763 million tonnes. The reported production of coal is around 1.9 million tonne per annum and 90% of this production finds consumption in Brick Kiln Industry.
This indicates that the coal produced is already committed.

The data on indigenous coal reflect variable coal characteristics. The known coal resources range lignite to sub-bitumine and occur in the basal parts of the Tertiary sequence, ranging in age from 50 to 60 million years. These are non-coking, and largely high in ash and sulphur contents, friable and often liable to spontaneous combustion. They are characterized by marked physical and chemical variation both within individual beds and from one coal field to another.

The Makarwal coal of Punjab and Baluchistan coals have the requisite calorific value for use in the Cement Industry.

The Punjab Coal from the Cis-Indus Salt Range are of poor grade for industrial application. The Lakhra Coal of Sind contain high sulphur and chloride contents with low calorific value and variation in ash contents. The

composition of ash also varies very widely especially the iron oxide contents (17.3 - 70.8%) which may cause ring problem in the kiln itself. Some of the typical analyses of proximate, ultimate, and ash composition of local coals are given at Table-I and II.

APPRAISAL ON COAL CONVERSION VIABILITY

Cement is a consumable commodity. The fuel used in burning constitute about 32% of the total cost. To maintain the operational cost to an economical level, selection of a cheaper fuel source with adequate composition is usually warranted. The furnace oil costs Rs.0.176 per mega calorie inclusive of freight to destination. The indigenous coals and imported coal (Australian C&F Port-Bin Qasim @ US $ 55/- per ton) would cost as under on per mega calorie basis without freight i.e. ex-mine or port terminal.

		Rs: per mega calorie at source
Lakhra Coal	=	0.076
Baluchistan coal	=	0.170
Makerwal Coal	=	0.163
Imported Coal	=	0.133

The landed cost of these fuels to cement plants would obviously be higher than the prevailing fuel cost. Looking into various aspects of energy conservation, SCCP has undertaken studies at its own and with the assistance of consultants. It is envisaged that ;

a. 100% firing with indigenous coal, other than Makerwal and Baluchistan is not feasible because of the chemical constraints and inadequate calorific value. Even with Makerwal and Baluchistan coals, mixed oil and coal firing may be necessary to off-set the variations in quality of coal and raw materials. In dry process plants, a by-pass may be necessary to offset the impurities resulting an increase in equipment cost and heat consumption.

b. The chemical constraints of the indigenous coal such as Lakhra can be upgraded to make them usable at a certain ratio by blending with high grade imported coal or mixed firing with furnace oil.

c. 100% firing with imported coal of adequate quality is possible.

Working on this analogy M/s Chemical Consultants - 1985 have proposed Coal-firing for nine Wet process and four dry process (under commissioning at that time) Cement plants at an estimated cost of Rs.820 million including Rs.555 million foreign exchange component (estimates does not include duties, financial charges, surcharge etc). As per their calculations about 907,000 TPY of the indigenous coal from Lakhra, Baluchistan and Makerwal Coal-fields was anticipated to be used and blended with 190,000 TPY of imported coal (Australian). Due to proposed conversion about 280,000 TPY of the furnace oil utilization would be released.

M/s Japan Consulting Institute (JCI-1984) Coal conversion studies were mainly based on use of imported coal for Thatta, Javedan and National Karachi. For Dandot Cement they have proposed substitution of Makerwal coal @ 100% firing. The coal conversion cost estimates were as under:-

Javedan Cement	(2000 TPD)	Rs 46,205,000
National Karachi	(750 TPD)	Rs 25,009,000
Thatta Cement	(1000 TPD)	Rs 49,237,000
Dandot Cement	(1000 TPD)	Rs 56,215,000

M/s UBE Industries Ltd(Japan) have worked out a preliminary Coal-firing proposal for D.G.Khan Cement plant and Maple Leaf Cement Factory using indigenous coals. The coal conversion cost was estimated as under:-

D.G.Khan Cement(2000 TPD SP-dry process)
Rs. 37, 900,000

Maple Leaf Cement(1000 TPD wet process)
Rs. 36, 180,000

The above studies have indicated various plausibilities to make use of indigenous coal @ 100% or in blended or mixed form with imported coal or furnace oil. All proposals pertain to fire kilns at the existing process.

The production cost of cement after including the investment cost handling machinery & equipment, financial cost, increased power & labour expenses, indicate a rising cost factor. For example 100% firing with imported coal at Thatta Cement (1000 TPD SP dry process) would raise the production cost to about 13% and on a COM of Lakhra and furnace oil in 30 : 70 ratio may also raise production cost to about 3%. Similarly

TYPICAL ANALYSIS OF INDIGENOUS COALS

TABLE-I

Source of Coal	PROXIMATE ANALYSIS						ULTIMATE ANALYSIS							Source of Analysis
	Moisture %	Ash %	Volatiles %	Fixed Carbon %	Sulphur. %	Calorific value K.Cal./Kg.	C %	H %	S %	N %	O %	Cl %	Ash %	
LAKHRA	6.40-16.00	8.20-44.30	28.10-40.80	21.20-43.30	4.10-9.80	3190-5900	65.10	4.90	9.80	1.20	18.80	-	22.80	J.I.C.A.
"	25.00	19.30	28.80	26.90	6.00	3797	-	-	-	-	-	-	-	S.W.E.C.
"	23.20	24.90	39.30	35.80	5.10	4625	52.00	4.70	5.10	1.10	12.40	0.234	24.90	DYCKERHOFF.
Lakhra Air-Dry (Lallian)	9.00	21.40	35.40	34.60	7.00	4800	54.00	4.20	6.50	1.10	12.60	0.180	22.20	Assumed Average.
MAKERWAL	3.60	20.80	37.60	38.00	6.10	5587	-	-	-	-	-	-	-	PD-N.C.B.
"	4.30	27.20	37.00	31.50	6.00	4850	-	-	-	-	-	-	-	U.B.E.
"	2.70-5.00	18.20-41.70	31.10-42.70	32.40-35.30	3.70-7.10	3985-6458	-	-	-	-	-	-	-	CHEMCON.
"	3.40	25.90	37.20	36.90	9.70	5129	-	-	-	-	-	-	-	DYCKERHOFF.
SHARIGH	9.11	43.11	34.80	43.80	5.00	5305	-	-	-	-	-	-	-	P.M.D.C.
"	4.30	26.50	39.60	31.80	6.30	5600	-	-	-	-	-	-	-	DYCKERHOFF
SOR-RANGE	14.70	7.10	36.40	41.80	5.00	5235	51.20	4.10	5.00	-	-	0.020	7.10	HOLDER BANK.
"	8.60-16.40	5.50-23.60	30.40-46.70	31.50-43.10	0.80-3.80	4937-6507	-	-	-	-	-	-	-	CHEMCON.
"	14.81	5.30	45.60	49.10	1.22	6110	71.40	5.68	1.22	1.61	14.62	0.0098	5.30	DYCKERHOFF.
DEGHARI	12.10	18.00	35.50	34.40	2.20	4622	50.90	4.20	2.20	-	-	0.020	18.00	HOLDERBANK.
Run of Mine	7.30-10.30	10.50-29.20	33.40-43.50	30.10-36.90	0.90-6.60	4800-5890	-	-	-	-	-	-	-	CHEMCON.
"	11.54	9.80	45.80	44.20	2.74	5967	66.40	5.36	2.74	1.53	14.01	0.0079	9.80	DYCKERHOFF.

TABLE- II

TYPICAL ASH ANALYSIS OF INDIGENOUS COALS

CHEMICAL COMPONENT	Lakhra	Lakhra	Makerwal	Makerwal	Sharigh	Sharigh	Sor-Range	Deghari
SiO_2 %	1.10-44.40	38.97	51.12	35.53	20.20-25.60	52.40	26.75	36.43
TiO_2 %	-	2.21	2.56	2.00	0.25-0.42	1.25	0.65	0.86
Al_2O_3 %	9.50-	29.15	24.35	20.41	8.00-9.50	17.73	12.48	12.21
Fe_2O_3 %	17.30-70.80	18.87	17.61	37.55	16.90-21.00	13.13	12.59	20.56
MgO %	0.90-7.00	3.24	0.50	0.48	1.80-1.90	1.35	4.68	3.01
CaO %	1.30-12.50	4.17	1.54	1.58	26.40-30.40	5.42	18.58	14.42
Na_2O %	0.40-3.20	1.44	0.22	0.40	0.22-0.36	0.99	4.87	2.27
K_2O %	0.30-2.00	0.56	1.06	0.95	0.60-1.02	2.07	0.58	1.36
MnO%	-	0.11	-	0.09	-	0.16	0.07	0.13
P_2O_5 %	-	0.10	-	0.06	0.88-1.40	0.14	0.05	0.05
SO_3 %	1.90-16.90	1.22	1.12	0.55	9.89-12.56	4.65	18.91	8.85
Source of Analysis	JICA	Dyckerhoff	U.B.E.	Dyckerhoff	Middle Seam.	Dyckerhoff	Dyckerhoff	Dyckerhoff

1000 TPD wet process plant at Maple Leaf on 100% firing with Makerwal coal or 50 : 50 blend of Lakhra and imported coals would raise the production cost to about 9% and 14% respectively. Due to high fuel cost factors and need for energy conservation, the reduction of energy consumption per tonne of cement is under active consideration of SCCP. It is considering that rehabilitation and/or conversion of its plants to more energy efficient processes.

Recently a technical study on BMR, process conversion and feasibility of coal firing of the six plants of SCCP has been undertaken by M/s Dyckerhoff Engineers, GMBR, under the World Bank Technical Assistance to the cement sub-sector. The consultants, taking into consideration the chemical constraints of the indigenous coal as compared with imported coal and furnace oil have proposed process conversion and rehabilitation programmes for the individual unit. The consultants are of the view that coal firing would be feasible on SP-PC dry process plants using 60% thermal load at the precalciner. However, the high sulphur contents of the local coals and in raw-materials at certain units would necessitate provision of by-passes. Taking into account that concentration of SO_3 in the hot-meal is limited to 3% i.e. corresponding to an increase of SO_3 content in clinker upto 1.8%, the by-pass requirements are compiled at Table-III

With the use of indigenous coal, all the dry-process plants will need provision of by-passes. At Zeal Pak a by-pass rate of more than 100% is calculated (with Lakhra Coal as fuel) on conversion to dry process. This implies that despite 100% by-pass operation it would not be possible to reduce the SO_3 content in the hot-meal to 3%. However, on rehabilitated wet-process plants, the dust has to be discarded to off-set the impurities by using the local coals. In case of Zeal Pak, on rehabilitation about 200 TPD dust has to be discarded and its disposal would be cumbersome arrangement.

The financial cost of 1000 TPD SP-PC-dry process plant with coal mill is estimated at around Rs.849 million.

TABLE-III: By-pass Calculations.

Constant used for calculations.

Fuel consumption	S-content %	Calorific Value Kcal/Kg
Oil	3.5	9750
Lakhra Coal	7.0	4800
Australian Coal	0.6	6600
Heat consumption	Clinker burning	760 Kcal/Kg
Additional heat consumption	With by-pass	4 Kcal/kg by-pass
Precalcination rate	60%	
Restrictions	3% SO_3 in hot-meal	

Dry process	By-pass size on 100% fuel			
	Fuel oil	Lakhra coal	Makerwal coal	Australian coal
Zeal Pak	37.9%	109.2%	-	17.0%
AC Rohri	8.0%	88.6%	-	Nil
Maple Leaf	Nil	-	53.7%	Nil
Gharibwal	5.1%	-	60.2%	Nil
Mustehkam	Nil	-	41.8%	Nil
AC Wah	Nil	-	45.8%	Nil

CONCLUSION

The preliminary feasibility report of M/s Dyckerhoff Engineers, GMBR, is being reviewed by SCCP and will be further discussed with them to adjudge the techno-economical factors. It is most likely that Zeal Pak, A.C.Rohri and Maple Leaf may be considered for conversion to coal-firing in the first instance. These plants are also located in close proximity to coal-bearing fields of Lakhra, Baluchistan and Makerwal. But to economise and assure sustained fuel supply to the plant the following factors are of prime importance to precede coal-firing:

1- Adequate coal reserves of the prospective coal to sustain supplies for atleast 20 years. This would need detailed geological exploration of the coal-field and re-assessment of the reserves.

2- Assured qualitative supply of coal with minimum variance.

3- Development of mines to raise additional coal for cement

4- The ex-mine cost of Makerwal & Baluchistan coals are almost equivalent to C&F cost of imported coal. Therefore, some rational measures would need to be adopted to economise the local coals.

5- Extra rolling stock of railway wagon would need to be generated for coal transport.

6- Extra berthing and conveying facilities would need to be improvised at Port Bin Qasim to handle imported coal for cement. Present facilities are supposed to have been committed for PASMIC.

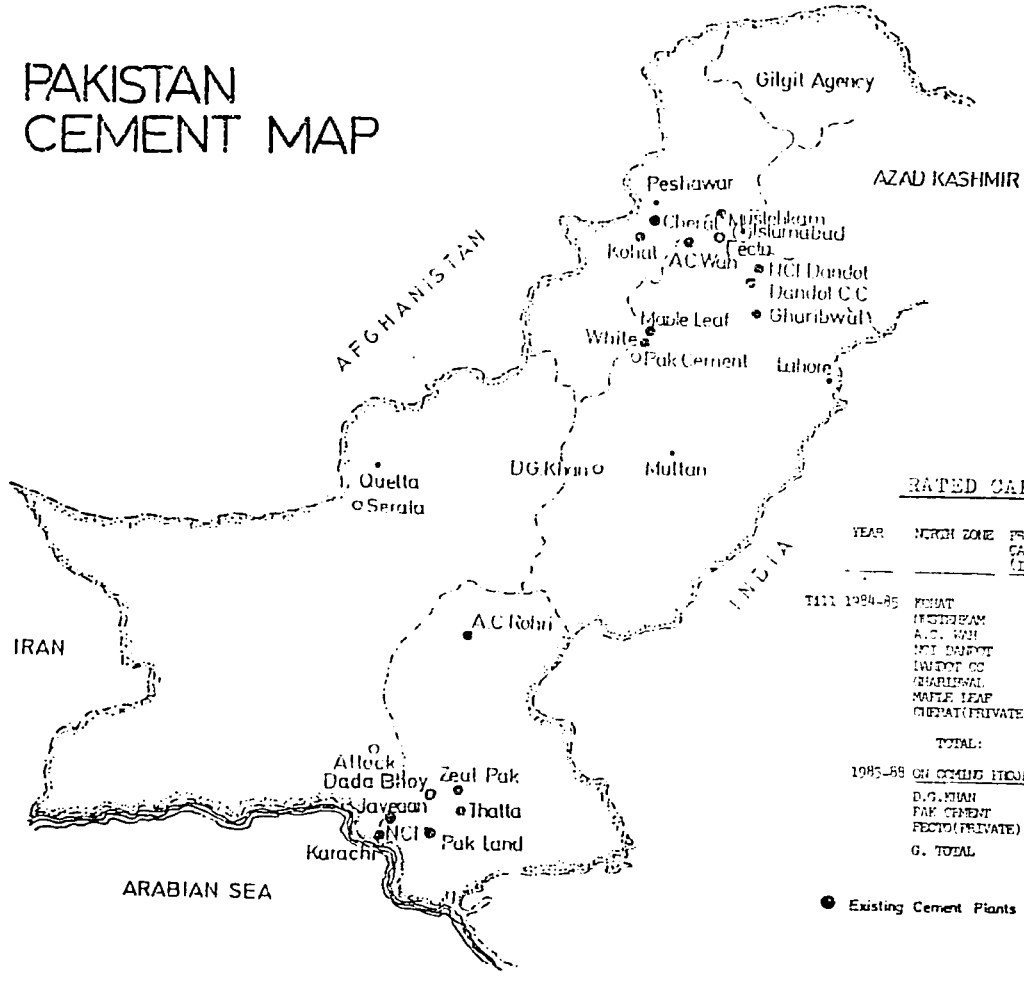
7- A policy decision by the Government will need to be made:-

a) for off-setting the price increase by converting to coal firing.

b) an incentive oriented policy may be developed for the promotion to use coal in cement industry.

c) There should be no duty on the import of coal and coal-processing machinery & equipment.

PAKISTAN CEMENT MAP



RATED CAPACITY OF CEMENT PLANTS

YEAR	NORTH ZONE	PRODUCTION CAPACITY (IN 1000 TONNE)	SOUTH ZONE	PRODUCTION CAPACITY (IN 1000 TONNE)
TILL 1984-85	KOHAT	300	A.C.ROHRI	270
	MUSTEHKAM	600	ZEAL PAK	1080
	A.C. WAH	450	THATTA	330
	NCI DANDOT	50	NCI KARACHI	160
	DANDOT CC	300	JAVEDAN	600
	GHARIWAL	600	PAK LAND(PRIVATE)	800
	MAPLE LEAF	300		
	CHERAT(PRIVATE)	300		
	TOTAL:	2900	TOTAL:	2740
1985-88	ON GOING PROJECT		ON GOING PROJECTS	
	D.G.KHAN	600	DADA BHOY (PRIVATE)	300
	PAK CEMENT	171	SERALA(PRIVATE)	75
	FECTO(PRIVATE)	600	ATTOCK (PRIVATE)	600
	G. TOTAL	4271	G. TOTAL	3715

● Existing Cement Plants O. On Coming Projects

FEASIBILITY OF LOW-GRADE COAL AS FUEL IN THE CEMENT KILN

Misbah Ul Haq Ansari
M.Y. Hassan
Cemtech Consultants (Pvt) Limited

H. Pauls
Progressive Engineering Gestion (PEG)
Geneva

COAL AS A FUEL IN THE CEMENT INDUSTRY

Since 1973's big jump in the price of oil, coal has again become a very important fuel for the cement industry. It is likely to remain so until the price of oil goes so low as to compete favorably once again with coal. In Europe almost all plants previously using oil as fuel have been converted to coal-firing because of economics.

For Pakistan it is also important to revive the use of coal as fuel as much as feasible, keeping in view the process parameters. The presently used oil is largely an imported item costing the country valuable foreign exchange. Over 75% of oil used in the country is imported.

REQUIREMENTS OF QUALITY OF COAL

Normally good anthracite of high percentage of fixed carbon and low ash content is a good fuel for the cement industry. The ideal coal should contain the least amount of volatile materials because volatile combustibles, if found in excess in coal, result in partial escape of unburnt gases from the burning zone where ideally all the fuel fed most burn almost instantaneously on introducton in the kiln burning zone. Secondly, the more volatile combustibles in the coal, the greater the hazard of explosion in the coal processing machinery and equipment. Also, the other advantage of high grade coal is that a minimal amount of unwanted and nuisance chemicals from the left out ash after combustion will not go into the resultant clinker or otherwise affect the process due to cyclic phenomena. Standard texts on cement technology state that coal used in the cement industry should comply with the following rquirements:

Net Calorific Value	6500-7500 Kcal/kg
Ash	12-15%
Volatile Matter	18-22%
Moisture as delivered up to	12%

In the case of gas and furnace oil all the parameters are well defined. Such is not the case with coal. The consumer pays for coal on ex-mine basis, the user computes its consumption on an as-fired basis; then there are moisture free basis, air dried basis, as analyzed basis, etc., so that proper inventory control is rather problematic. In case the low grade coal has to be used in the kiln firing it has to be seen that the ash and sulphur present in the coal do not disturb the requisite composition of the meal being processed beyond the acceptable limits. Also in the case of dry SP kilns, if the coal is high in sulphur and/or chlorides and alkalies it can create cyclic phenomena which can result in the choking of the kiln pre-heater and other gas ducts. In order to ensure that excessive process disturbances in kiln do not crop up, the composition of meal fed to the kiln has to be adjusted to provide for the addition of volatile and uncombustible compounds resulting from the combustion of low grade coal.

In case the composition of the raw-meal fed to the kiln cannot be adjusted beyond a certain limit to accommodate for the addition of ash, etc. into clinker then

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the quantity of coal has to be reduced to meet the chemical parameters of the process and the additionally required heat has to be obtained by blending the low quality coal with other purer fuels like low-sulphur, oil or gas with coal or high quality.

CALORIFIC VALUE AND LIMITATIONS ON NUISANCE COMPOUNDS

Ideally the coal as fuel for the cement kiln should be of calorific value above 6500 Kcal/kg in order to provide a properly hot flame so that clinkering is possible. Clinkering temperature is about 1400°C so that the flame temperature should be over 1600°C. If the coal is poor in calorific value additional high grade fuel will be necessary to help produce a flame of requisite temperature so that clinkering becomes possible. It is known in the cement industry that each 100° increase in flame temperature increases kiln production by 1% minimum. The limits on impurities can be generalized but will vary from case to case depending on what composition is available from the clinker raw-mix.

The impurities of Silica and Alumina and Iron in the coal should be assessed and adjustments made in the raw mix to retain the overall Silica, Alumina and LSF ratios within the permissible limits. Also MgO should not be too high to exceed the limits of maximum 4% in cement. In addition to the above chlorides, alkalies and sulphates should also be so low as not to start the cyclic phenomena which are very disturbing, especially if the process used is a suspension pre-heater without a bypass. The generally acceptable limits for chlorides in raw materials for the straight pre-heater or pre-calciner system is 0.02%. Also for low alkali cements the limits of total alkalies present is 0.6 percent.

In addition to the above, the coal must not contain too much moisture as its presence not only brings down the net-calorific value, thus affecting the economics of coal as a fuel, but also affects the flame temperature adversely. Each 1% rise in moisture of coal at the burner can reduce flame temperature by 10 to 14C°. In case the coal as mined is very moist, it must be air dried to the acceptable limits of the coal mill.

If the sulphur and other cyclic compounds are in excessive quantity these can be to a certain extent eliminated with a by-pass, but the cost of a heavy by-pass and the resultant loss in heat efficiency must be accounted for in estimation of economics.

METHODS OF FIRING CEMENT KILN WITH COAL

The usual method of firing the cement kiln is to pulverize the coal and feed this powder with primary air in the kiln burning zone where the mixture of coal powder and air instantly ignites as it comes in contact with the hot gases and surfaces of the kiln's burning zone. There are two methods of firing the kiln with coal powder. One is the direct and the other the indirect method. In the direct method the coal mill is feeding the mixture of coal powder and the vehicular air stream to the kiln directly without an intermediate stage of storage of powdered coal.

There is also a semi-direct method which basically is the direct method, but allows more control on primary air and some storage of pulverized coal.

In the indirect method of firing, the coal mill operates as an independent unit irrespective of kiln's operation. The mill discharges the coal powder into a hopper where it is stored and only as much coal is drawn from it as is required for the kiln firing.

EXAMPLES OF DIRECT FIRING

A roller mill as per attached Sketch No. 1 forms a convenient method of direct firing of the kiln. The mill has to run continuously so long as the kiln is

operating and only so much air and raw-coal is fed to the mill as is required by the kiln. From a safety point of view this mill is better in the sense that storage of powdered coal is eliminated which can alwasy be hazardous as hot pockets can come up in powdered coal lying dormant for long durations. These mills have a short residence time of material under grinding and therefore the operation can be quickly adjusted to suit the firing requirement at any time.

EXAMPLE OF INDIRECT FIRING

Attached Sketch No. 2 shows a mill in a typical system of indirect firing. This mill operates independent of the kiln operation. The output of this mill is taken into a storage hopper from which it can be conveyed to a kiln for firing. The advantages of this system are that the mill does not have to operate all the time with the kiln and firing of kiln can be continued from this storage hopper while the mill is stopped, either for repair or for adjustment of maximum demand of power. The disadvantages are of greater hazard due to spontaneous combustion in storage as indicated above. It may surprise our new generation of cement technologists that coal used to be the main fuel for the cement industry in Pakistan until the late fifties. This used to be mostly imported coal with some cement plants using local coal. However, as the economics of using furnace oil and later on of natural gas became more favorable, coal was totally dropped as the process fuel. Both the above systems entail heavy investment by way of very expensive coal handling, grinding, firing, by-pass and safety equipment.

COAL FED TO KILN BACK END

Several modern plants with S.P. kilns are these days using old automobile tires as additional fuel by feeding these in shredded form or as a whole at the back end of the kiln. Also in the early precalciner kilns, fuel was introduced by itself in the rising duct with encouraging results. The authors are of the view that in the same manner low grade coal can also be used as fuel to supply a part of the process heat. Like low-grade coal automobile tires are also carboncous material with high volatile and high ash content. The object of this paper is to recommend the same mode of feeding the kilns with local coal as is being used for feeding the waste rubber tires in the kilns of Europe and abroad.

Sketch No. 3 shows a flow sheet of the proposed system.

COST COMPARISON OF CONVENTIONAL AND THE PROPOSED SYSTEM

Coals of calorific value 6500-7000 Kcal/kg are very scarce and costly. A simple calculation will show they will be more expensive than oil even without taking into account the capital cost of the coal firing plant. Lakhra coal is the only coal which is readily available at a reasonable price and the deposit is reasonably close to a few existing cement plants. However, development of the deposit will require considerable time and investment. However, Lakhra coal has low colorific value and higher sulphur content. Data about the Lakhra coal is given in the Table I. Therefore it cannot be used alone; a certain proportion of furnace oil has to be used with it. Our calculations show that absorption of SO_3 by clinker can be kept within specification limits by using at least 22% furnace oil with this coal. The relevant calculations are shown in Table II.

We have also considered the possibility where in the burning zone only 60% furnace oil is used and 40% Lakhra coal is injected into the feed end of the kiln. This possibility will avoid the need for expensive coal grinding, prehomogizing facilities, etc.

Table III gives a comparison of cost of fuel in burning clinker in a 1000 T.P.D. kiln with various proportions of oil and Lakhra coal in an existing plant using fuel oil.

Here it may be pointed out that Alternative A is not technically possible as Lakhra coal alone cannot maintain adequate burning zone temperatures. There will also be excessive absorption of SO_3 in clinker. Alternatives C and D have about the same fuel cost per ton clinker. Alternative C, however, involves heavy capital investment and may take at least two years in implementation. Alternative D does not need heavy capital investment and can be implemented in a relatively short period. It will also be able to take care of high sulphur absorption problem as quantity of coal fed can be adjusted as per the situation of coal supply which cannot be done if a very heavy investment has been made in the coal firing system. We are of the view that the proposed simple installation for partial utilization of local coal in the existing S.P. kilns can be introduced with resultant savings in fuel cost.

QUALITY
OF
LAKHRA COAL

1- Moisture on ROM basis : 30%

2- Gross Calorific Value 4613 Kcal/kg on air dried basis
Net Calorific Value 4000 Kcal/kg on air dried basis

3- Analysis of coal on air dried basis:

PROXIMATE			ULTIMATE		
Moisture	:	9·5%	Carbon	:	65·2%
Ash	:	23·7%	Hydrogen	.	5·2%
Volatiles	:	34·7%	Oxygen	:	18·0%
Fixed Carbon	:	25·0%	Nitrogen	:	1·1%
Total Sulphur	:	7·1%	Sulphur	:	10·5%

4- Ash Characteristics

ANALYSIS		REFRACTORINESS OF ASH	
SiO_2	32·70	Initial deformation point	1310°C
Al_2O_3	20·18	Melting Point	1380°C
Fe_2O_3	30·23	Fluid Point	1410°C
CaO	4·55	Electric Resistivity of Ash	
MgO	2·28	at 100°C	$2·9 \times 10^{13}$
Na_2O	1·18	130°C	$3·5 \times 10^{13}$
K_2O	0·62	160°C	$2·5 \times 10^{13}$
So_3	6·23		
Cl	N.D.		

TABLE I.

SULPHUR CYCLING CALCULATIONS

The following assumptions are made

1- COAL

% Ash	23.7
C.V. Net Kcal/kg	4000
% Sulphur	7·1 (Equivalent to 17·75% So_3)
Ton coal/ton clinker	0·25

2- FURNACE OIL

% Ash	NIL
C.V. Net Kcal/kg	9750
% Sulphur	3.5 (Equivalent to 8.75% S_3)
Ton Furnace oil per ton clinker	0·1026

3- RAW MEAL

Ton Raw Meal/Ton clinker	1·6
So_3 in raw meal%	0·5

4- MAXIMUM SO_3 IN CEMENT

Standard specifications allow a maximum of 3·0% So_3. Out of this it may be assumed that 1·0% has to come from gypsum added to control setting time of cement. The remaining 2·0% is So_3 absorbed in clinker due to sulphur present in raw meal, coal and furnace oil.

5- CALCULATION OF ABSORBED SO_3 IN CLINKER

So_3 absorbed by clinker can be calculated by the following formula (Ref: Cyclic Phenomena in Rotary Kiln Systems by H. Ritzman)

$$So_3 \text{ Clinker} = RM_{So3} \left(1 + \cdot 56 \frac{\text{Coal } So3}{RM_{SO3}} - 0{\cdot}44 \times E \right) \text{ where}$$

So_3 Clinker = So_3 absorbed in clinker in terms of g per kg clinker.

RM_{So3} = So_3 in Raw Meal in terms of g per kg clinker.
= $\frac{0{\cdot}5}{100} \times 1{\cdot}6 \times 1000 = 8$ gm per kg clinker

Coal So_3 = So_3 in coal in terms of g per kg clinker
= $\cdot 25 \times \frac{17{\cdot}75}{100} \times 1000 = 44{\cdot}38$ g/kg Clinker

E = Volality of Raw Meal So_3 (taken as 0·67)

Furnace oil So_3 = So_3 in furnace oil in terms of g per kg clinker
= $\cdot 1025 \times \frac{8{\cdot}75}{100} \times 1000 = 8{\cdot}79$

TABLE II.

Substituting these values in the above formula we get

$$So_3 = 8\left(1 + \cdot 56 \times \frac{44 \cdot 38}{8} - \cdot 44 \times \cdot 67\right)$$

$$= 8\left(1 + 0 \cdot 56 \times 5 \cdot 5475 - \cdot 44 \times \cdot 67\right)$$

$$= 8\left(1 + 3 \cdot 1066 - 0 \cdot 2948\right) = 8 \times 3 \cdot 8118 = 30 \cdot 4944 g/kg \text{ Clinker}$$

So So_3 in clinker with coal firing alone is 3·0494%
This figure has to be reduced to 2·0% by using suitable proportion of furnace oil with coal and this So_3 in fuel in g per Kg clinker is x.

Therefore the above equation becomes

$$20 \cdot 0 = 8\left(1 + \cdot 56 \frac{x}{8} - \cdot 44 \times \cdot 67\right)$$

$$= 8\left(1 + \cdot 07x - \cdot 2948\right) = 8\left(0 \cdot 7052 + \cdot 07x\right)$$

$$= 5 \cdot 6416 + \cdot 56x$$

$$\cdot 56x = 20 \cdot 0 - 5 \cdot 6416 = 14 \cdot 3584$$

$$x = 25 \cdot 64$$

Therefore So_3 from coal-oil mixture should be maximum 25·64g/kg clinker
So_3 from coal alone is 30·4944 and from furnace oil alone is 8·75
Suppose y parts of coal are mixed with (1-y) parts furnace oil to get So_3 25·64g

per Kg clinker. Thus we have the following equation.

$$30 \cdot 4944\, y + (1-y) \times 8 \cdot 97 = 25 \cdot 64$$

$$30 \cdot 4944\, y + 8 \cdot 75 - 8 \cdot 75y = 25 \cdot 64$$

$$21 \cdot 7444y = 16 \cdot 89$$

$$y = \cdot 7768 \text{ say } 78$$

$$1 - y = \cdot 2232 \text{ say } 22$$

So to get 2·0% So_3 in clinker we could use a mixture of upto 78% coal and 22% furnace oil provided that So_3 in raw-meal does not exceed 0·5%.

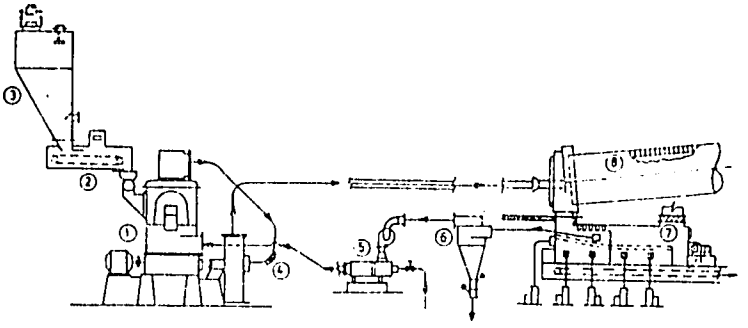
TABLE II. (cont.)

	Conventional Firing			Furnace Oil 60% in burning zone+ Lakhra coal 40% in kiln Feed End
	Lakhra Coal	Furnace oil	Lakhra and Furnace oil 70:30	
	A	B	C	D
Net C.V. Kcal/kg	4000	9750	5725	7450
Kcal/kg Clinker	1000	1000	1000	1000
Kg fuel/kg clinker	0·25	0·1026	0·1746 (F.O.:0·0524 coal:0·1222)	0·1342 (F.O.:0·0805 coal:0·0537)
Fuel Price per ton at Kiln	450	1700	825	1200
Fuel Cost/Ton clinker	112·50	174·42	144·05	161·04
Investment cost total	Rs.25 mio	-	Rs. 25 mio	Rs. 0·4 mio
do per ton	* Rs.21·25	-	* Rs.21·25	* Rs.0·33
Furnace Oil	already		exist	
Labour & Power for coal	3·00	-	3·00	0·50
Total Fuel Cost/ton clinker	136·75	174·42	168·3	161·87

(* Component of interest and depreciation on investment made to introduce coal firing)

TABLE III.

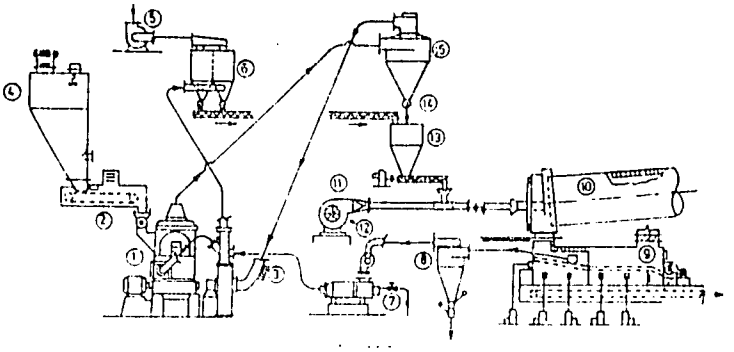
DIRECT COAL FIRING MILL



SKETCH NO. 1

1- ROLLER MILL
2- WEIGH FEEDER
3- RAW COAL HOPPER
4- DAMPER
5- AIR-HEATER
6- DUST TRAP
7- CLINKER COOLER
8- ROTORY KILN

INDIRECT COAL FIRING



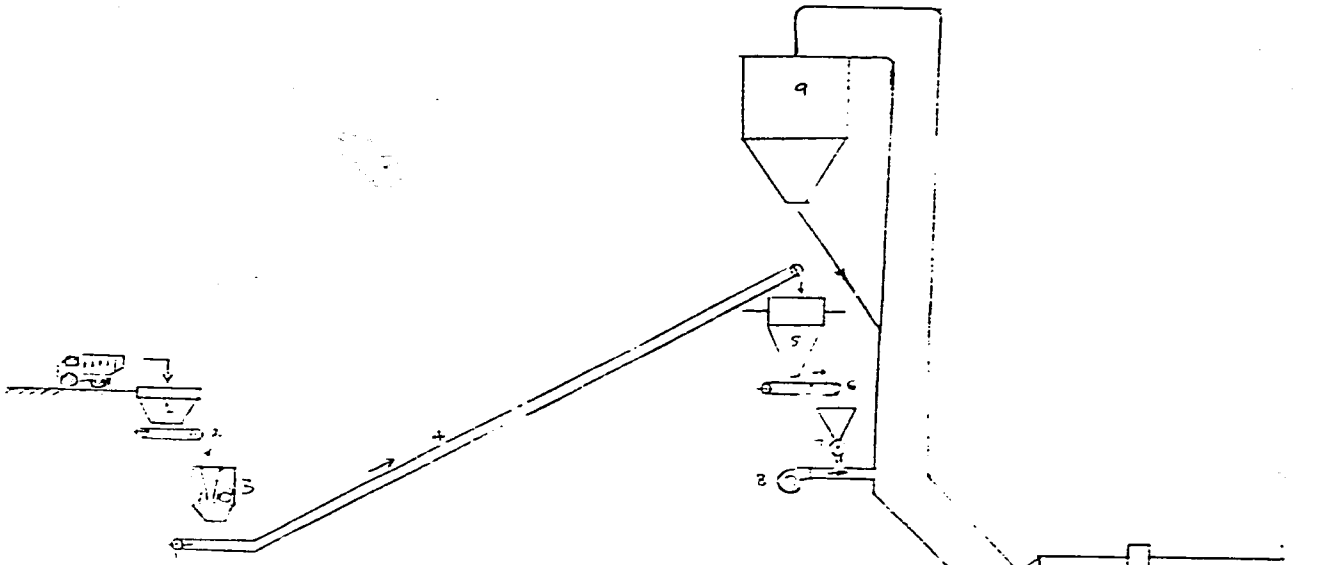
SKETCH NO. 3

1- ROLLER MILL
2- WEIGH FEEDER
3- DAMPER
4- RAW COAL
5- VENT FAN
6- DUST COLLECTOR
7- AIR HEATER
8- DUST TRAP
9- CLINKER COOLER
10- ROTORY KILN
11- PRIMARY AIR-FAN
12- AIR DAMPER
13- GROUND COAL HOPPER
14- ROTORY SEAL
15- CYCLONE

CEMTECH CONSULTANTS (PVT) LIMITED

PROPOSAL FOR BACKEND COAL FEEDING TO AN S.P. KILN

SKETCH NO. 3



1- DUMP HOPPER FOR COAL
2- FEEDER CONVEYER
3- COAL CRUSHER
4- BELT CONVEYER
5- DAILY SUPPLY HOPPER
6- WEIGH FEEDER
7- ROTORY SEAL
8- AIR BLOWER
9- PREHEATER
10- ROTORY KILN

THE FIRST INTERNATIONAL COAL CONFERENCE

KARACHI, PAKISTAN

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"PRODUCTION METHODS AND APPLICATIONS FOR SLURRY FUELS USING PAKISTAN COALS"

PRESENTED BY R. A. POWELL, C. ENG. P. ENG.
INTERNATIONAL MARKETING DIRECTOR
COALIQUID INTERNATIONAL
LOUISVILLE, KENTUCKY 40223 U.S.A.

AND

SHIRISH PHULGAONKAR
DIRECTOR OF RESEARCH & DEVELOPMENT
COALIQUID, INC.

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INTRODUCTION TO COALIQUID

CoaLiquid was founded in 1976 by private investors in Kentucky -- a coal producing state --solely for the purpose of developing and commercializing slurry fuels.

Considerable progress was made towards commercialization in the late 1970's and the first production plant to manufacture coal oil water mixtures was built in Shelbyville, Kentucky to produce commercial batches of slurry using a patented ultrasonic process for stabilizing the fuel. (At that time all other companies were using chemical stabilizers).

In 1980, the McDonnell Douglas Corporation acquired a majority interest in CoaLiquid, Inc. and as part of the Energy Systems Ventures group (ESV, Inc.) of McDonnell Douglas, the company has advanced to recognized leadership position in the slurry fuels business.

Today, CoaLiquid still operates a facility in Shelbyville, Kentucky: operates a 3600 barrel per day plant in Mulberry, Florida and has interests in operating plants in the Pacific Rim and in the Middle East. In addition, CoaLiquid has modern well equipped laboratories in Louisville, Kentucky -- its headquarters -- capable of analyzing most of the world's coals and determining appropriate processes for the beneficiation of such coals and for the manufacture of slurry fuels.

Slurry Fuels

The term slurry fuels in this paper is used in the context of a combustible fuel for industrial and utility boilers, open hearth furnaces, dryers, kilns, and other fairly large volume users of combustible fuel. It should not be confused with the composition of slurries produced solely for the purpose of transportation by pipeline and in a form which cannot be burnt without further processing.

Coal based slurry fuel is primarily used as a substitute for fuel oil in boilers, dryers, furnaces, etc. with the objective of reducing costs for the user and of using indigenous coal wherever possible, thereby reducing a country's dependence upon imported oil or, alternatively, making more indigenous oil supplies available for export and earning hard currency.

Slurry fuels comprise the following:

1. Coal oil water mixtures (COM)
2. Coal water mixtures (CWM)
3. Petroleum coke mixtures (PETCOM)
4. Coal methanol mixtures

CoaLiquid designs its plants to be multifuel capable -- that is to be able to produce at least 1, 2 and 3 above from the same facility and, of course, pulverized coal.

Today it is not particularly "fashionable" to talk about coal oil water mixtures (COM) and most activity has been focused on coal water mixtures (CWM). While this makes economic sense in that it eliminates oil from the fuel entirely, it overlooks economies which are still possible in fuel costs where other factors, such as inability to separate out some types of ash, for example, preclude use of CWM in some boilers. The incentive to concentrate on CWM has been the potential utility boiler fuel market, although no really major conversion has yet taken place, except in Japan.

CoaLiquid Experience

Notwithstanding this, CoaLiquid has built and operated more slurry fuel plants than any other company in the world. While some other companies have repeatedly announced plans for various facilities, CoaLiquid has actually

gone ahead and built plants to be in position to supply the market with fuel, both for demonstration and actual commercial use.

CoaLiquid is also in negotiation for its technology to be used in five other industrial countries for both COM and CWM processes.

CoaLiquid constructed the first ever commercial scale preparation plant for COM in 1979. A major production facility to serve the phosphate industry in Florida was constructed at Mulberry and came on stream in December, 1983. This plant has a capacity of 3600 barrels (638 tonnes) of coal slurry fuel per day (200,000 tonnes per year) and was designed for continuous processing. This plant has been in continuous commercial operation for over 2 years.

A prefabricated batch scale production plant was shipped to the Middle East and has been supplying fuel for a commercial fire tube boiler for almost two years and is now supplying fuel for a commercial drying operation. The plant has a capacity of about 20 tonnes COM a day on a single shift basis and is now operated by our national licensee.

Perhaps of more interest in Pakistan is CoaLiquid's unique experience of building and operating a slurry fuel plant in the Republic of Korea. Although much of the equipment was supplied from the U.S.A. in the interests of saving time, the resources of our local in-country partner were used for construction, erection, commissioning and operation.

This plant has a capacity of 120 tonnes per day and is supplying fuel to commercial boiler operators in Korea. CoaLiquid learned a number of valuable lessons from this project, particularly in relation to storing and handling coal and plant operation under very harsh winter conditions. Considerable experience has been gained in the importance of quality control for the incoming feedstock materials. While other companies have announced plans to construct slurry fuel plants in Asia and the Orient, CoaLiquid has the actual experience of having done it successfully and already being a commercial supplier.

More recently, CoaLiquid participated in a U.S. AID program aimed at eventual conversion of the Philippine Sucat power station to use of CWM fuel. In this program, CoaLiquid was one of the companies who produced a successful combustible CWM from low grade Philippine coal and is continuing work on this project with U.S. AID and directly with the National Power Corporation in Manila. This would eventually require production of some 800,000 tonnes CWM annually in the Philippines and would result in a very substantial reduction in oil imports by that country.

In addition to experience in designing, building and operating slurry fuel processing plants, CoaLiquid has now had substantial experience in converting industrial boilers so that slurry fuel is substituted for fuel oil in all normal use. Not being a boiler or burner manufacturer has allowed CoaLiquid to maintain an independent position in selection of the optimum equipment to meet particular conversion needs.

CoaLiquid also has experience in shipping various slurry fuels to overseas destinations and by both road and rail tank truck.

Slurry Fuel Technology

Probably the general technology is well known to you. In this paper, we will, therefore, only briefly recap the processing methods and feedstock requirements. Let us assume initially a low ash > 6%, coal is available and that beneficiation is not required.

The coal is pulverized to 80% passing mesh 200 (approximately 150 microns) and 100% passing 100 mesh (approximately 25 microns). In a coal oil water mix this pulverized coal is then blended with oil and water -- in the proportions 50% coal, 40% oil, 10% water by weight and, for CoaLiquid, is ultrasonically treated to achieve stabilization for long periods. A typical coal oil water mixture using a good grade of U.S. or British coal will have a heating value of about 15000 (or more) BTU's per lb. (say 8325 k. cal per kg), a specific gravity of about 1.08 to 1.09 and a viscosity at 122°F (50°C) of 6000 cps. After ultrasonic treatment, the slurry fuel is then pumped to storage tanks heated by steam coils. Either batch or continuous procesing can be used. Chemical additives are not required with ultrasonically stabilized coal oil water mixtures.

CoaLiquid's experience with coal water mixtures (which do require chemical additives and stabilizers) has ranged from coal loadings as low as 62% to as high as 75% by weight. The balance is usually made up of about 1% chemicals and the rest water. If the coal has an inherently high moisture content, the coal loading tends to be at the lower figure.

CoaLiquid has employed flotation, spirals and a new proprietary technique for beneficiation. In this context, beneficiation is specifically "deep cleaning" to remove ash and sulphur and is not to be confused with normal colliery or mine washery processes.

In use, slurry fuels can be handled in much the same way as boiler fuel oils with only a few special requirements.

Thus it is ideally suited to situations where it is not possible, either for environmental or economic reasons, to switch from oil to direct coal firing.

Slurry Fuel Economics

The actual economic advantages of switching from oil to slurry fuel will vary according to a number of factors. The determining factor is that the fuel producer must provide economical savings to the user (purchaser) to be acceptable. The end user is never, or rarely, influenced by "patriotic" savings in oil imports, only in the economics to his operation.

Hence CoaLiquid evaluates the feedstock materials, the fuels currently used and the costs of conversion to arrive at a proposal to a potential customer.

For example, we have demonstrated savings of 12 to 18% to users in some countries for Coal Oil Water mixtures (COM) and payback periods for the conversion has short as 10 months. In the case of conversion of oil fired boilers to COM, this payback period is more often in the range 1 1/2 to 3 years depending on the complexity and need to comply with emission control laws.

Greater savings are usually possible with Coal Water Mixtures (CWM) although some derating of boilers may be the penalty to be paid due to the inability of the boiler to accept larger quantities of fuel, i.e., less BTU's in, less BTU's out.

Various pricing formulas are possible for slurry fuel ranging from price per tonne, per million BTU to a "pass through cost" of feedstock plus a processing fee per gallon or liter.

Internationally, there are sometimes restrictions which preclude a private sector organization preparing, processing and selling fuel. In such cases, CoaLiquid seeks a

licensing agreement with the government or state owned agency and a royalty on fuel processed.

Beneficiation

It has already been stated that beneficiation in our context relates to "deep cleaning" of coal, usually after a preliminary grinding stage. Not all coals are receptive to economical beneficiation processing.

For example, South African coals delivered to Mediterranean area countries often have ash content of around 12% and no economical process has yet been found to reduce this to an acceptable 5-6% for production of slurry fuels.

At the other extreme, Cerrejon coal from Colombia hs been found to be relatively easily and economically reduced to around 1-2% ash from an initial level of 12%.

Many Indian coals contain ash levels as high as 30% or more and may compare in this regard with some of the Pakistan sub-bituminous coals. Clearly in these cases, it is preferable, if possible, to leave the ash at the mine rather than pay to transport it to an end user who doesn't want it anyway.

In this regard, we are concerned with use of such coal for slurry fuel applications and an economic analysis must be carried out to balance beneficiation processing cost and location thereof against the other parameters of transport costs and disposal of ash at the fuel processing location.

This gives rise to consideration of a further option of blending high grade coals with poorer quality to "average" out the results.

In general, for slurry fuel use in a boiler designed for oil firing, the ash level in the resulting mixture should not exceed about 4%, although CoaLiquid has produced fuels without detrimental effects on the boiler, with higher ash content. However, ash fusion temperature is also an important factor as well as the calorific value of the feedstock coal.

It may be preferable to pay for a premium low ash coal for manufacture of slurry fuel when compared with the cost of beneficiation processes and chemicals for poor quality coal. Hence CoaLiquid reviews and evaluates the costs and physical characteristics of the coal as well as its acceptance to slurry formulation and beneficiation and to compatibility with proposed combustion applications.

Applications for Slurry Fuels

The applications suitable for slurry fuels are those currently burning fuel oil in industrial boilers, dryers, kilns and utility size boilers. CoaLiquid has additional experience in open hearth and blast furnace applications.

While it is recognized that the optimum low cost fuel for boilers generally is direct firing of coal, this would usually entail the replacement of oil fired boilers at considerable expense and disruption to processing operations.

CoaLiquid's experience ranges across the wide spectrum of boiler design from a small 7 tonnes per hour three pass water tube boiler, D type "packaged" boilers (in Korea specifically a 20 tonne per hour 2 pass water tube boiler) to converted Riley Stoker type boilers (the McDonnell Douglas boiler in St. Louis being of about 35 tonnes per hour capacity). Projects currently under way include an even larger range of boilers and a large MW sized utility boiler.

CoaLiquid has installed various types of soot blowing equipment, including infrasonic devices to prevent soot accumulations in boilers.

In boiler applications, consideration has to be given to possible derating effects, to possible maintenance arrangements for removal of accumulated ash periodically, to environmental and other auto pollution restrictions on emissions and, in particular, to the burner and atomization requirements. While it is not necessarily true for coal oil water mixtures (COM), coal water mixtures invariably require heated comubstion air and even, sometimes, (depending on boiler/burner design) auxiliary fuel support, or at least, firing up an oil initially to preheat the combustion area adequately.

Many types of burners can be adapted or modified to burn slurry fuels. Among the burners with which CoaLiquid has had experience are guns of its own design, ENCO, Hauck (low pressure air atomized), Coen (steam atomized), with modified and developed nozzles, Forney Verloop and others. Considerable development work in conjunction with burner manufacturers has now resulted in nozzle materials and designs with adequate life to withstand the abrasive nature of the coal in the fuel.

In conversion from oil to slurry fuel, a number of other important factors arise. CoaLiquid has found that pumps of the progressive cavity type were superior to other designs in performance and reliability, heat exchanger design is fairly critical to avoid coking (and blockages) of the slurry fuel and, of course, maintenance of the correct temperature and viscosity of the fuel in storage and supply lines is important.

In addition to boiler applications, slurry fuel can be used in cement kilns, phosphate and fertilzer dryers, open hearth and blast furnaces and others.

Considerations of cost of conversion against fuel savings will usually be a determining factor in considering application prospects. For example, if it is not possible to use direct firing of pulverized coal in a cement kiln, the savings arising from conversion to a slurry fuel will likely pay for the cost of conversion in a short period of time, but if a small industrial boiler requires expensive emission control equipment to be added, it may not, in isolation, justify the change unless other factors influence it.

Larger utility boilers, often being owned by governments or state corporations, can often justify the change on strategic grounds rather than purely economic.

In the foregoing part of this paper, we have provided a summary review of slurry fuels, technologies, economics and applications. The next section will deal with the production of slurry fuels specifically related to available Pakistan coal types.

POTENTIAL FOR PRODUCING SLURRY FUELS FROM PAKISTANI COALS

As discussed before, CoaLiquid has been conducting research on various worldwide coals for slurry fuels applications. Even though CoaLiquid has not directly experimented with Pakistan coals, it has successfully produced slurry fuels from several other coals strikingly similar to Pakistan coals.

This part of the paper outlines typical technical considerations and parameters required to be studied to evaluate potential cleaning characteristics and slurriability of a given coal. Then it compares typical Pakistan coals to similar foreign coals.

There are four major operational steps involved in production of slurry fuels. They are:

1. Grinding and classification
2. Beneficiation (if required)
3. Mixing
4. Quality Control

In each of the above steps, several technical considerations are involved. Cost of the final product is an important consideration of actual operating conditions. Grinding of coal is a well known art. For slurry production, coal can be ground wet or dry. Wet grinding typically consists of several ballmills, while dry operation consists of several pulverizers. Even though wet grinding results in better quality of product, we have discovered that dry grinding of coal results in substantial cost savings without harming reasonable performance if appropriate surface chemistry considerations are given.

Beneficiation is a general term used for removing inherent ash and sulfur from coal. Coal washing is different from beneficiation, as washing is restricted only to removal of rocks mined along with coal. Surface chemistry parameters such as electrophoretic mobility and hydrophobicity of coal play an important role in ash reduction and recovery. CoaLiquid has developed a proprietary flotation process for coal beneficiation. A simplistic flow diagram of this process is shown in Figure 1.

After beneficiation, another important stage of operation for slurry fuels is mixing slurry components. Some of the necessary considerations for mixing are surface chemistry, coal particle size distribution, and energy per unit mass of mixing. Surface chemistry of coal, which may vary from coal to coal, plays an important role in determining chemical package required to formulate a stable slurry. No chemicals are used in the case of COM, but surface chemistry helps determine emulsification characteristics of oil present in coal. Coal particle size distribution needs to be determined for optimum coal loadings. As different coals have different fracturing tendencies, the shape of particles also needs to be considered for a required rheology of slurry. Fines and coarse particles have to be in balance, as more fines result in greater surface area, which further results in more demand on chemicals. Energy required or put in during mixing should be optimum. Technically, it has been found that excessive mixing results in destruction of chemicals and then high viscosity dilatent slurries. When it comes to quality control, viscosity (rheology) and settling are the most important considerations.

Typical viscosity of COM is 4000 centipoise, where as that of CWM is 1000 centipoise. Table 1 shows characteristics of typical coals used in slurry production.

Table 2 shows characteristics of Pakistan coals. Tables 3 and 4 show characteristics of some coals similar to Pakistan coals and which are used by CoaLiquid in slurry production. Figure 2 displays typical rheology curve of CWS made from Semirara Philippine coal, which appears to be similar to Pakistan Lakhra coal. It appears that, even though Lakhra coal is a lignite, it may be possible to make COM and CWM. However, actual experiments are needed to explore coal behavior in detail. Table 5 displays beneficiation data on high ash Indian coals, low rank Australian, and Philippine coals. Again, more work is needed on Pakistan coals to see if they show similar results.

A Program for the Introduction of Slurry Fuels into Pakistan

CoaLiquid has developed a number of program formats for the introduction of slurry fuels. Generally, an important prerequisite is a potential partner or licensee and a market need/opportunity to both produce the fuel and users who want to take advantage of the savings accruing from the use of a liquid type fuel produced from an indigenous coal.

Where the industry is primarily in the "public sector", i.e., owned or controlled by Central Governments or State Corporations, a potential arrangement is a license to that organization, with a pilot plant supplied by CoaLiquid either on an outright sale or lease basis, technology transfer and an agreement covering future production arrangemnts. This may take the form of CoaLiquid supplying the design for a production plant (including all the applicable process design) or alternatively, CoaLiquid acting as the engineer and constructor of the plant on a contract basis, that is, a "turnkey" project. The owner/operator then pays CoaLiquid a royalty based on volume of fuel produced. Naturally, it is anticipated that maximum Pakistan content would go into such a plant.

Where the industry operates in the "private sector" (as in Korea for example), then CoaLiquid will entertain joint venture arrangements with a reputable "in country" partner. Such a partner will usually conduct a market survey with the assistance of CoaLiquid market experts.

A minimum production level of about 100,000 tonnes of slurry per year is usually necessary to achieve an economic processing volume and satisfactory return on the plant investment cost. This, of course, requires that potential customers who will use that volume of fuel are located within reasonable distance (say not more than 50 KM from the processing plant) be identified.

Another factor is the potential customer size. Obviously, it is better to have 5 customers each using 20,000 tonnes than it is 100 customers using 1000 tonnes. In case of a potential large volume user, say above 50,000 tonnes, the economics may favor the construction of a smaller "captive" plant on site just for that customer.

Given the above potential production levels in a specific geographic area, the program would call for the following approach.

1. Identification of potential partner/licensee in geographical market area.

2. Identification of user who will dedicate an industrial boiler or dryer, or kiln, etc. to be demonstration combustion unit.

3. Construction of (or supply of) pilot plant to supply fuel for demonstration projects.

4. Market study carried out in parallel with above demonstration projects.

5. Given market potential,decision to construct a production processing plant in location suitable for:

   a) receiving and handling coal feedstock materials

   b) regional market supply

6. Determine financial arrangements and preproduction user commitments.

While it would be inappropriate at this time to make specific time and cost statements because these will be affected by feedstock type, whether COM or CWM or both, Pakistan project content, etc., size of market, whether public or private sector, interest cost, and

many other factors, as an approximate guide only to the investment levels required, the following would apply in the USA.

1) Cost of pilot scale plant without beneficiation, say about $200,000 and about $300,000 with some types of pilot scale benefication.

2) Cost of converting a suitable oil fired burner to burn slurry fuel from $100,000 upwards depending on type and such things as emission controls, whether "on site" storage for slurryfuel available, etc.

3) Cost to construct a 100,000 tonne per year slurry fuel plant about $5 million,more for applicable type of beneficiation equipment.

Conclusion

In this short paper we have attempted to bring to your attention that coal can be used in liquid form (slurry) to replace oil without the disruption and major cost of replacing the whole boiler system. It is also applicable to dryers, kilns, etc., where the conversion cost is usually much less.

With the great emphasis to encourage the use of coal in Pakistan, we believe there will be many opportunities to use slurry. Although we have not emphasized the use of slurry fuel in utility type boilers in this paper, it does have wide potential applicability in this area and considerable work is going on internationally to better define the technical characteristics for these conversions.

In presenting this paper to you, we have drawn your attention to the international experience and expertise of our company, CoaLiquid, Inc., in the slurry fuel business. We will be very pleased to discuss specific details with interested organizations in Pakistan and to assist with identifying potential applications.

• In conclusion, we thank you for the opportunity to present to you an overview of the slurry fuel industry at this, your first, International Coal Conference.

TABLE 1

TYPICAL U.S. COALS USED IN SLURRY FORMULATIONS

COAL ANALYSES

	HORSECREEK ROM (KY)	SPLASH DAM WASHED (VA.)	LOWER KITTANNING WASHED (W. VA.)
As Received:			
Ash %	2.27	6.82	5.7
Moisture %	5.79	2.43	1.8
Volatiles %	37.39	29.21	34.1
Fixed Carbon %	54.55	61.54	58.4
Sulfur	0.65	0.75	0.78
Ash Fusion			
Temperature (°C):			
Initial Deformation	1343+	1237	1482+
Softening	1454+	1482+	1482+
Fluid	1482+	1482+	1482+

TABLE 2

PAKISTAN COALS AND THEIR ANALYSES

COAL	MOISTURE (%)	VOLATILE MATTER (%)	ASH (%)	SULPHUR (%)
Kost-Sharigh	10	35-45	9-35	5-7
Sor Tange Degari	16-19	34-40	10-35	0.5-6
Mach	10	35-39	10-20	3-7
Makerwal	4-7	37-45	7-21	4-6
Salt Range	3-7	26-39	12-38	4-11
Lakhra*	32-36	28-31	7-11	3-6
Meting Jhimpir	15-20	30-35	8-75	3-7

*Largest coal field in Pakistan

TABLE 3
COALS SIMILAR TO LIGNITES
COAL ANALYSES

	BISLIG	SEMIRARA (PHILIPPINE)	BAGACAY	LIGNITE (GREECE)	WABASH VALLEY POND FINES (U.S.A.)
As received:					
Ash %	14.49	8.85	11.78	8.28	18.8
Moisture %	18.92	25.66	33.11	33.12	12.37
Volatiles %	30.73	32.08	28.23	36.80	28.20
Fixed Carbon %	35.86	33.40	26.88	21.28	40.63
Equilibrium					
Moisture %	18.96	25.96	32.27	N/A	N/A
Free Swelling Index	0	0	0	N/A	N/A
Hardgrove Grindability	43	42	47	N/A	N/A
Sulfur:					
Total	0.57	0.58	5.44	0.43	1.29
Sulfate	0.01	0.03	0.04	N/A	N/A
Pyritic	0.20	0.15	1.91	N/A	N/A
Organic	0.36	0.40	3.49	N/A	N/A
Ash Fusion					
Temperature (°C)					
Initial Deformation	1388	1260	1232	1121	1238
Softening	1438	1299	1293	1232	1293
Fluid	1460	1321	1316	1302	1387+

TABLE 4
LIGNITIC COALS USED IN COMMERCIAL SLURRY FUELS TESTING
COAL ANALYSES

	S. CEBU	PLATEAU MINING AMAX (U.S.)	CUMBERLAND ELKHORN (U.S.)	KENTUCKY BLUE GEM (U.S.)	BLAIR ATHOL (AUSTRALIAN)	KALIMANTAN (INDONESIA)
As Received:						
Ash %	4.43	9.51	8.19	6.9	8.0	7.3
Moisture %	9.93	8.74	4.44	4.8	16.0	3.3
Volatiles %	42.35	38.19	33.31	35.0	27.2	44.0
Fixed Carbon %	43.29	43.56	54.06	53.2	57.3	45.6
Higher Heating Value (Cal/g)	6,784	6,397	6,999	6,921	6,527	7,109
Sulfur:	1.74	0.58	0.83	0.84	0.30	0.3
Ash Fusion Temperature (°C):						
Initial Deformation	1121	N/A	1427+	1149	N/A	1140
Softening	1165	N/A	1427+	1204	N/A	-
Fluid	1182	N/A	1427+	1232	N/A	1371

TABLE 5

BENEFICIATION ANALYSIS

	INDIAN COALS		PHILIPPINE COALS		AUSTRALIAN COALS
	COAL-1	COAL-2	COAL-3	COAL-4	COAL-5
Original					
Ash %	28.13	34.75	11.78	14.49	10.31
Product					
Ash %	5.86	6.96	3.21	5.11	3.04
% Heating Value					
Recovery	81	79	85	89	88

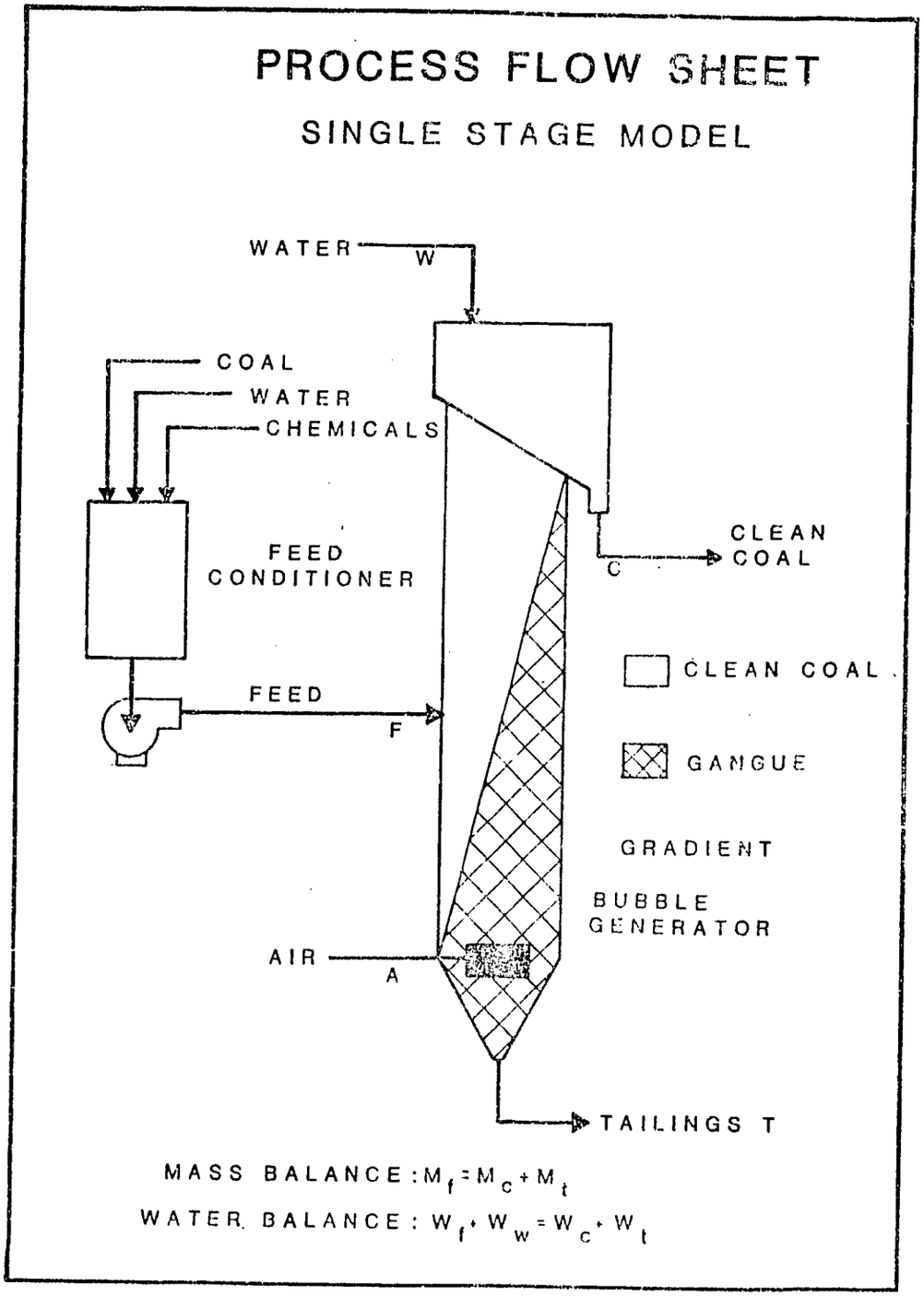

FIGURE 1 CLI BENEFICIATION PROCESS

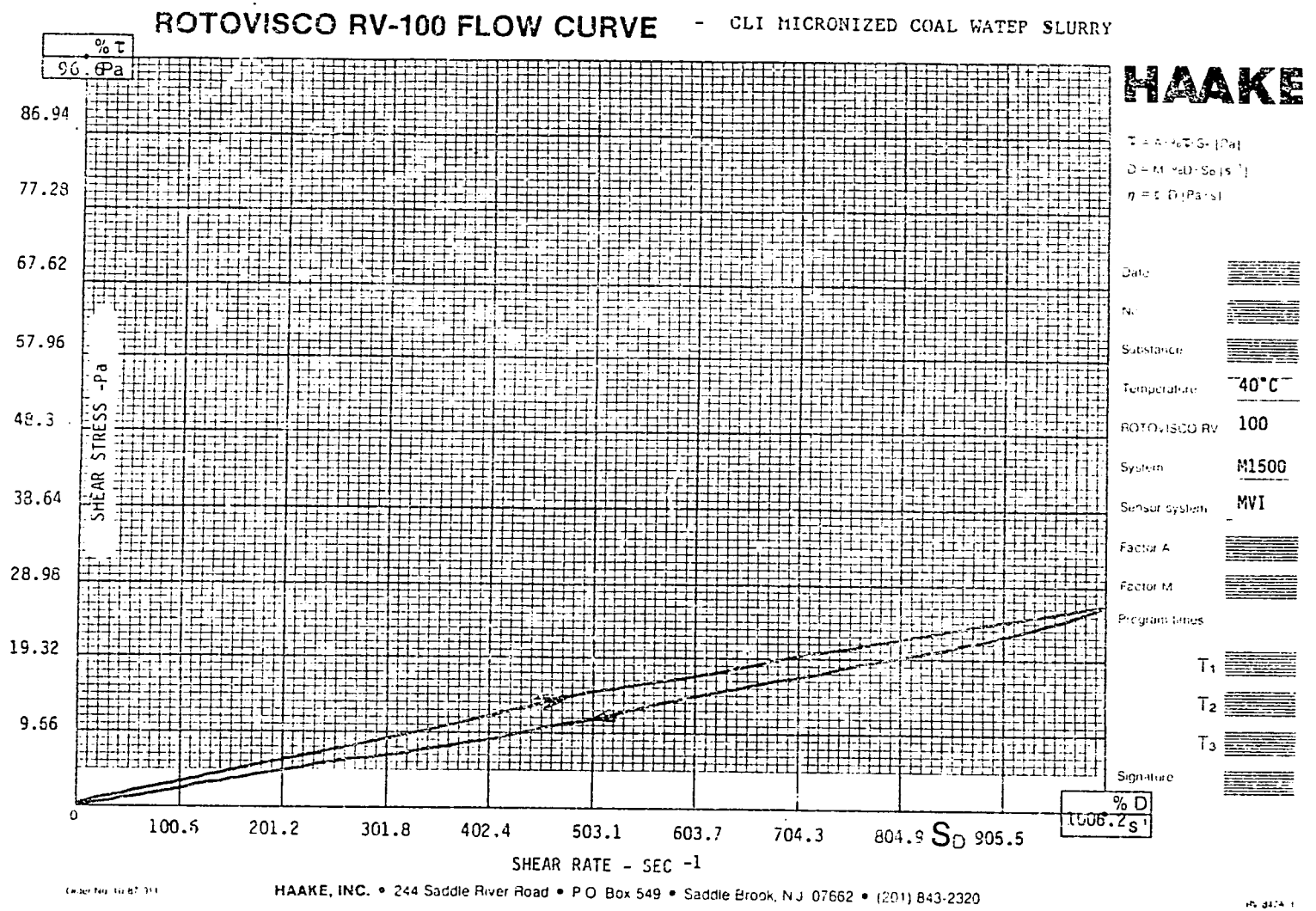

FIGURE 2 RHEOLOGY OF CLI MICRONIZED CWM

FLUIDIZED BED COMBUSTION TECHNOLOGY FOR INDUSTRIAL USE IN CHINA

Mao Jianxiong
Department of Thermal Engineering
Tsinghua University, Beijing, China

STATUS OF CHINESE COAL RESERVES

In the 1960s and 70s, initial work on fluidized bed combustion (FBC) technology in China was concerned with the use of local low grade coal for industrial use. This was (and is) due to the Chinese energy structure and the distribution of coal reserves in China, which have the following features:

1. China is a country rich in coal reserves. By 1984, proven national coal resources reached 781,500 million tons. There are over 53,000 coal mines in China, including over 500 state-run coal mines, producing about 400 million tons in 1984; over 2,500 provincial coal mines, producing 180 million tons in 1984; and over 50,000 collectively and individually run small mines which produced 190 million tons in 1984. The raw coal production in 1984 was 772 million tons and 847 million tons in 1985, ranking second in the world. In addition, the waste from coal mines is about 100 million tons per year, some with a heating value of over 1,500 kcal/kg.

2. The rich coal reserves and rapid increase of coal production make coal a predominant factor in primary energy. In 1983, coal constituted 73.7% of primary energy consumption in China, and it will not be less than 70% for a fairy long period in the future.

3. Even though China is one of the largest coal producers in the world, the distribution of coal mines is not uniform, most coal mines are concentrated in North China, such as in Shanxi Province (with 30% of the total coal reserves), and the regions of Inner Mongolia and Xinjiang. The developed industrial areas (south of the Yangtse River, coastal areas and the northeast of China) lack coal deposits, especially high grade coal deposits, but consume a large proportion of coal production. Local high grade coal production cannot satisfy their industrial and domestic needs, and deposits of local low grade fuels such as oil shale, lignite, low quality bituminous coal and anthracite are difficult to burn by conventional combustion equipment. Also, because of the difficulty of long distance transportation of coal from north to south and from west to east, there is a certain shortage of energy resources in these areas.

4. The sulfur content of some Chinese coal is high. Coal with a sulfur content greater than 2% accounts for 20% of total production. In some provinces such as Guizhou, Sichuan, Guangxi, Hubei and Zhejiang, the Production of coal with high sulfur content is higher than 50% of their total production, 80% of the local coal production is burned directly without washing. Therefore, the air pollution caused by sulfur dioxide formed by coal combustion has become more and more serious. Acid rain has been measured in marked concentrations in 23 cities in these areas.

DEVELOPMENT OF FBC TECHNOLOGY IN CHINA

History

In view of the status of Chinese coal resources, early in 1965, a joint force, including members from Tsinghua University, designed and installed the first fluidized bed boiler (FBB) with a capacity of 14.5 tons per hour for burning oil shale in Maoming city, Guangdong province, where there is a lack of high quality fuel deposits. Since then, the application of FBBs has quickly spread in China because of its following basic advantages:

1. Various kinds of low grade fuels can be easily and stably burned in FBBs.

2. Low combustion temperature (800-950°C) can reduce the emission of sulfur dioxide from sulfur containing fuels by addition of limestone or dolomite and can also reduce No_x formation.

3. High heat transfer coefficients can make the heating surface in a FBB smaller than that of a conventional boiler.

4. Ash and slag from FBBs can be used as building construction materials.

During the 20 year history of developing FBC technology, more than 2,500 FBBs have been in operation throughout the country, mostly burning different varieties of low grade fuels including oil shale, lignite, low grade bituminous coal and low grade anthracite with high ash content and low heating value, and even coal mine refuse. The steam generating capacity of these FBBs varies from 0.2 t/h to 130 t/h. Most of them have a capacity of 4 t/h, 10 t/h to 20 t/h (FBBs with capacities of 2 t/h, 10t/h, 24 t/h, 35 t/h and 130 t/h are shown in Fig 1 to Fig 5 respectively). Those with a capacity of less than 35 t/h are usually used in light industries, chemical plants, and in the heating of homes and factories. Those with a greater capacity are used for electric power generation.

Application

The successful development of FBC technology in China makes the utilization of local low grade fuels possible and eases the shortage of energy sources in those areas which have only deposits of low grade fuels, which are difficult to burn by conventional combustion equipment. For instance, there are 1,200 small ammonia fer-

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tilizer plants in China which need steam for their productive process. Before the application of FBBs, the gap between fuel supply and steam demand impaired production in many places. But since local low grade fuels and industrial refuse can be burned in FBBs, the production costs of ammonia have been greatly reduced. In Guangdong province alone, the application of over 500 FBB units has raised the percentage of self supply of fuel to 50%. In the Tangshan region of Hebei province, there are 50 FBB units burning 324,000 tons of Coal mine waste per year. This means that 128,600 tons of high grade coal and 3 million yuan (about $ 1 million) can be saved annually.

Because coal mine waste with a heating value of approximately 1500 kcal/kg can be burned in FBBs, about 600 FBB units are being installed and put into operation in coal mine regions. They are used for home heating and industrial processes, and for generating electrical power. A power station equipped with two 35 t/h FBBs and two 6 MW steam turbo-generators can burn 200,000 tons of coal mine waste and generate 50 million KWh electrical power per year. The cost of electricity is only 4-5 Fen/KWh (100 Fen = 1 Yuan, 1USD = 3.19 Yuan), while the commercial price of electricity in coal mines is 7.14 Fen/KWh. This means that not only 80,000 tons of high grade coal can be saved in a year, but also 720,000 Yuan ($230,000) for buying electricity per year. One KWh of electricity is able to create 2.63 Yuan of production value and hence 130 million Yuan of production value will be achieved per year. For example, two 35 t/h FBB units were installed in the Gaokeng Power station at the Pingxiang coal mine. The fuel used for these FBBs is Pingxiang coal mine waste with a heating value of 1560 Kcal/Kg. The economic benefit realized by the power station is remarkable because of its very low fuel cost. In 1984, its net profit was 1.3 million Yuan ($400,000). Therefore, more than ten FBB stations with the total capacity of 1000 MW will be built at coal mines throughout China to burn coal mine waste in the next few years.

Manufacture

Most FBB users retrofitted conventional boilers with FBBs under the direction of universities during the early period of FBC technology development. Presently, there are 21 industrial boiler works producing 29 different types of FBBs in China. In 1984, these factories designed and manufactured over 240 FBB units. of the 21 industrial boiler works, Guangzhou, Jiangxi and Wuzhou Boiler Works are best known for manufacturing FBBs.

The Guangzhou Boiler Works has a 10 years history of FBB production. 359 FBB units, including 10 different types with capacities from 2 t/h to 20 t/h, have been manufactured by this boiler works. Fig.6-Fig.9 shows the FBB products produced by the Guangzhou Boiler Works; Table 1 shows the main specification of the FBBs.

The Jiangxi Boiler Works has produced over 120 FBB units which can burn different kinds of low grade coal with a thermal efficiency higher than that of the Chinese Code. Its 35 t/h FBB (see Fig.4) for an on-site coal mine power station has been in operation for over 15,000 hours, while burning coal mine waste with a heating value of 1500 Kcal/Kg, thus winning the "Golden Dragon" Prize in 1983 and the "New Product Excellence" Prize in 1984, awarded by the state Economic Commission of the P.R.C. In order to further develop FBC technology, the Jiangxi Boiler Works has cooperated with Tsinghua University to form a joint technology-production organization: the Jiangxi-Tsinghua Thermal Energy Technology Development Center.

Large size utility FBBs are produced by utility boiler works such as the Shanghai and Dongfang Boiler Works.

FUELS USED AND OPERATION PARAMETERS FOR FBBs

The representative fuels used for FBBs in China are oil shales, lignites, low grade bituminous coal, anthracite, stone-like coal and coal mine waste. The heating value of fuels used ranges from 1,000 to 3,000 Kcal/Kg; some fuels have an ash content of up to60-70%, or a moisture content of up to 50%, as shown in Table 2.

The difference in the varieties of fuels reguires a variety of construction and performance features in the FBBs. Therefore, the design and operation parameters for FBBs vary according to application. For example, the Combustion efficiency of FBBs in China is 60-90% and boiler efficiency is 50-85%, depending upon the different kinds of coal used, as can be seen from Table 3.

Table 4 shows the particle size range of fuel used and the typical design and operation parameters for FBBs in China.

LIGNITE-FIRED FBB

Northeast and Southwest China are rich in lignite reserves. In general, it is difficult to burn lignite with conventional boilers such as stoker-fired boilers because lignite has a high moisture content (740%) and a low heating value (2000-3000 Kcal/Kg). The successful application of FBC technology makes the use of local lignite possible and has spread quickly in northeast China. At present, there are more than 800 FBBs in Northeast China for local industrial use.

In China, lignite with wide-size distribution is used in FBBs. The particle sizes in general are 0-25 mm. But due to lignite's pyro-cracking characteristics, the allowable particle size can be augmented to 50mm.

In order to burn lignite in FBBs with high combustion efficiency, one of the key factors is to extend the resident time of unburned both volatile and carbon in flyash. Many different methods have been utilized and have gained excellent results in burning lignite in FBBs: combustion efficiency can reach 90-95%.

Different cyclone furnaces have been developed in Northeast China to extend the resident time of fine particles with unburned carbon. Fig 10-Fig 12 shows different types of lignite-fired FBBs with cyclone

furnaces respectively. Fig 10 shows a 10t/h FBB with a rear cyclone unit which is installed at the back of the boiler furnace and alongside the convection bank. Fig 11 is a 12 t/h FBB with a side cyclone unit which is installed on the side of the furnace, the convection bank at the back. A 10 t/h FBB with a top cyclone unit is shown in Fig 12, from which we can see that the cyclone unit is installed at the upper part of the freeboard, supported by a refractory brick arch. The ash particles separated in the cyclone return to the boiler furnace through the small holes on the bottom of the cyclone.

ENVIRONMENTAL PROTECTION

As mentioned earlier in this paper, coal with a sulfur content greater than 2% accounts for 20% of total production. As a result, the air pollution caused by sulfur dioxide formed by direct combustion of coal has become more serious. In order to control air pollution by using FBC technology, Tsinghua University began early in 1973 to develop desulfurization technology, and gained remarkable results.

The consumption of limestone----Calcium utilization----is one of the most important indexes economically for sulfur retention by FBBs. According to our investigation, the calcium utilization for raw limestone is low. It is only less than 5% for sizes larger than 3 mm, and 18% for sizes of 1 mm. Theoritically, the finer the sizes of limestone particles, the higher the utilization because of the larger specific surface area of their reactive surface. But, in fact, utilization is still smaller than 10% because of the elutriation of the fine particles, this is the resident time for finer particles is shorter.

In order to improve efficiency of utilization, a new, specially treated limestone----Huayi Desulfurizer----has been developed by Tsinghua University in 1984. The results of experimental investigation have indicated that calcium utilization can reach 60-85% for a size range of Huayi Desulfurizer Particles from 0 to 5 mm. Also, a field test has been carried out on a 4 t/h FBB in 1984, burning bituminous coal with high ash and high sulfur content, which indicated a calcium utilization of over 65% and a sulfur capture efficiency of 83.6%. Although right now the cost of the treated limestone is 20% higher than that of raw limestone, it can be compensated for from reduction of consumption of limestone.

CONCLUSION

In order to further promote the application and development of FBC technology in China, the Chinese government has organized universities, research institutes, boiler works and FBB users to cooperate with each other, and has allocated a special fund since 1981 to develop FBC technology. The funds will increase by one and a half each year within the next five year. We are sure that the development of FBC technology in China will soon enter a new stage. The application of FBBs will be further spread, both in quantity and capacity and in variety.

We expect that a new generation FBB, with high combustion efficiency, low pollution and low energy consumption, will be developed in 5 to 10 years to replace most conventional industrial boilers, which have low combustion efficiency, high pollution and high energy consumption; more than 10 on-site coal mine FBB power stations with a total capacity of 1000 MW will be built; large size utility FBBs will be installed in high capacity central power stations; the pollution of those cities where coals with high sulfur content are burned will be reduced to meet the Chinese Code; and sulfur in coal will be conerted by FBC into a resource to serve the development of fertilizer production and building construction materials.

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Table 1. Main Specification of the FBB

Model		SHF2-13	SHF4-13	SHF4-25	SHF6-13	SHF8-13	SHF10-13	SHF10-25/400	SHF20-25/400
Steam Evaporation	kg/hr	2000	4000	4000	6000	8000	10,000	10,000	20,000
Max. Working Pressure	kg/cm²	13	13	25	13	13	13	25	25
Steam Temperature	°C	Saturated (194)		Saturated (225)	Saturated (194)		Saturated (194)	400	400
Feed Water Temperature	°C	60	60	105	60	60	60	105	105
Air Temperature	°C	30	30	30	30	30	30	30	30
Heating Surface Area									
Fluidized Section Surface	M²	5.1	9.56	8.16	7.6	12.5	11.32	13.1	30.82
Suspended Section Surface	M²	3	5.96	5.6	29	26.4	18	17.95	30.4
Superheater Surface	M²							61.36	110
Convection Section Surface	M²	70	120	120	106	106	174.7	175.8	315
Economizer Surface	M²			60	94.4	94.4	165.2	165.2	312.52
Air Preheater Surface	M²						179.6	179.6	441
Fluidized bed Area	M²	1.03	1.608	1.608	2.53	2.53	3.835	3.835	6.84
Fuel		Low Grade Fuel (2500 Kcal/kg, 3500 Kcal/kg) Such as Poor Coal, Inferior bituminous Coal and Boxes Coal or Inferior Anthracite Coal							
Size Range of Coal-Fired	mm	0-8	0-8	0-8	0-8	0-8	0-8	0-8	0-8
Dimension L	M	4.62	6	6	6.5	6.5	5.11	5.11	11
B	M	2.55	3.5	3.5	4.08	4.08	9.07	9.07	6.5
H	M	4.9	6.5	6.5	11.6	11.6	12.08	12.08	14
Main Auxiliaries: Blast Fan, Draft Fan, Boiler Feed Pump, Fuel Feeder, Coal Crusher & Vibrating Screen, Dust Collector, Water Treatment Equipment, Boiler Instrument & Control Panel									

Table 2. Characteristics of fuels used for FBBs in China

Type of fuel	Volatile matter (moisture & ash free basis) %	Ash Content (as received basis) %	Moisture content (as received basis %	Lower heating Value Kcal/Kg
Oil Shale	30-40	50-70	16	1000-3000
Lignite	40	20-35	20-50	2000-3000
Low grade	14	40		2500-3500
Stone-like Coal	7-25	60-85	2-10	850-1500
Anthracite	3-10			4500-6000
Coal mine Waste	14	60-75	12-18	1000-2000

Table 3. Combustion and Boiler Efficiency of FBBs in China

Fuel Rank	Combustion Efficiency %	Boiler Efficiency %
Oil Shale	91-92	-70
Lignite	85-95	78-87
Low grade Bituminous Coal	70-90	60-75
Stone-like Coal	60-80	50-60
Anthracite	65-85	55-80
Coal Mine Waste	60-85	55-75

Table 4. Typical Design and Operation Parameters for FBBs in China

Max particle size of fuel	normal range: 0-10 mm. Max 20 mm (for lignite, 25 mm)
Heat Release Rate per bed area	$(1.5-3)\times10^6$ kcal/m^{2}h
Superficial Velocity (cold State)	0.6-1.4 m/s
Hight of fixed bed	300-500 mm
Nominal bed depth	800-1200 mm
Windbox Pressure	400-700 mm H_2O
Excess Air at Furnace Exit	10-40%

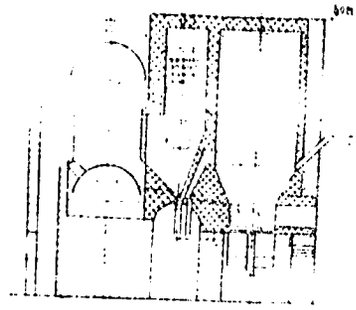


Fig.1 2 t/h FBB

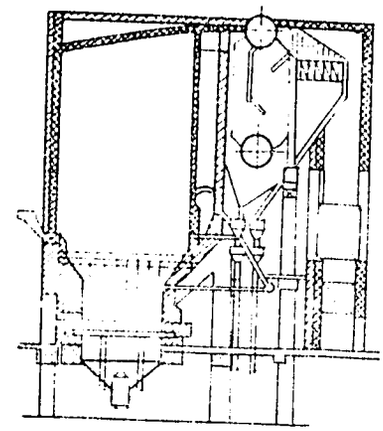


Fig.2 10 t/h FBB

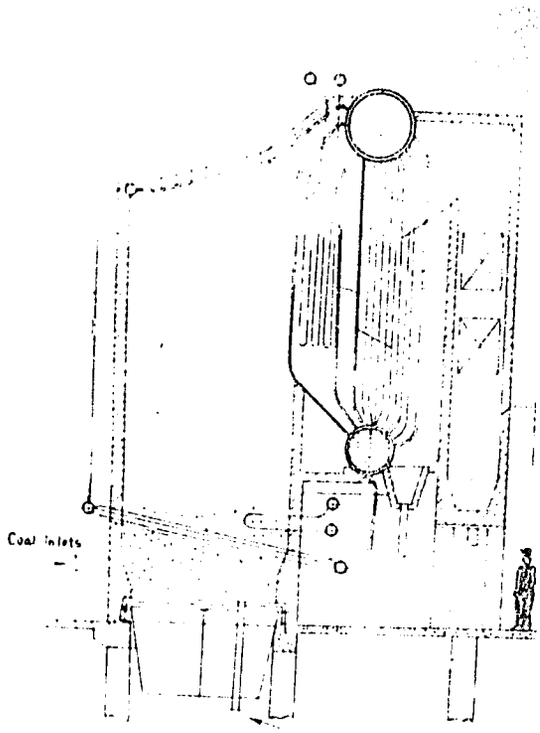


Fig.3 24 t/h FBB

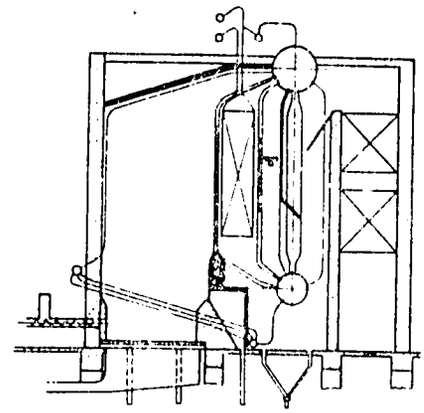


Fig.4 35 t/h FBB

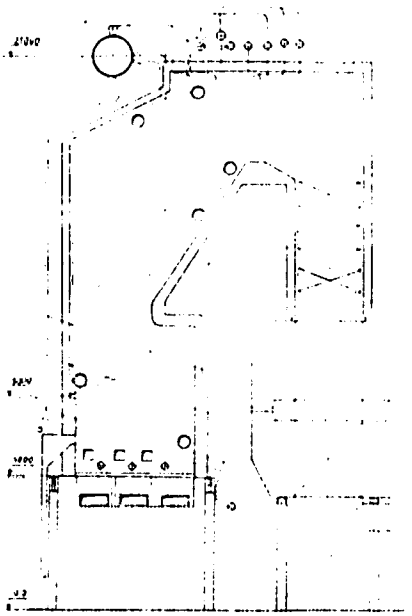


Fig.5 130 t/h FBB

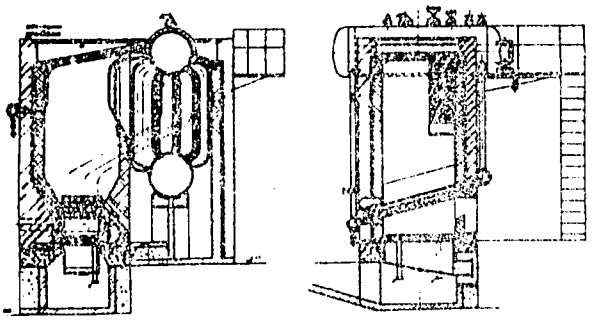


Fig.6 2-4 t/h FBB manufactured by Guangzhou Boiler Works

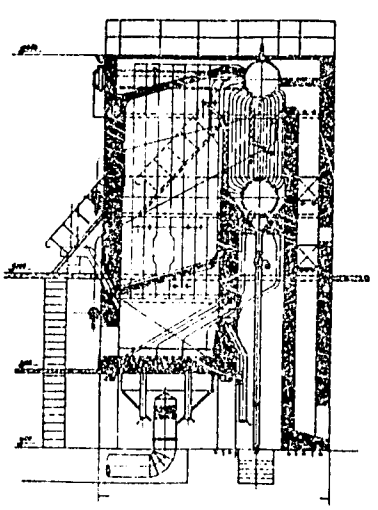


Fig.7 6.5-8 t/h FBB manufactured by Guangzhou Boiler Works

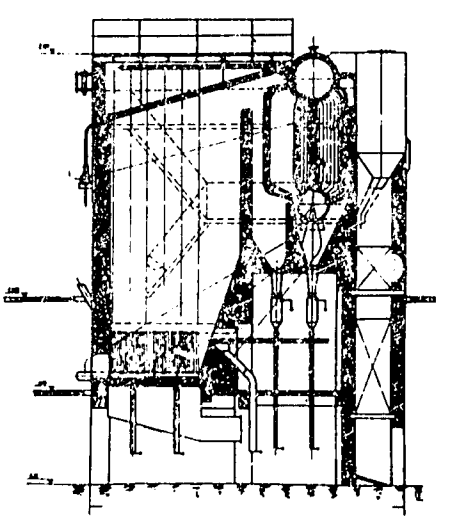


Fig.8 10 t/h FBB manufactured by Guangzhou Boiler Works

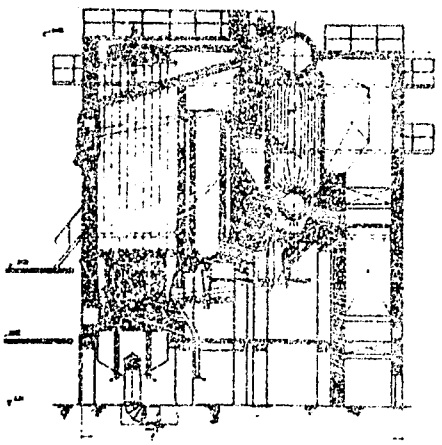


Fig.9 20 t/h FBB manufactured by Guangzhou Boiler Works

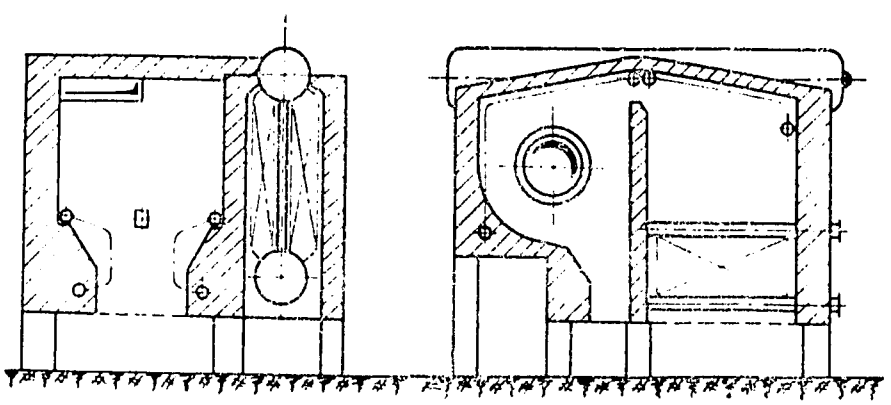


Fig.10 Lignite-fired FBB with rear-installed cyclone

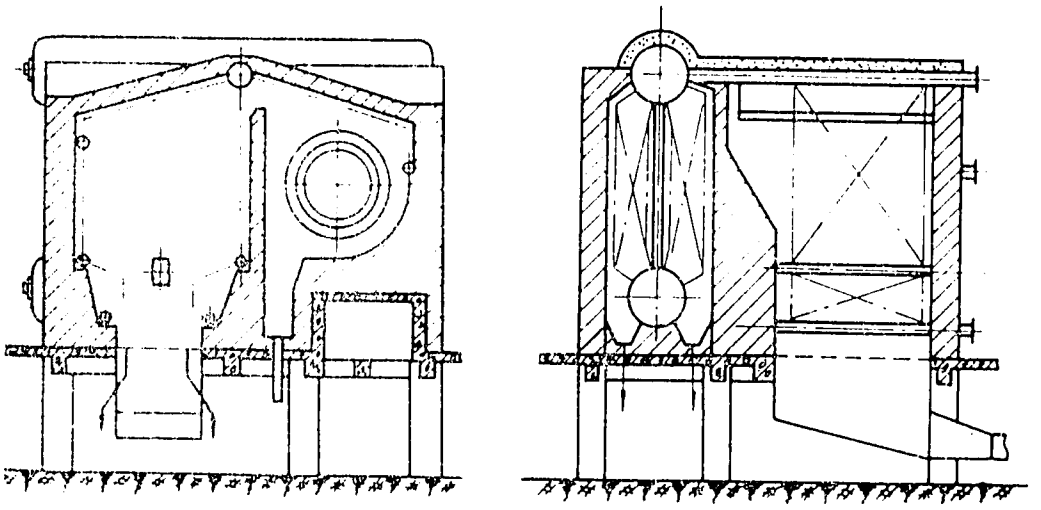


Fig.11 Lignite-fired FBB with Side-installed cyclone

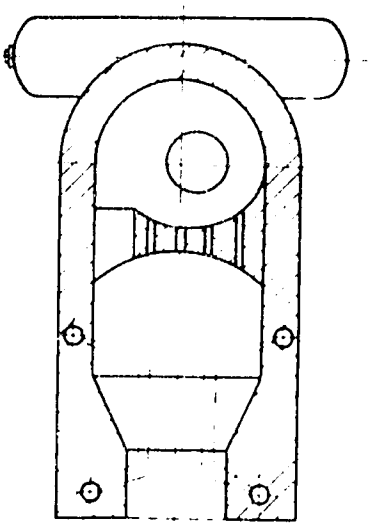


Fig.12 Lignite-fired FBB with top-installed cyclone

THE APPLICATION OF SMOKELESS BRIQUETTES IN DEVELOPING COUNTRIES: THE CASES OF HAITI AND PAKISTAN

A. SABADELL,* R. SHELTON,† G. STEVENSON,‡ T. WILLSON**

ABSTRACT

Traditional energy sources are a significant fraction of energy demand in developing countries. These sources have become increasingly scarce because of clearing of land for agriculture, charcoal production, and excessive timber harvesting. One option for mitigating one aspect of this multidimensional problem is the use of smokeless coal briquettes. Resource and market conditions are excellent in some developing countries for the substitution of smokeless briquettes for fuelwood (which includes firewood and charcoal). U.S. Agency for International Development (USAID) has developed a five-step procedure for determining the potential substitution of smokeless briquettes for fuelwood: resource evaluation, market assessment, technological assessment, government policy and institutional assessment, and business and market assessment. Through recent assessment activities in Haiti, we have gained knowledge and understanding of the market mechanisms for fuelwood substitution which we intend to apply in Pakistan.

In Haiti the fuelwood situation is critical, but there are domestic lignite resources which serve as a potential substitute for fuelwood. The first issue addressed is a review of previous assessments of Haitian lignite reserves for prospective production of smokeless briquettes. Current estimates indicate economically recoverable reserves of approximately six million metric tons, with high levels of water, ash, and sulfur, and a low caloric content. The resource assessment is followed by an evaluation of the technical feasibility of producing smokeless briquettes from the Haitian lignite. This is being done in conjunction with the University of North Dakota Energy Research Center. The Center is making different types of briquettes using various binding agents to determine the most efficient type of briquette for use in Haiti.

Another major thrust of our analysis in Haiti is the identification of the likely markets for lignite briquettes through the use of marketing survey techniques. In particular, we are looking at the potential for briquette use in urban households, small commercial enterprises, small [illegible] industries, school canteens, and small institutional establishments. The current system of fuelwood supplies is being assessed in Haiti as to type, size, and ownership, in order to analyze the potential for using the current distribution infrastructure for supplying smokeless briquettes. In addition, the East-West Center in Hawaii is performing environmental tests on the Haitian briquettes, as well as Haitian charcoal, to discover any detrimental environmental effects which may constrain market penetration.

Important policy issues also are being addressed as the analysis includes an assessment of the best institutional arrangements for mining the lignite, including private, joint-venture, and state mining operations. Another particularly interesting part of the study is determining how to involve the private sector in the manufacturing, transport, and wholesale and retail marketing aspects of smokeless briquettes.

With some modifications, it is anticipated that in some aspects this model of analysis can be used in Pakistan. Since the resource base is significantly larger, and production of coal is already taking place, many of the mining/importing issues can be resolved much easier than in the Haitian context. Furthermore, many institutions have already been involved in a preliminary way with the potential for introducing smokeless briquettes, therefore, the focus in Pakistan will be on an assessment of the current market, examination of government policy and institutional issues, and the development of a business implementation plan.

*U.S. Agency for International Development (US AID), Washington, D.C.

†Oak Ridge National Laboratory (ORNL), Oak Ridge, TN.

‡Haiti Project Leader, ORNL, Oak Ridge, TN.

**JDS Group, Inc., Cambridge, MA.

BACKGROUND

The traditional energy sources, fuelwood (which includes both firewood and charcoal), animal dung, and agricultural residues, account for nearly all of the rural household energy demand, and a significant portion of the energy demand among the urban poor in most LDC's.* In Africa, it has been estimated that traditional fuels account for about 5 percent of total per capita energy consumption; in Asia they account for nearly 30 percent; and in Latin America traditional energy comprises approximately 25 percent of total per capita energy consumption.[8] In many of these countries, the percentage of traditional energy consumption is expected to increase concomitantly with expanding populations, particularly in urban areas.

The principal causes of deforestation in developing countries usually can be attributed to three factors: (1) the clearing of land for subsistence and plantation agriculture; (2) the production of charcoal to meet rapidly rising demands by urban populations; and (3) excessive and inefficient commercial timber harvesting for domestic and export construction and manufacturing industries. The demand for firewood by rural populations is generally not the major cause of deforestation. Rural firewood demand is often characterized by the cutting of branches from live trees, shrubs, and bushes, and gathering of seed wood and does not always require the destruction of whole trees.

The rate of deforestation has been estimated at about 7.3 million hectares per year for tropical forests and about 4 million hectares per year in semi-arid regions.[5] New wood supplies from reforestation programs have had little real impact to date. The Food and Agriculture Organization (FAO) estimates that for every ten hectares of cleared forest there is only one hectare replanted.[5] The environmental impacts of land clearance are cumulative and usually begin with reduced infiltration rates, increased water runoff, and increased soil temperatures. Water and wind erosion quickly sets in motion an almost irreversible process of soil degradation. In West Africa, soil loss from cultivated fields is as much as 6300 times greater than that for forest land; in Senegal, soil loss from groundnut cultivation is nearly 750 times greater than that for dry forest.[10]

*Portions of this paper are taken from Ref. 9.

Deforestation also reduces upland water storage and intensifies siltation of reservoirs and rivers resulting in higher incidences of seasonal flooding, which leads to additional soil erosion. Moreover, the removal of bush vegetation in arid and semi-arid regions contributes to the onslaught of desertification. In some areas, particularly the Indian subcontinent, the rural population has turned to the burning of dung and agricultural residues. The use of these fuels deprives the land of crucially needed nutrients and soil conditioners. The end result is a dramatic decline in agricultural productivity--the backbone of most developing countries.

Reduced agricultural productivity sets in motion a cycle of unemployment and underemployment that serves only to accelerate the migration of rural populations to overly crowded urban centers. The scarcity of fuelwood also means that wood gatherers, primarily women and children, must now spend considerably more time in search of fuelwood. For example, in upland areas of Nepal households are spending from 60 to 230 workdays per year on firewood collection, and up to 300 workdays per year in some parts of Tanzania have been observed.[1] The scarcity of wood has, in most urban areas, resulted in the creation of markets for fuelwood. These markets have placed a heavy burden on the cash resources of the rural and poor urban populations. In the capital of Burundi, households are spending as much as 30 percent of their income for fuel. As prices rise for wood and charcoal, populations begin to cut back on their consumption, and in some cases are reduced to cooking only once per day. In acute scarcity regions, fuelwood disappears altogether from the urban markets.[2] The fuelwood crisis can become so severe that in some African towns the cost of fuelwood exceeds the costs of commercial fuels such as kerosene and electricity.

THE POTENTIAL FOR SMOKELESS BRIQUETTES

The penetration of coal briquettes for fuelwood will be greatest in urban areas, where fuel choice is largely determined by price. The possibility of fuel substitution in rural areas is less promising since most people live outside the commercial economy.

On the supply side, virtually all aspects of coal briquetting manufacture and distribution can

be controlled by the private sector. Under agreement with the government, which most often has ownership rights to coal in developing countries, private enterprises can mine the needed coal. Whether this means expanding existing mining operations or establishing new ones, significant new employment is possible. Private manufacturers can briquette the coal--especially if an intermediate level of technology with reasonable capital costs is used. In some countries, the needed machinery can be manufactured locally, as is the case in India. Finally, the distribution network can easily consist of private dealers. Indeed, in many countries where fuelwood or charcoal is traded as a commercial item in urban areas, the potential private distributors already exist in the form of wood and charcoal dealers.

Coal Briquetting

Coal is often described as a "dirty" fuel, which upon combustion emits smoke that is offensive and contains constituents that are harmful to human health. Moreover, some raw coals are highly friable and are not easily handled or distributed in their natural state. However, by briquetting and pyrolyzing when necessary, coal can be put into a relatively clean, compact, and stable form for use. The resulting fuel is also relatively inexpensive.

Coal briquetting is a process by which raw coal is compacted into uniform, usually hard, and impact-resistant agglomerations, making it more suitable for use, transport, and/or further processing. It has been practiced for many years, at least since the beginning of this century.[7] It is also a technology that has been researched in many different countries, including such widely dispersed places as East and West Germany, USSR, Australia, Korea, India, China, and the United States. The wide extent of the research has several reasons. First, all coals are not alike, and often research has been aimed at developing an improved briquetting process for a particular coal. Second, briquetting can be done with or without an additive (binder) to help in agglomerating and giving cohesive strength to the briquette. Much research has gone into suitable binders, as well as into processes by which briquetting can be performed without a binder. Third, some research has been directed at improving the properties of the briquettes, such as maintaining ignitability while keeping volatile matter low as well as reducing smoke and sulfur emissions upon burning.

It should be emphasized that there is not just a single briquetting technology, nor even a set of two or three or a half dozen well-defined technologies for coal briquetting. Rather, a set of parameters for the briquetting of coal, such as temperature, pressure, pressing time, binder, type of coal, type of press, pretreatment, etc., can be varied to produce unique briquetting processes.

Coal briquetting can be performed on lump coal or on coal fines, the latter application often being an attempt to salvage an otherwise wasted product of coal handling. The usual process of coal briquetting consists of crushing, sizing, drying, possibly mixing with a binder, often heating, pressing in molds, cooling, and packaging or loading.

Although substantial adverse health effects could be expected from burning coal or coal briquettes for cooking purposes, a well-developed technique exists to convert coal to a safer form for combustion. This is coal carbonization, converting it to a "soft coke" by pyrolysis. This is similar to the conversion of wood to charcoal. During the heating of the coal without its combustion, volatile content is reduced, and gases and tars containing some of the other harmful constituents are given off. The result is a product high in fixed carbon, which can be burned with little or no smoke and few harmful emissions. Carbonization can be performed before or after briquetting--or even without briquetting, if irregular "soft coke" lumps and loss of the coal fines are acceptable. Because the soft coke is virtually smokeless, it will be referred to often as "smokeless coal" in the remainder of this paper.

Health and Environmental Issues

One of the important aspects of the coal carbonization process is that many of the potentially harmful constituents of coal are removed. As mentioned, most of the volatiles are driven off during pyrolysis into the off-gases, tars, or liquors. A certain level of volatiles is left in the soft coke (approximately 15% to 20%) to promote its easy ignition, but this level is deemed safe and does not allow the fuel to smoke significantly.[3] Many of the potentially carcinogenic and other organic constituents, such

as benzo(a)pyrene (BaP), toluene, benzene, etc., come out in the tar.

The sulfur content is also reduced as the sulfur is converted to hydrogen sulfide gas. Actually, several steps can be taken for sulfur removal to make the final smokeless coal lump or briquette rather clean with respect to sulfur emissions. Washing the coal with water prior to pyrolysis is a simple, inexpensive, and often effective step. More sulfur is removed during the carbonization process. Finally, if the coal is a higher sulfur coal, lime or limestone can be added to the final briquette so that any remaining sulfur combines with it and remains in the ash upon combustion.

Particulates are considerably reduced by the process of carbonization. Only minor fly ash results from combustion of the carbonized fuel. Also, while the temperature of carbonization is not high enough to remove many of the trace elements by volatization, neither is the temperature of combustion of the smokeless coal. Thus, without particulates to which to adsorb, the trace elements remain in the ash when the smokeless coal briquettes are burned. This keeps the level of human exposure to trace elements at an insignificant level.

One remaining health effect should be mentioned. The production of soft coke can expose workers to dangerous conditions unless strict controls are imposed. Coal dust in coking plants is often very high and difficult to suppress. The potential carcinogens in the coal tars, such as BaP, suggest careful handling of these by-products. Worker safety precautions in carbonization plants are well known and they should be properly considered in the design of new plants.

It should be noted that carbonization is only needed for coals below the rank of anthracite, that is, for bituminous, subbituminous, and lignite coals. Anthracite in its natural state is sufficiently low in volatile and ash contents and high in fixed carbon that carbonization is unnecessary for a smokeless fuel. However, anthracites are relatively rare.

Production Costs for Smokeless Briquettes

Fabuss and Tatom [3] estimate the costs of constructing a 100 metric ton per day (coal input) briquetting and carbonization plant for Pakistan. While this is a moderately sized plant and to a certain extent tied to conditions found in Pakistan, a review of their estimates can give an idea of the economic viability of the coal briquetting/carbonization technology.

The plant viewed in their scenario takes the path of an "intermediate technology." It would be capable of recovering the coal tar and oil, but none of the aqueous liquors. The process off-gas would be used to generate 100% of the power requirements for the plant. Utilizing Pakistan's high sulfur lignite coal, the briquettes would be formed without a binder, but lime would have to be added prior to briquetting to reduce sulfur emissions. The plant would have 66 tons per day output of smokeless coal briquettes. The ratio of 100 tons per day coal input to 66 tons per day output of smokeless coal briquettes was figured for a particular Pakistani coal, and other coals would give varying yields. However, the 100 to 66 ratio is in the middle of a range of about 55% to 75% that might be expected from various coals.

Total investment costs, including the cost of installed equipment, site preparation, buildings, engineering and contingencies, are put at 2,130,000 U.S. dollars (1982$). About half of this amount would be required in foreign exchange. Operating costs, including coal, lime, labor, maintenance, loan retirement, and profit on these manufacturing costs, and transportation bring the price of smokeless coal briquettes to 1528 Pakistani rupees (Rs.) per metric ton of oil equivalent (TOE) anywhere within a one hundred mile radius of the plant.† By varying the scale of the plant, Fabuss and Tatom further estimate that the cost of smokeless coal briquettes per TOE would be Rs. 1622, Rs. 1466, and Rs. 1407 for plants with coal inputs of 25, 300, and 1,000 metric tons (tonnes) per day, respectively. By comparison, firewood costs an average of Rs. 2117/TOE. Thus, the coal briquetting/carbonization operation appears to be economically competitive. Moreover, this is the case without even considering the potential value of the coal tar by-product. If a market for this can be found, even if used only as boiler fuel, either plant profits could be raised or the price of the smokeless coal briquettes could be subsidized with the by-product income and brought to a yet lower level.

†In 1982 when the cost estimates were made, one US$ equalled approximately 12 Rs. In 1985, the exchange rate is approximately one US$ to 16 Rs.

STEPS NECESSARY FOR IMPLEMENTING THE TECHNOLOGY

There are a number of steps necessary to implement this technology in any country. Not all the steps need to be performed in every country, since in many countries, the activities have already been performed or the circumstances are such that certain steps should be skipped. We briefly discuss these steps below.

1. Resource Evaluation. The size and workability of coal deposits from a geological standpoint must be ascertained. The location of coal deposits, economic viability, and proximity to existing transportation systems and markets must also be defined. The location of coal deposits and their proximity to existing infrastructure will affect the cost of the coal briquetting technology.

2. Market Assessment. In order to determine the best candidate communities and users, a market feasibility study should be undertaken. The market assessment itself should include examination of the target population, socioeconomic and cultural characteristics (particularly with respect to cooking), urban fuel use, fuel prices, and obstacles to acceptance of the new coal-based fuel, etc.

The market assessment should examine energy use by fuel type in different economic sectors, including households, commercial establishments, small industries, and public institutions. The potential for substitution of smokeless coal briquettes in each of these sectors must be evaluated. Besides price, one highly significant factor for substitution possibilities is consumer acceptance. What characteristics must the briquette have to obtain acceptance, e.g., size, shape, ignitability, packaging, distribution points, needs for new equipment? How does the user feel about using smokeless coal relative to the current fuel used? One approach is to conduct surveys of certain sectors, say the household and commercial sectors. These surveys assessing the potential acceptance of smokeless coal briquettes could be tied together with the information gathering on current fuel use and prices.

3. Technological Assessment. The technological assessment of the coal under consideration should include an analysis of coal characteristics, an engineering study of the appropriate type and scale of briquetting and carbonizing operations, and capital availability.

The grade of coal and its sulfur and ash contents will affect the type of briquetting and carbonization operation that is appropriate. Therefore, a representative sample of coal must be obtained, shipped to a laboratory, and assayed. Behavior of the coal under briquetting and carbonization conditions must be ascertained, e.g., relation between time/temperature conditions and residual volatile content, ignitability vs. volatile matter content, suppression of residual sulfur content during combustion, the optimal type of binder for briquette strength and durability, etc.

In addition, an engineering study is necessary to design the type of plant appropriate to the coal and the size of plant that is appropriate to the market. Which of the many carbonization and briquetting processes should be used? Should off-gases be recycled or be used off-site? Should by-product electricity be produced? Will the correct binder be reliably available? Where should the plant be sited--taking into consideration coal supply, labor supply, availability of utilities, transportation, and proximity to markets. How labor intensive should the mining and briquetting/carbonization operations be? What measures are needed to protect health, safety, and the environment?

4. Government Policy and Institutional Planning Assessment. While coal carbonization and briquetting provides an excellent opportunity for eventual control largely by the private sector, the roles of the host country government in start-up operations must be assessed. This involves assessing both policies that are directly aimed at coal briquetting and other government policies that have indirect impacts on the new technology.

Other direct and indirect effects will result from current government pricing policies. The extent to which smokeless coal briquettes will be accepted in the market place will be affected by such policies as subsidization of alternative fuels, as is the case for kerosene in many countries. Differential taxation or price controls on energy products would have similar effects. While not generally advised, the government might reverse the roles just mentioned by subsidizing smokeless coal prices and promoting their use over fuelwood.

In addition, there are a number of actions that the host government may plan to undertake to promote the use of smokeless coal briquettes directly. The

government might provide information on use to potential users and information on production and markets to potential producers. The government might support a small pilot plant or intermediate-sized demonstration plant. This would indicate the viability of the technology, its costs, and the potential market acceptance to entrepreneurs. Also, the output would provide samples for market testing, would demonstrate to consumers the advantages of smokeless coal briquettes, and could establish a "seed" market.

The government might assist in overcoming some of the market uncertainties facing producers by implementing such programs as loan guaranties and purchase agreements. Market uncertainties can affect the ability of private individuals to obtain financing, and loan guaranties are one method to offset these obstacles in the market. This, however, would depend upon the scale and relative capital scarcities in the country. An additional way the government might help in overcoming market uncertainties would be to provide a ready market so that producers would be assured that they can sell at least some portion of their output. For example, the government could enter into long-term contracts for buying coal briquettes for use in public facilities, or for use in the military.

5. Business and Market Implementation. Coal briquetting is an excellent technology for private sector initiative, since all phases from mining to manufacture to distribution can be undertaken by private entrepreneurs. Beyond some of the policies mentioned in the previous section and maybe building a pilot plant, the goal is for the role of the government to remain minimal. Thus, there should be an early assessment of technical talent and potential entrepreneurs for getting production and distribution started. Also, capital markets must be assessed for their sufficiency to finance the ventures.

To involve private individuals who have the expertise, the financial attractiveness of the venture must be well documented. Does the financial attractiveness match the economic attractiveness from a societal standpoint? Have processing risks been considered and solutions proposed? Are there mining risks that affect the costs estimated? A full description of the design and operations must also be provided.

In implementing distribution of the smokeless coal briquettes, the current dealers of firewood and charcoal might provide a ready distribution system. The examination of sources and distribution of fuelwood made under the market assessment can provide valuable information in setting up briquette distribution. The existing dealers should be encouraged to take on the new product.

Finally, initial marketing to consumers is extremely important in assuring the success of the briquettes. It may be advantageous in some locations to concentrate on a certain sector of the market in initial efforts to sell smokeless coal briquettes, such as the commercial sector. Restaurants, hotels, and street vendors currently making use of fuelwood and charcoal may be a ready-made market for the smokeless coal briquette. They are often a small, well-defined group that uses a significant amount of fuel, and they could be instrumental in establishing a market. They also provide free demonstrations for the new product to purchasers of their food products. Moreover, they may have the financial capacity to continue to buy the product once they decide to switch to it.

THE HAITI EXPERIENCE

Haiti occupies the western third of the island of Hispanola in the Carribean Sea, sharing the island with the Dominican Republic. It is a country of about six million people, and the population density at 211 people per square kilometer is high. Haiti is the poorest country in the Western Hemisphere, with per capita income of only US$ 270 per year. Great pressure has been put on the land for food production, because agriculture--much of it subsistence agriculture--supports approximately 80% of the population.

Land clearing for agriculture, along with the demand for wood and charcoal for fuels, has contributed to widespread deforestation in the country. Whereas 40 years ago wood was gathered and charcoal produced for the capital and largest city of Port-au-Prince in the countryside only a few kilometers beyond the city limits, today trees are felled and wood gathered at the extremities of the country to supply the capital city. As a result of the increasing scarcity of wood, the real price of charcoal in Port-au-Prince has doubled in the last ten years. Yet even with the increasing real price of fuelwood, it is still

relatively inexpensive. Charcoal, for instance, ranges in price at retail in Port-au-Prince between US$ 110 and US$ 135 per metric ton (Mt)--and in the countryside comparable prices are typically one-third to one-half of these figures. These low prices arise because property rights to land and trees are very poorly defined in Haiti, and the original wood resource is harvested at virtually zero cost to the harvester.

With wood a rapidly dissipating resource in Haiti, the price of wood fuels on the rise, and the existence of lignite deposits in the country, Haiti was a logical choice for an examination of coal briquetting. The five evaluative steps described before were initiated in Haiti by the Government of Haiti (GOH) with the assistance of U.S. AID. AID, in turn, initiated work with relevant individuals and organizations, including Oak Ridge National Laboratory (ORNL). Each of the five assessments as they have been implemented in Haiti is described below, with summary results determined at the time of writing described for each.

1. Resource Evaluation

Haiti has several deposits of lignite, of which the better known at this time lies near Maissade in the country's Central Plateau region. An assessment of this deposit was conducted by the German Federal Institute for Geologic and Material Sciences in 1982 [4]. Proven reserves amount to approximately six million metric tonnes, although this is based upon a survey of only 2% of the total area in the Maissade with potential reserves. The reserves are high in water, ash, and sulfur contents, and low in caloric content. See Table 1.

2. Market Assessment

As alluded to above, the major market for a coal briquette in Haiti probably lies with present users of wood and charcoal, which together supply 75% of Haiti's total energy supply. Markets that appear most easily penetrable by this substitute fuel include residential and commercial establishments, particularly in urban areas. Indeed, the capital city of Port-au-Prince appears to be the primary potential market. Here the prices for wood and charcoal are higher than in other parts of the country. In Port-au-Prince, the dichotomy exists that wood is almost exclusively an input to certain commercial establishments, while charcoal is the primary residential fuel--used exclusively for cooking. No fuel is necessary for heating.

Among the commercial establishments, surveys have been conducted for essential oils plants (root and wood oils used in perfumes), school canteens, bakeries, dry cleaners, restaurants, and street food vendors. All of these, except the last, use wood. From the surveys, prices paid for fuels, the amounts of fuel used, firm characteristics related to size--such as number of employees, sales, and taxes paid--and fuel preferences and technologies were gathered. Scale ups to full market size will be done primarily upon the basis of the numbers of firms in each industry.

In the residential market, a survey of 142 households scattered about Port-au-Prince and stratified by income category was conducted. Questionnaires for this survey were developed through extensive pre-testing, and the final survey form included questions related to prices paid, amounts of charcoal used per week, family characteristics, uses for the fuel in addition to cooking (such as boiling and pressing laundry, small commercial activities, etc.), and other cooking fuels used. To ensure geographic diversity, metropolitan Port-au-Prince was divided into 28 neighborhoods and households were surveyed in each. Economic diversity was ensured by interviewing households in each of three income categories--poor, medium, and rich. The first of these was interviewed most extensively since it represents by far the majority of households. From the survey, regression relationships using family size and income category will be estimated, which in turn will be used to scale up to a full market estimate. Finally, the survey provided answers to questions about consumer preferences in their fuels which should aid the introduction of a briquette.

In addition, a separate project being conducted for U.S. AID by the University of Maine has gathered information on total wood and charcoal imports to Port-au-Prince by stopping all boats and trucks entering Port-au-Prince at the five major access points for a full week, 24 hours per day, and asking for counts of wood and charcoal aboard. This information will be used to compare with the estimates obtained from the survey scale-up method. The information from this survey also provided extensive information on the geographic sources of wood and charcoal as well as transportation costs.

Table 1. Analyses of Maissade lignite

Proximate analysis	Wt. %, as received
Moisture	28.8
Volatiles	27.9
Fixed carbon	18.6
Ash	24.6
Ultimate analysis	**Wt. %, as received**
Hydrogen	5.4
Carbon	28.9
Nitrogen	0.6
Sulfur	4.8
Oxygen	6.8
Ash	24.6
Sulfur forms (2 samples)	**Wt. %, as received**
Total sulfur	5.40, 7.19
Sulfates	0.47, 0.63
Pyrites	0.49, 0.65
Organic	4.44, 5.91
Inorganic analysis by X-ray fluorescence (Oxides as % of total ash in coal)	
Silicon, as SiO_2	36.1
Aluminum, as Al_2O_3	17.0
Iron, as Fe_2O_3	10.8
Titanium, as TiO_2	0.8
Phosphorus, as P_2O_5	0.6
Calcium, as CaO	13.6
Magnesium, as MgO	3.2
Sodium, as Na_2O	0.5
Potassium, as K_2O	1.6
Sulfur (inorganic), as SO_3	15.8

Mineralogical analysis by X-ray diffraction, following ASTM ashing at 750°C

Major components: $CaSO_4$, SiO_2, Fe_2O_3 (hematite)
Minor components: Fe_3O_4 (magnitite)
Trace components: $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$ (plagioclase)

Heating value, Btu/lb

as received: 5,207
dry basis: 7,309

Source: Ref. 6

Besides interviewing the potential users of the briquettes, questionnaires for wood and charcoal producers, transporters, wholesalers, and retailers have been administered. The purpose of these questionnaires is to better understand the existing fuel supply system and to determine if it can be adopted to the distribution of coal briquettes. Part of the chore here is to determine profit margins at various points in the supply chain and where in the supply chain it makes sense to introduce the briquette. For example, one approach for briquettes manufactured in the Maissade countryside would be to ship to Port-au-Prince under ownership of the briquette manufacturer and to sell to Port-au-Prince charcoal wholesalers directly. At this point the existing distribution network would take over.

With the information on wholesale prices for wood and charcoal and information on transportation costs, one primary objective of the market analysis is to back up the costs of producing a lignite briquette to the mine mouth, to determine if the briquette could be produced at a competitive cost. That is, we subtract from the wholesale price at which the briquette would have to sell in Port-au-Prince to compete with charcoal and wood, the transportation costs to the briquetting plant, and processing costs as determined under the Technological Assessment described below. If the difference is sufficient to cover the cost of mining, which is yet to be estimated, then the briquette could compete economically. One alternative that will also be considered in this context is the possibility of substituting imported coal for Maissade lignite. This route must also be considered to determine how the briquettes could be produced most economically.

3. Technological Assessment

The Technological Assessment of the Haitian lignite has been performed by the University of North Dakota Energy Research Center (UNDERC) and the East-West Center in Hawaii. The analysis performed by UNDERC utilized a sample collected from the Maissade deposit by the Haitian Ministry of Mines and Energy Resources (MMRE) supported by the U.S. Geological Survey in May, 1985. After exposing fresh lignite by removing 0.6 meters of a weathered outcrop, approximately 300 kilograms of lignite were sampled and sealed in an air-tight steel drum for shipment to North Dakota.

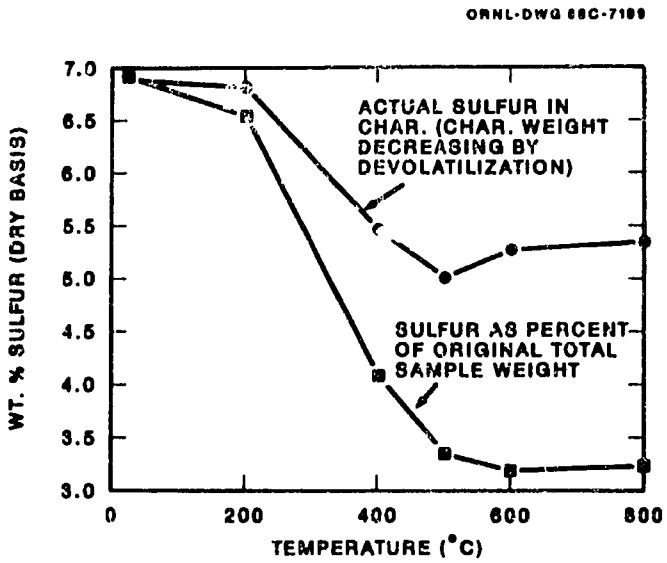
UNDERC performed proximate and ultimate analyses on the coal, revealing a sulfur content of 4.8% and an ash level in the as-received sample of 24.6%.[6] Some preliminary washing experiments were performed for sulfur and ash removal, with limited success. To produce an optimal briquette, over 60 experimental combinations were tried, with the resulting "optimal" briquette having the percentage distribution of constituents found in Table 2.

Table 2. Percentage distribution by weight of constituents of optimum briquette

	Percentage
Haitian lignite char (Maissade lignite pyrolyzed at 760°C)	61.0
Bagasse (the cellulose by-product from sugar cane milling)	15.0
Water	12.6
Borax	.2
Sodium nitrate - $NaNO_3$	2.0
Calcium hydroxide - $Ca(OH)_2$	3.1
Haitian molasses	6.1
	100.0%

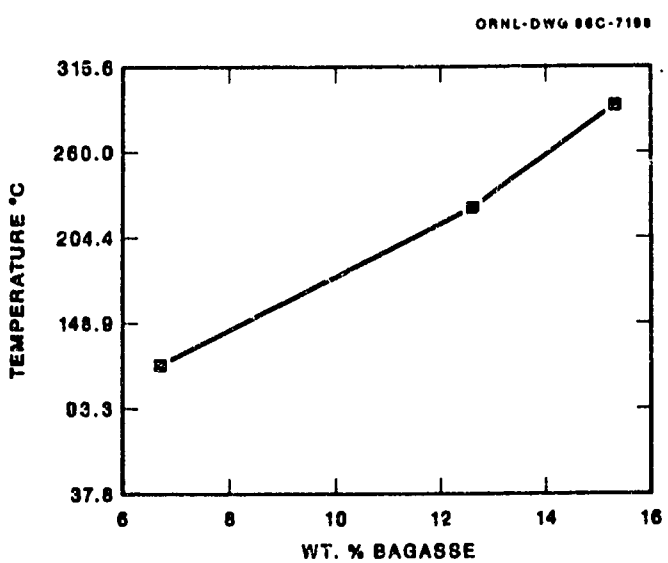
Carbonization, of course, helps reduce the sulfur content, and also reduced noxious odors from the briquette. (See Figs. 1 and 2.) The bagasse addition helped improve the ignitability and heat content of the briquette, and also seemed to assist in the binding of the briquette. The sodium nitrate was also added in order to increase ignitability, as the original Haitian lignite char resisted combustion. The calcium hydroxide (lime) was added to precipitate sulfur and reduce sulfur emissions upon combustion, as well as to help serve as a binder in conjunction with the molasses. Borax is a wetting agent and aids in removal of the briquette from the mold.

The briquettes were produced in different shapes, including a "twin pyramid" and a log (cylindrical) shape, the latter to simulate the shape of charcoal presently being used. The optimal shape was determined to be pillow shaped with maximum dimensions of 5 cm x 5 cm and 2.5 cm thick. (See Figs. 3 and 4.) The one major problem with the final briquette was a rather high ash content, which could inhibit marketability with



Source: Ref. 6.

Fig. 1. Residual sulfur in char vs. pyrolysis temperature. Maissade lignite.



Source: Ref. 6.

Fig. 2. Effect of bagasse on combustion.

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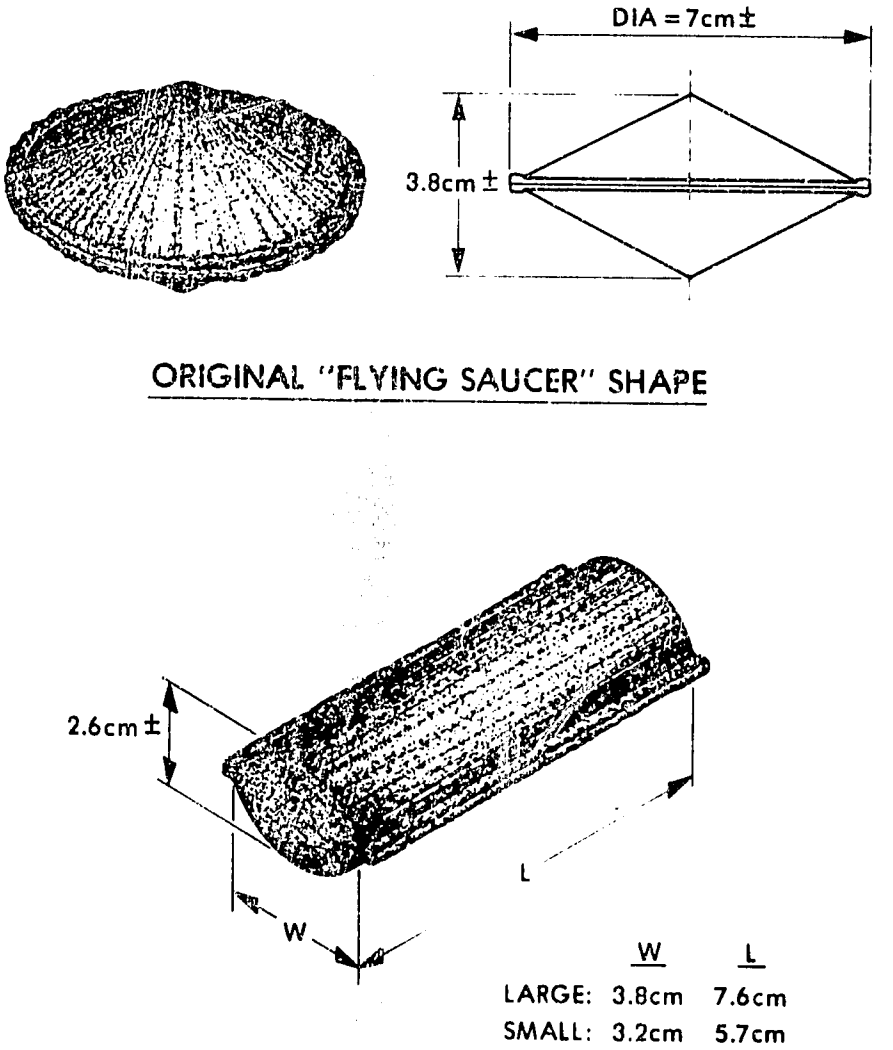
DIMENSIONS OF TEST BRIQUETTES



Source: Ref. 6.

Fig. 3. Some of the shapes of briquettes tried.

Fig. 4. Near-optimum briquette.

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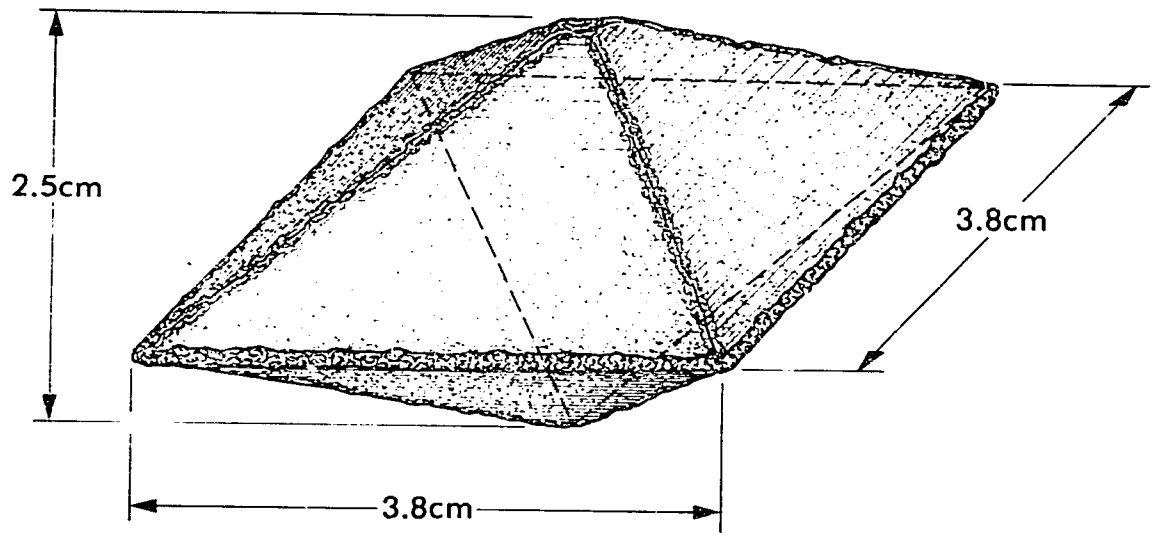

Source: Ref. 6.

consumers who are used to low ash in wood charcoal. Additional work on washing the coal to reduce ash content may be performed, as well as changing the bagasse content of the briquettes.

The final task for UNDERC under the Technological Assessment involves designing a full scale briquetting plant and estimating costs.

Other work under the Technological Assessment is being performed at the East-West Center in Hawaii. The Resource Systems Institute within the Center will test the briquette produced by UNDERC for emissions that may be harmful to human health--in particular, carbon monoxide, sulfur dioxide, and total suspended particulate matter. Comparisons will also be made with emissions from the current primary residential fuel, charcoal. The Resource Systems Institute will use Haitian stoves, an improved Haitian stove, and a scientific combustor in their evaluations and comparisons of charcoal with lignite smokeless briquettes.

4. Institutional and Government Policy Assessment

The investigation of institutional and policy issues in Haiti has involved reviewing mineral and land rights issues, mining regulations, tax codes that would affect the mining and manufacture of the briquettes, existing infrastructure such as roads, capital markets, social and environmental impacts, and the degree of interest among potential investors. The investigation was undertaken in part by employees of the GOH's Ministry of Mines and Energy Resources and in part by ORNL. A few highlights of these issues will be recounted here.

The mineral rights to the lignite in the Maissade belong to the Government of Haiti, while the surface rights are held by a variety of small landowners involved in subsistence farming. In order to gain access to the deposit, the government would be required by law to reimburse the peasants for any land that they condemn for the purposes of mining. No particular arrangements, however, are made for relocation of the displaced farmers. Explicit regulations allow corporations to obtain concessions from the government to mine mineral deposits, and Haiti, with a tradition of allowing the private sector to work, would allow a completely private venture in mining and manufacturing of the briquettes to be established.

The roads from major population centers such as Port-au-Prince to the Maissade are generally poor, involving long sections of dirt and gravel road and even several stream crossings. Transit time is between four and five hours to traverse the 160 kilometers to Port-au- Prince. Thus, improved infrastructure is sorely needed.

Indigenous financial capital exists in Haiti, with which mining and briquetting ventures might be financed--although potential Haitian investors traditionally prefer going to domestic and foreign banks for debt financing of projects. Current interest rates on loans are typically 16% to 19% per year, with rates as low as 14.5% considered a bargain. Thus, returns on investment must be in the range of 20% to 30% to be attractive. This is all set in the context of an inflation rate of about 10% over the last several years. Several industrial development organizacions also offer loans at preferential rates, including the local "National Bank for Agricultural and Industrial Development," and the "Industrial Development Fund."

Much of the physical capital for mining and manufacturing of a briquette may have to be imported. This is a significant negative factor, since Haiti's currency has recently undergone extreme pressure in trying to maintain its parity with the dollar.

Tax policies are extremely favorable to new industrial development in Haiti. New manufacturing firms setting up in metropolitan Port-au-Prince enjoy a tax holiday for the first five years and reduced taxation for the following five. Those established outside the metropolitan area of Port-au-Prince pay no income taxes for the first fifteen years, and reduced taxes until the twentieth year. Direct government subsidies of products in Haiti, however, generally do not occur.

The social and environmental impacts of coal briquetting could be significant--both positively and negatively. From a positive standpoint, new jobs would be created in the poor interior of the country if briquetting were initiated near the Maissade deposit, and the people here would probably welcome new mining and briquetting ventures. On the other hand, charcoal is currently produced in other parts of the country by low income people. However, the displacement of charcoal producers resulting from manufacture of lignite briquettes would be mitigated to the extent that the market for these fuels is growing, and to the extent that trees are disappearing so rapidly that current charcoal producers would soon

be unable to continue in any event. Laws on the books in Haiti require mining operations to reclaim land, which would keep environmental impacts low. And the advances in reforestation and control of soil erosion resulting from the use of coal briquettes would result in positive environmental consequences.

A final task to be performed in the market and policy studies will be to interview potential private investors. The investors will be presented with the results of the study in order to assess their participation in a briquetting enterprise.

5. Business and Market Implementation

This final step to implementing a coal briquetting venture still lies in the future for Haiti. The planning for this step will depend upon the final outcomes of the four previous assessments, but it will probably include some kind of test market in which actual briquettes are introduced to a sample of consumers. One possibility involves the building of a pilot plant to produce these briquettes. It looks at this point as though more private sector involvement would be sought, through Haitian consulting firms and investors, than has existed during the current phase of the work. This is as it should be, as the transition is made towards full private sector management of coal briquetting in Haiti.

THE PAKISTAN APPROACH

In Pakistan, firewood is the predominant residential cooking and heating fuel, accounting for about 70% of the total consumption, and is becoming increasingly scarce and expensive. For example, fuelwood prices increased nearly 400% between 1972 and 1982. Since more wood is consumed than produced each year, firewood use contributes directly to the problems of deforestation in Pakistan. Kerosene use has increased in recent years as replacement fuel for firewood, but its use consumes valuable foreign exchange and is costly to the Government of Pakistan (GOP) due to its subsidized price.

Coal briquettes made from indigenous Pakistani coal offer an attractive alternative to these fuels, especially in the coal producing regions of Baluchistan, Lakhra and Punjab. While these coals are of relatively low quality (high ash and sulfur), processing and briquetting offers the possibility of upgrading the quality to an acceptable level. In particular, very useful analysis and test work has been carried out by The Fuel Laboratories of the Pakistan Council of Scientific and Industrial Research (PCSIR) in Karachi, indicating the feasibility of making acceptable briquettes. With coal reserves in Pakistan estimated at one to two billion tons, and an incipient coal mining industry, a new coal-based fuel could make a significant contribution to Pakistan's energy self-sufficiency, improved foreign exchange and reduced deforestation.

The situation in Pakistan is much different than that in Haiti since the resource base is larger, better known, and partially developed, there is a history of briquette manufacturing, and there are institutions already in place to assess and test the briquette product in selected markets. As a result, some of the steps that have been undertaken in Haiti can be circumvented or modified. In particular, the initial stage of analysis in Pakistan will focus on the market, government policy and planning assessments, and the business and market implementation aspects of the general strategy outlined above.

Background and Preliminary Findings

To provide focus and direction to the planned market and business assessment, USAID has undertaken a preliminary review of the prospects for coal briquetting in Pakistan. This review was aimed at understanding activities already underway in coal briquetting in Pakistan, identifying private and public sector organizations which could be involved in coal briquetting, and defining more precisely the market and policy related issues which should be addressed in the planned market investigation in 1986. Before describing this planned market assessment, it is useful to describe the findings of this preliminary review into existing activities.

Many Pakistani companies and organizations have current activities or plans in the area of coal briquetting, and the more prominent are described below. Also included are groups that while not yet directly involved, could participate in the development of a commercial market for coal briquettes in Pakistan.

Fuel Research Centre, Pakistan Council for Scientific and Industrial Research (PCSIR)

The Fuel Research Centre (FRC) of PCSIR in Karachi has undertaken research for private and public sector groups for many years. Recently,

the FRC has manufactured and tested several types of briquettes using coal from different mines of Pakistan. These tests have included adaptability to typical cooking practices of Pakistan, as well as rudimentary transportation and handling characteristics. Binderless briquette manufacturing processes were examined, as well as processes using various binders including clays, starch, molasses and organics such as P.V.A. Briquettes were made from coal, and from the char resulting from carbonization. The results of these tests will be reported separately by PCSIR.

A new FRC facility is under construction and is expected to be completed by April 1986. New laboratory scale coal briquette manufacturing equipment is being procured from the U.S. under a program sponsored and funded by USAID. The new labs will be adequately equipped to carry out more comprehensive research activities on Pakistani coals.

Pakistan Mineral Development Corporation (PMDC)

PMDC is a public sector organization with about 15% of the total coal market share. It owns and operates the largest coal mining area in Pakistan and sells the coal to agents on competitive bidding. The PMDC is currently planning to assess coal briquetting, with the objective of producing a coal based fuel to substitute for kerosene oil in market areas where natural gas is not available. PMDC has plans to evaluate the feasibility of a plant for smokeless coal briquettes in collaboration with Sofremines of France. This feasibility study has been approved but no funds have been made available to date.

PMDC has for many years operated a coal briquetting plant in Quetta to produce a winter heating fuel for use by the military. Output in recent years has been 5,000-10,000 tonnes per year.

Enerplan - Ministry of Planning and Development

Enerplan is the energy planning authority in the Ministry of Planning. Enerplan could assist in a coal briquetting program by providing coordination within the Government of Pakistan (GOP), and by assisting in making policy and legislative recommendations for governmental actions to facilitate market penetration.

Appropriate Technology Development Organization (ATDO), Ministry of Science and Technology

The ATDO interfaces with the population through organized practical demonstrations, exhibitions and distribution of literature for developing small scale commercial technologies suited to local conditions and needs. With offices in every province of Pakistan and about 500 staff members, the infrastructure for promoting and marketing of specific technologies exists. ATDO has designed and developed an energy efficient charcoal and firewood stove to suit the household cooking practices in Pakistan. It is planned to introduce this stove to the rural and urban population through a mobile exhibition program - now pending approval from the Ministry of Planning.

Private Sector Companies

Discussions were held with several private sector businessmen who could play a role in the development of a coal briquette industry in Pakistan, including coal mine operators, wholesalers and retailers of wood, charcoal, and coal, and representatives of other industrial concerns. There was strong interest expressed and most stated they would consider participating in such an industry if they were convinced that it was commercially viable. They confirmed the need to examine this commercial viability, and also to ensure that Government policies for pricing and availability of alternate fuels (especially natural gas and kerosene) would be consistent with allowing such a market to develop.

Most businessmen believed that coal briquettes would be most competitive in small to medium sized towns not yet served by natural gas, and in urban or suburban areas as a substitute for currently subsidized kerosene. It was believed that the coal briquettes would have difficulty competing against wood in rural areas where it is gathered directly by the users or against natural gas in urban areas. It was believed that those markets could only be made attractive by government policies which restricted the availability and/or raised the price of the alternate wood or natural gas fuels.

United Nations High Commission for Refugees (UNHCR)

More than 2 million Afghanistan refugees are now in Pakistan, and providing for their cooking and heating fuel needs has put a considerable strain on the fuel supply situation in those areas. UNCHR provides relief to these Afghanistan refugees, and energy assistance in the form of 20 litres of kerosene per month to each of about 370,000 families in the Afghan refugee camps. UNCHR obtains 50% of its kerosene requirements from donations--mostly from countries of the Middle

East--and purchases the remaining 50% with its own funds.

The use of coal briquettes for the refugees could have considerable benefits in cost and foreign exchange savings. UNCHR and the National Logistics Cell (GOP counterpart agency for affairs related to Afghan refugees) could provide a mechanism for providing coal briquettes to this relatively fixed and certain market.

In a similar activity aimed at reducing the kerosene requirements and using available indigenous fuels, a small scale rice husk briquetting plant has been set up near Gujranwala by UNCHR for refugees in the Punjab province.

Pakistan Assessments

Because considerable work has already been done to assess the coal resource base in Pakistan, and the technical feasibility of producing briquettes from local coals, USAID will focus its initial stage of investigations on market-related questions. In particular, USAID is planning to commission a study to examine circumstances required for coal briquettes to be commercially competitive with existing fuels and how a largely private sector coal briquetting industry could be initiated. The study is beginning in early 1986, and will have three broad areas of investigation:

1. Assessment of the Current Market
2. Examination of Government Policy and Institutional Issues
3. Development of a Business Implementation Plan.

1. Assessment of Current Market

The market assessment will provide a detailed evaluation of the present markets for fuel use among the likely target customers for coal briquettes in Pakistan. For each market, the study will indicate the quantities of fuel used for different purposes (e.g., heating, cooking, and lighting), and the prices of each at the retail and wholesale levels up the supply/distribution chain to the supplier. Data on the present quantities and prices will be collected, as well as recent trends. Geographical breakdowns to the provincial level will be determined, and an assessment made of important variations in prices and/or mix of fuels within provinces where it is believed to have a critical effect on the market prospects for coal briquettes.

The sectors to be covered include the domestic, commercial, and industrial markets, as well as other potential captive or special markets such as government installations, refugee camps, schools, or other institutional establishments.

In addition, a survey of the types of fuel-using equipment presently utilized among these target markets will be made to identify where new equipment would need to be developed and/or introduced to allow the utilization of coal briquettes.

The entire fuel supply chain from customer to supplier will be examined for each fuel to determine who is presently involved, what are approximate costs and prices at each stage, what equipment or expertise exists which would support marketing and/or distribution of briquettes, and if the present participants are willing to handle coal briquettes for these markets.

Fuel use patterns will be analyzed for each target market group, including when and how fuel is used, what equipment is utilized, what are typical fuel purchasing behavior patterns and criteria for choosing a fuel, and what are the necessary/desirable characteristics for a potential coal briquette.

From this data, the desirable characteristics of the briquettes will be defined, and a judgment made as to the price required for briquettes to successfully displace existing fuels.

2. Government Policy and Planning Assessment

The Government of Pakistan is heavily involved in many aspects of the markets where briquettes could penetrate, such as in setting prices and controlling supplies and/or availability of fuels. The policy assessment will identify and assess such issues as pricing of kerosene, natural gas and other competitive fuels, policies toward cutting of firewood, plans for extending the availability of natural gas, what environmental requirements would apply to the manufacturers of briquettes, and what standards for health and safety should apply to the utilization of briquettes.

3. Business and Market Implementation

Having determined the likely prices necessary for coal briquettes to be attractive, and the size and location of the markets for these briquettes, the final step is to evaluate the financial attractiveness of coal briquetting in Pakistan and to develop a business implementation plan. Using existing information on the costs of coal in each

region, and the likely transportation costs to different markets, the total allowable briquette manufacturing cost will be estimated.

Several internationally recognized technical specialists in briquette manufacturing will then be consulted to judge the feasibility or practicality of producing briquettes of the required technical characteristics from the available coals in Pakistan within these identified allowable briquette manufacturing costs. The likely range of capital and operating costs will be estimated based on the specialists' judgment from similar situations in other countries in recent years.

Finally, meetings will be held with appropriate representatives of the private sector in Pakistan, including financial institutions, to evaluate their interest in investing in a briquetting venture, and to determine how the business could be structured. The business implementation plan will then be prepared, including assessment of the potential role of the Government of Pakistan, USAID (e.g., the Agricultural Commodities and Equipment Program) or other organizations, if necessary.

CONCLUSION

This paper has shown that there is a need for a substitute for firewood and charcoal in many developing countries, and that there are significant opportunities for smokeless briquettes to penetrate certain markets. We have outlined the USAID program for assessing the potential of smokeless briquettes in any particular country. The program developed by AID has a five-step assessment procedure: resource evaluation; market assessment; technological assessment; government policy and institutional assessment; and business and market implementation.

Through a pyrolysis process the coal briquettes can be made relatively clean and capable of having burning attributes that make them attractive to current users of firewood and charcoal. The technology has undergone development and refinement in many different countries and the production costs of the briquettes appear to make them competitive with charcoal in many urban areas.

Application of some of the elements of the AID assessment program have been applied in Haiti and are being undertaken in Pakistan. Haiti is the poorest country in the Western Hemisphere and has a significant deforestation problem. While the Haiti deposits of lignite are limited, there appears to be a significant opportunity for the displacement of firewood and charcoal with smokeless briquettes. The briquettes that have been made have desirable burning characteristics, although they are very high in ash.

In Pakistan, we find that firewood accounts for 70% of total consumption, and is becoming increasingly scarce and expensive. However, in Pakistan the resource base is significantly larger for the potential production of briquettes, and unlike Haiti, a number of institutions already have been working on the briquetting issue. Therefore, the study in Pakistan will concentrate primarily on the assessment of the current market, an examination of government policy and institutional issues, and development of the business implementation plan.

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KH. ASIFULLAH

PAKISTAN EXPERIENCE IN COAL BRIQUETTES PRODUCTION

1. INTRODUCTION

1.1. The economic development plans of the country lay emphasis on continuing agricultural development and industries based on modern technology as well as increased production of manufactured goods, leading to establishment of a strong industrial base. The achievement of the planned growth rate will require higher energy consumption which indicate higher imports at considerable cost which would place strain on country's foreign exchange.

1.2. Pakistan is presently faced with a serious energy crisis which is hampering all sectors of economy. The dependence on imported oil on account of limited domestic supplies is causing severe drain on foreign exchange resources of the country and to that extent the investment plans and economic growth are restrained. Pakistan's energy needs are increasing at a faster pace. According to an estimate the demand will increase from 27.10 MTOE in 1987-88 to 69.48 MTOE in 2002-03 (High case). The domestic supplies, on the other hand are projected at 17.93 MTOE in 1987-88 and to 55.30 MTOE in 2002-03 leaving a wide gap of 9.17 MTOE and 14.18 MTOE during these years. The situation seems to be rather grim and it will become difficult to realize the targets unless a basis for long-term expansion of energy supplies is laid.

1.3. Recognizing that adequate and reliable supplies of fuels is essential to economic development of the country and to sustain the economic growth, the Government has formulated a National Energy Policy which lays emphasis on the rapid and balanced development of indigenous energy resources, conservation of energy without constraining the economic growth, suitable fuel substitution and upgradation of fuels wherever significant foreign exchange savings could be effected. The upgradation and substitution of fuels also applies to coal and production of smokeless coal briquettes for domestic consumption in substitution of Kerosene oil.

2. COAL BRIQUETTING

2.1. Coal briquetting technology is well established. During the last two decades, competition from other fuels resulted in improvement in quality and economics of the process as well as automation of briquette production. On a world wide basis over 69 million tonnes of briquettes are produced which find a ready sale in the domestic market. Germany is the largest producer and 80% of the coal briquettes produced are used as domestic fuel and rest is sold to the industry. National Smokeless Fuel Limited, West Britain, produces over one million tonnes of smokeless briquettes per annum. In Korea briquetting was started in 1930 and about 20 large briquetting plants are in operation. However, during the last 20 years development and improvement studies on briquetting of brown coals have been undertaken mainly in East and West Germany. The object of briquetting is to convert low grade fuels into one of superior quality with good calorific value. The process of briquetting consists of applying pressure to a mass of particles with or without addition of binder to form compact agglomerates. In briquetting coal the physical properties of coal and the chemistry of its surface is important in carbonizing briquettes. In briquetting of hot and devolatized coal, it is essential to have a knowledge of both physical and chemical changes that take place when coal is heated. In

briquetting coal without binder the following steps are involved.

2.2.1. RAW COAL PREPARATION

The object of raw coal preparation is to produce fine coal in the required size. In practice the coal is crushed to a top size of 4mm and contains about 60% below 1mm. Screens with a higher capacity than normally used, twin swinging screens have been used. Now a days electrical resonance or vibrater screens are employed. Further improvements were made by the use of classifiers and the highest output in classifying coal was achieved with inclined chamber classifiers in which wet coal is so greatly comminuted that additional grinding of the dry coal is not required.

2.2.2. DRYING

The optimum moisture content of the coal is generally the moisture content in equilibrium with a 75% saturated atmosphere and vary from 12% to 18%. If the moisture content is too low the briquettes swell and may lose strength. A distinct advance in coal drying was achieved by the development of tubular dryers with narrow drying tubes. Previously tubes with a diameter of 94-104mm were used but subsequent developments indicated that hourly evaporation rate considerably increased in the narrow drying tubes.

2.2.3. TEMPERATURE OF BRIQUETTES

In order to achieve optimum moisture content, drying and cooling or, for a coal with low moisture content steaming may be required. A retention of time is also necessary to permit an equilibrium of the moisture content to be established between the larger and the smaller coal particles. The temperature rise during briquetting may be of the order of 60°F while the discharge temperature in excess of 550°F has been reported. In semi bitumenous plants extensive cooling is done.

2.3. BRIQUETTING WITH BINDERS

The binding materials most commonly used for making water resistent briquettes are coal tar pitch, bitumen or asphalt. The non-water proof binders are sulphite liquors from paper pulp plants, starchy waste materials, molasses, lime, silicate of soda or cement. The binders are usually applied in quantities varying from 4 to 9% of the coal feed. The following stages are involved in briquetting coal with binder:-

2.3.1. DRYING

The moisture content of coal is reduced to 2 to 4% as moisture in excess of this results in higher binding material requirement.

2.3.2. GRINDING

The coal is usually crushed to a size where about 93% is less than 0.88mm and 80% less than 0.55mm. However, for making briquettes of larger size, the coal with larger fraction are used.

2.3.3. MIXING, HEATING AND TEMPERING

The binders are mixed with coal either in liquid or solid form. The mixture is passed through a mixing mill where super heated steam is injected into the mix. The mixture is heated to 200 to 210°F and then cooled to a temperature which is slightly above the softening point of binder.

2.3.4. PRESSING

For briquetting coal, rotary table press or double roll press are used. In rotary table press the table containing the moulds rotates intermittently and the moulds are alternatively filled, pressed and discharged. The time of pressing is 0.25 to 0.40 seconds and the pressure is between 0.36 to 1.8 tonnes per sq.inch.The roll press consists of two rolls of equal diameter, rolling in opposite direction with equal speed. A set of identical half moulds is cut into surface of each roll and as the rolls rotate these sets coincide. The hot mixture is fed between the rolls

and compressed in moulds. The pressures developed on briquetting is about 1.75 tonnes per sq.inch and the briquettes are usually 1.25 to 2 inches in size.

2.4. CARBONIZATION

Carbonization before or after briquetting is done to produce smokeless briquettes. High volatile coals are subjected to limited carbonization to remove the excess of volatiles and the residual char is briquetted with or without binder.

At present the best choice for Pakistan is probably to briquette the coal first and then carbonize because in this process:-

i) the use of binder can be eliminated or atleast reduced, since the coal contains a significant amount of bitumen which acts as a natural binder. This will minimize the cost of production;

ii) processing the uniformly briquetted coal through coking system will present less problems than processing the raw coal whose particles vary widely in size and shape.

3. PAKISTAN EXPERIENCE IN COAL BRIQUETTING

The coal briquettes are being produced at Quetta and the record available with PMDC shows that the existing briquetting plant was shifted from Assam in 1942. The main purpose was to make the fuel available for comfort fire to the defence personnel stationed at Quetta and other hilly stations.

3.1. The coal briquettes are manufactured by convential briquetting process i.e. preparation, drying, treatment and pressing. The coal is fed to the hopper and taken to crusher and mixer by means of bucket conveyor. The crushed coal is carried by another bucket conveyor to steam cooker where it is roasted by super/heated steam and then fed to a hopper placed over the press roller which produces oval shaped briquettes. The briquettes are loaded into truck by a chain conveyor and chute. Prior to 1960, bitumen was used as a binding material but the steep rise in the prices of bitumen during 1971-72 made the process uneconomic. In order to bring down the cost of briquettes to an acceptable level super heated steam was introduced to utilize the tar of the coal itself as a binding material without appreciably affecting the strength of the briquettes. The power required to run the plant is provided by a smoke tube boiler which produces steam at a pressure of 150 lbs. per sq. inch. A steam engine runs the briquetting plant.

3.2. The run-of-mine coal, containing high ash and sulphur is used for making briquettes. The quality of the briquettes is therefore as inferior as that of the coal. The briquettes are however, of adequate strength to be handled and transported without excessive breakage or dusting. The limited market demand in the country did not justify any improvement in the process or modernization of the plant nor the washing of coal before briquetting was economically feasible.

3.3. The capacity of the plant was reported to be 50,000/60,000 tonnes per annum but it has never been operated to its full capacity because of limited market for briquettes. Although it is a very old plant yet PMDC has been successfully operating the plant and it can still produce 50 tonnes of briquettes per shift.

3.4. Like other coal producing countries, the production of briquettes has been showing declining trend. The availability of lumpy coal from PMDC Mines in Baluchistan, and subsequently the establishment of LPG plant at Quetta and then extension of gas pipe line was the main cause for sharp decline in briquettes consumption. The production of briquettes declined from 30,000/35,000 tonnes during sixties to only 5000 tonnes in 1984-85. The production of coal briquettes from

1974-75 to 1984-85 is shown in the table-I as annexure.

4. SMOKELESS BRIQUETTES

4.1. The lignite coals found in Pakistan are relatively inferior and have the following characteristics:-

- High sulphur content. The burning of these coals pollute the environment due to emission of sulphur dioxide.
- High ash which is converted into flyash.
- High volatile matter cause smoke as condensable hydro-carbon.

4.2. The present energy crisis and the trends it implies for the future places increasing stress on utilization of these coals as fuel for power generation, industries and space heating. The development of coal utilization processes that are sufficient and environmentally acceptable is a matter of priority. PMDC has been examining the possibility of converting lignite coals into sweet smelling smokeless briquettes for use as a domestic fuel in substitution of Kerosene oil.

4.3. In rural and the urban areas that are not connected with natural gas transmission system, large quantities of Kerosene oil is used as a domestic fuel. The production of Kerosene oil in the country is not sufficient to meet the existing demand and nearly 60% of the total requirements is met through imports. During the year 1983-84 about 411.200 metric tonnes of Kerosene oil valuing US$.111.00 million (Rs.1.776 billion) were imported. The foreign exchange expenditure during the last six years varied from US$.82.00 million to US$.161.00 million. The annual consumption and imports of Kerosene oil from 1978-79 to 1983-84 are given in the table-II & III.

4.4. PMDC had commissioned a study in 1976 which was aimed at evolving an economic process for making smokeless coal briquettes for use as domestic fuel in substitution of Kerosene oil. The study was carried out by M/s. Sanderson and Porter Inc., USA on bench scale. The tests were conducted on two samples of Sharigh coal (STS and SMS) and two samples of Lakhra coal (WMI and HIM 3). It was observed that by mixing either lime or calcium carbonate with each of the coal the desired briquettes could be produced. A 100% addition of lime with Lakhra coal and 200% with Sharigh coal based on the sulphur content was found to be the optimum mix proportion. A partial devolatization of each of the coals was also carried out with a view to determining the potential of the coals for organic chemical feed stocks and using the resultant residue in the production of a sweet smelling, smokeless and easily briquetted fuel. This indicated that all four samples could be partially devolatized to 50% of the original or less volatile matter. The resultant pellets produced by mixing 100% calcium carbonate with Lakhra coal and 200% with Sharigh coal were considerably weaker in strength than the non-devolatized coals.

4.5. Using the sulphur content of 1.60 float fraction of each coal, calculations were performed to determine what addition of lime or lime-stone might produce sweet smelling smokeless fuel. The sulphur values of 1.60 float fraction were:-

Lakhra coal

ROM coal	1.60 float fraction
5.51 to 12.15	WMI 5.88%
4.68 to 17.96	HIM 5.65%

Sharigh coal

ROM coal	1.60 float fraction
6.82 to 7.0%	STS 5.56%
8.12 to 8.52%	SMS 8.35%

4.6. Due to high ash and sulphur content of these coals it was determined that adding lime-stone to Sharigh coa (SMS 8.35% sulphur) in double the quantity theoretically needed to convert all the

sulphur to sulphate but it resulted in an increase of ash from 13% to 40%.

4.7. Since these coals were high in ash it was observed that a specific gravity separation at 1.60 would yield much lower ash values at reasonable recovery rate. Ash values were reduced as under:-

Lakhra coal

ROM coal	1.60 float
WMI 15.6 to 26.1%	WMI 12.7%
HIM-3 11.6 to 30.2%	HIM-3 20.4%

Sharigh coal

ROM coal	1.60 float
35.0 to 36.5%	SMS 13.0%
23.9 to 25.2%	STS 7.6%

4.8. The levels of additions for both lime and lime-stone of 100,150 and 200% were chosen for the initial study using a press and a die to make individual pellets. The desired proportions of coal and lime-stone/ lime were mixed, placed in the die and pressure applied to form the pellets. As a guideline in selecting optimum lime or lime-stone contents for full size briquettes, compressive crush strength was determined for one pellet from each mixture, using universal testing machine. The results are given in the following table:-

Coal	Present level of lime or lime-stone	Crush strength in PSI for hydration lime addition	Crush strength in PSI for lime-stone addition
Lakhra coal WMI	100	1740	1090
	150	600	960
	200	1130	630
HIM-3	100	1400	1350
	150	1210	1210
	200	1300	1210
Sharigh STS	100	1040	720
	150	1060	920
	200	1300	870
Sharigh SMS	100	1620	1740
	150	1570	1210
	200	1690	1880

4.9. As indicated in the above table except for one case calcium hydroxide additions resulted in the pellet strength of over 1000 PSI. A crush strength of 750 PSI generally indicative of adequate strength to be handled and transported without excessive breakage.

4.10. Odor emission tests were performed by placing crushed pellets of the 24 coal mixture on a nichrome screen, one at a time and igniting the coal with fisher burner. Even though two persons participated in the test, no smell of carbon-dioxide was noted for any of the twenty-four coals. A volatile matter odor discerned for all coal and was noticeably stronger in Sharigh coal. A sweet smell, characteristic of heated lime was noticed to varying degrees for all the mixtures. When **untreated** coals were burned, a sulphurous odor was felt. To determine as to what degree a sweet smelling fuel could be produced a test was devised in which sulphur analyses were performed before the carbon burned off in a furnace and then the ash analysis were conducted. After combustion the ash residues were weighed, then analysed for sulphur content. By comparing the weight of sulphur in the unburned pellets with the weight of sulphur in the ash the percentage of sulphur retained in the ash was determined. Sulphur rentention values for all four coals are given in the table below:-

Coal	Lime-stone/ lime additions %age	Sulphur retention %age	
		Calcium Hydroxide	Calcium carbonate
WMI	100	48.06	53.27
	150	71.40	77.41
	200	101.50	85.26
HIM-3	100	36.96	41.10
	150	69.28	68.18
	200	98.78	84.36
STS	100	51.59	33.15
	150	71.63	46.56
	200	80.00	53.71
SMS	100	51.69	43.28
	150	70.37	46.15
	200	69.08	46.06

4.11. In nearly every case the percent sulphur retained varied as the amount of sulphur sorbent added. In most of the cases calcium hydroxide was more effective. In the case of Lakhra coals, all or nearly all the sulphur present was retained in the ash when 200% calcium hydroxide was added, 101.5% for WMI and 98.78% for HIM-3.

4.12. The ash percentages determined during the pellet combustion tests are given hereunder:-

Coal	Additions %	Ash percentages Calcium Hydroxide	Calcium Carbonate
WMI	0	12.70	12.70
	100	23.20	23.03
	150	28.26	28.21
	200	33.66	30.65
HIM-3	0	20.40	20.40
	100	29.11	28.94
	150	34.98	33.69
	200	39.72	36.55
STS	0	7.60	7.60
	100	19.54	19.85
	150	24.93	21.10
	200	28.48	23.52
SMS	0	15.00	13.00
	100	30.31	27.31
	150	36.36	30.56
	200	38.93	32.61

4.13. It is evident from the above table that the percentage of ash increased with the increase in the amount of additions. In almost all the cases calcium carbonate produced less residue than calcium hydroxide.

4.14. The main consideration in attempting to produce briquettes from treated mixtures of coals examined was strength. It was determined from compressive strength data collected on the pellets that 100% calcium hydroxide and 200% calcium hydroxide would give better results for Lakhra and Sharigh coal respectively. The flow diagram for a briquetting plant as evolved by the consultants is given at Annexure-I.

5. ESTIMATED CAPITAL AND OPERATING COSTS

The estimated guideline to capital costs for a briquetting plant with a production capacity of 100,000 tonnes per year of briquettes was estimated to be as under:-

Description	Foreign exchange(US$)	Pak currency
1. Floatation	250,000	25,00,000
2. Driers and conveyors	-	5,00,000
3. Mill and screening plant	200,000	2,00,000
4. Lime-stone mill and Screen	150,000	1,50,000
5. Mix Muller	100,000	2,00,000
6. Press and Conveyors	100,000	5,00,000
7. Packer	25,000	1,00,000
8. Site preparation etc.	-	15,00,000
9. Buildings	-	10,00,000
Total:-	825,000	76,50,000
Engineering and contingency	200,000	11,91,000
	1025,000	88,41,000

5.1. The operating cost for 100% and 200% addition of lime-stone was estimated at Rs.453/- and Rs.399/- per tonne respectively.

The above estimates are no longer valid as the prices of men and materials have considerably gone up. However, even if the smokeless coal briquettes with a calorific value of 10,000 BTU are sold for Rs.1000/- per tonne, they would be competitive with Kerosene oil on heat equivalent basis. The cost of one million BTU of Kerosene oil on the basis of the consumption price of Rs.3.00 per litre or Rs.3,744/- per tonne works out to Rs.86.63 as against Rs.46.64 per million BTU for the coal briquettes. The smokeless briquettes could therefore play a significant role in substituting for Kerosene oil.

6. USAID STUDY

6.1. Another study was sponsored by USAID in October,1982 on coal briquetting

in Pakistan which was carried out by United Engineers and Constructions Inc., USA.

6.2. The consultants prepared a conceptual design and carried out economic analysis of a plant with 100 tonnes per day coal input. According to the consultants, the technology chosen by them indicated a compromise in the le ' of sophistication and only the coal tar and oil were assumed to be recovered. The exercise was carried out on the assumption that the briquettes can be produced without binder prior to carbonization of coal and internal combustion engine operating on excess off gas could provide all the power required to operate the plant.

6.3. The process consists of crushing, drying, milling and mixing of lime in the pug mill before briquetting followed by carbonization and cooling. The off gases will be cooled to recover tar and oil and they will be used to operate internal combustion engine. The engine will produce about 150 HP which will be sufficient to operate the plant. The exhaust from the engine could be supplied to the drier which will be adequate to dry the coal to about 15% moisture content.

6.4. ESTIMATED CAPITAL AND OPERATING COST

The capital cost of the plant was estimated at US$.213.00 million including 50% in foreign exchange. The details are as under:-

Equipment	Capacities	Installed cost in US$.
- Condenser/Scrubber	2MBTU	50,000
- Drier	5TPH	100,000
- Crusher	5TPH	45,000
- Roll Mill	1.5 TPH	60,000
- Vibrating Screen	1.5 TPH	54,000
- Carbonization Kiln	5TPH	450,000
- Pug Mill	5TPH	60,000
- Briquetting Press	5TPH	45,000
- Engine Generator	-	50,000
- Conveying system	5TPH	130,000
	Total:-	11,14,000

INVESTMENT COST

- Installed equipment	11,14,000
- Site preparation	1,50,000
- Buildings	2,50,000
- Engineering and contingency (40%)	6,16,000
Total:-	US$.21,30,000

6.5. The operating cost was estimated at Rs.832/- per tonne for smokeless briquettes and Rs.529.00 per tonne for ordinary briquettes. The details of cost estimates are given below:-

	Briquetting and coking (Rs./tonne)	Briquetting (Rs./tonne)
- Coal for briquetting	240.00	240.00
- Lime @Rs.80/- per tonne	8.00	8.00
- Labour and overheads	37.00	25.00
- Maintenance	20.00	10.00
- Loan repayment on 20 years interest @12%	103.00	73.00
Total cost	408.00	356.00
- Profits 25%	102.00	89.00
- Sale price FOB per tonne of coal feed	510.00	445.00
- Briquettes price FOB per tonne	772.00	469.00
- Transportation cost Rs.1.20 per tonne/mile, 50 miles average distance	60.00	60.00
- Average price within 100 miles	832.00	529.00

6.6. On the basis of the cost analysis the Consultants concluded that the briquettes can be produced at a price varying from Rs.33.30 to Rs.38.15 per million BTU and that there is no single fuel available except for natural gas that can compete with the coal briquettes. The comparison with other fuels prices was made as under:-

	Rs. per million BTU
- Briquettes price (delivered)	38.52
- Range (delivered)	36.11 to 40.93
- Firewood price	53.37
- Range	38.67 to 77.67
- Kerosene oil	81.88
- Natural gas	15.55

7. PRICING OF BRIQUETTES AND ECONOMICS

It is evident from the available data yet to be confirmed in a formal feasibility study, that briquettes could compete with other available fuels. However, the briquettes if to be made competitive should be priced at or below the price of urban wood. The USAID Consultants suggested that their price should not be above Rs.45.00 per million BTU initially and as the smokeless property and the higher cooking efficiency are achieved the price may be raised. Using the data derived through economic analysis the consultants concluded that if a family of six consumes fire wood energy at the rate of 24 million BTU per year, in six month they would buy firewood worth Rs.540/- as compared to smokeless briquettes valuing Rs.420.00 and Rs.300/-.

8. MARKET STUDIES

It is not easy to introduce any new product in the market particularly when it has to compete with other traditional products available at cheaper price. The briquettes will have to compete with Kerosene oil and natural gas which are cleaner and easy to handle. The penetration of the briquettes into the local market, will require Government support for briquetting concept before proceeding further.

9. FUTURE PLANS

Under the existing circumstances it is necessary to proceed with the project cautiously. Besides, the feasibility report a complete design and economic analysis report will have to be prepared in order to establish the market through consumer preference survey and appropriate technology to be used.

Accordingly, PMDC has prepared a plan for carrying out a detailed techno-economic study for establishment of a smokeless coal briquetting plant with an ultimate production capacity of 300,000 tonnes of briquettes per annum. The scheme will be executed in two phases. The first phase includes studies to determine their acceptability and consumers preference survey as a domestic fuel to assess the market demands and pilot plant scale tests for evolving a process of briquetting. The consumers preference survey is proposed to be carried out through introduction of the product in the market on trial basis. After detailed analysis of the data and subject to the positive results, detailed planning and designing of the project will be carried out. All the arrangements in this regard have been finalized and the studies will be started shortly.

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TABLE-I

PRODUCTION OF BRIQUETTES

Year	Production (Tonnes)
1974-75	14,889
1975-76	13,305
1976-77	10,015
1977-78	9,605
1978-79	14,390
1979-80	10,000
1980-81	9,626
1981-82	10,015
1982-83	10,000
1983-84	8,737
1984-85	4,985

TABLE-II

CONSUMPTION OF KEROSENE OIL

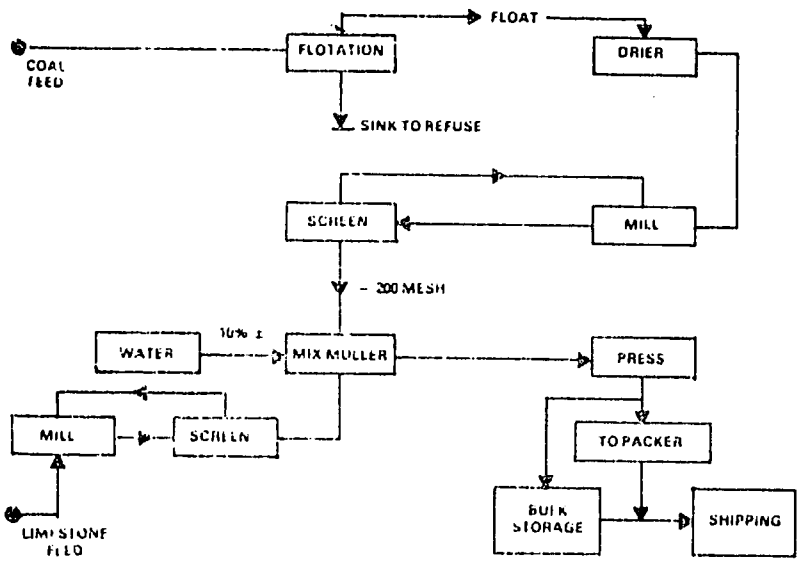
Year	Quantity (Tonnes)
1978-79	693,645
1979-80	637,311
1980-81	528,652
1981-82	553,496
1982-83	604,114
1983-84	690,036

TABLE-III

IMPORT OF KEROSENE OIL

Year	Quantity (Tonnes)	Value (Million US$)
1978-79	535,502	82.00
1979-80	519,902	161.00
1980-81	377,410	155.00
1981-82	352,420	124.00
1982-83	390,039	124.00
1983-84	411,199	111.00

FLOW DIAGRAM



BRIQUETTIBILITY OF COAL WITH REFERENCE TO PAKISTAN COSLS.

Dr. Nisar Ahmad
M.Zahid Raza,
S.K.Shah,
Farid Sibtain.

FUEL RESEARCH CENTRE,
P.C.S.I.R.,
OFF UNIVERSITY ROAD,
KARACHI-39

ABSTRACT.

Coal Briquetting, a process for agglutinating fine sizes of coal, lignite and other fuels to make composite larger sizes, has as its principal objective beneficiation of coal by providing a resultant size that can be more easily handled and burned. Various prevalent techniques of briquetting coals and chars with and without binders and the standards and methods for testing the quality of briquettes have been described. Keeping in view the quality of Pakistan coals briquetting is considered to be a necessary step in any programme directed towards domestic use of these coals. Coal briquetting status in Pakistan has been briefly mentioned. Studies conducted indicate the effectiveness of addition of lime for fixation of sulphur in ash in the presence of inorganic materials to a larger extent. The use of organic and inorganic binders for producting briquettes from coal and char and the quality of briquettes thus produced have been described. It has been concluded that Pakistan coals can be economically briquetted with and without binder,however for smokeless briquettes from char, use of binder is a must. The necessity of development of appropriate technology for the production of Processed Coal Briquettes and its introduction as domestic fuel has been emphasized.

INTRODUCTION :

Coal Briquetting, a term applied to processes for agglutinating fine sizes of coals, lignite, etc., so as to make composite larger sizes, has as its principal objective beneficiation of the fuel by providing a resultant size that can be more readily handled and burned in conventional equipment.

The materials adaptable to beneficiation through briquetting are : peat, lignite, bituminous coal, anthracite, charcoal, coke breeze, saw-dust, wood, lampblack, petroleum coke, lignite char, bagasse, straw, husks, shells, grain hulls, seeds and wood chips. Commercially anthracite, bituminous coal, brown coal, and lignite account for virtually all the briquetted tonnage, any of the others being for special purposes or local disposal.

Heat, pressure, binders or combination of the three are the mediums employed for securing the necessary cohesion, the choice depending almost upon the raw materials used and the stability of the product desired.

Lignite, which is a low rank coal, can be briquetted easily without binder. However, as the coal becomes more mature, it becomes harder and more difficult to briquette without a binder. As the change in the coal rank is gradual so is the change in the

briquettibility of coal.

The nature of the forces of adhesion involved in briquetting coals of different rank is the same, but the pressure required for their agglomeration differs. For this reason lignites and bituminous coals are not briquetted by the same process. Briquetting of bituminous and high rank coals require the use of a binder[2].

The methods which succeed in making hard briquettes are those which aim to bring the particles close together. With bituminous coals which is harder than brown coal, this is achieved by the adoption of one or more of the following conditions :

- Use of high pressures.
- Preparation of coal by fine grinding.
- Controlling the moisture content.
- Briquetting at appropriate temperature.

Apart from these factors the strength of the attachement will depend on the area of the surface in contact. It is also probable that the cleanliness of the surface is important and any contamination of the surface would tend to reduce its cohesive power.

Many advantages can be accrued by briquetting the coal:

- Waste coal fines could be utilized.
- Coals which are friable and cannot stand handling could be converted into more stable briquetted forms.
- Coals which are susceptable to weather or likely to ignite spontaneously could be briquetted into stable form.
- In high sulphur coals, sulphur could be fixed in ash by mixing suitable additives to the coal powder before briquetting. The briquettes thus produced pose least health or environmental problems.
- Relatively smokeless briquettes could be produced from high volatile coals by devolatilization.
- Combustion properties of the briquettes could be adjusted to an appreciable extent.
- Briquettes of desired size and shape according to the requirement of the consumer could be produced.
- Briquetted coal is environmentally more acceptable than run of mine coal or lumps. The scattering of coal dust/fines in homes and streets resulting due to breakage of coal lumps, could be avoided.

BRIQUETTING WITHOUT BINDER:-

Briquetting of coal without prior addition of a binder that promotes agglomeration of the coal particles is in practice restricted to relatively soft lignites demands careful attention to the size consist and the moisture content of the feed. To facilitate close packing of particles during compression it is generally essential to crush the coal to <4 mm, with 60-65% <1 mm., and for maximum briquette strength moisture content must be adjusted to values that vary inversely with the briquetting pressure[3,4]

Briquetting is usually conducted at 38-65°C i.e. at temperature at which advantage can be taken of enhanced plasticity of small particles.

It is possible to prepare binderless briquette on a commercial basis with sub-bituminous coals, lignites, or peat. In order to form satisfactory briquettes from lignite the follwoing conditions are necessary.

1. Drying to the stage of equilibrium moisture content of the coal.

The optimum moisture content varies from 12-16%.

2. The application of pressure sufficient to make the particles deform under load. The pressure required for self binding briquettes is relatively high usually about 500-1500 Kg/cm^2 for lignites.

Two types of presses are suitable for the manufacture of self-binding briquettes, namely: Direct acting plunger-type presses, preferably operating as extrusion presses and the ring-roll presses. The preferred press for lignites is the extrusion press which makes briquettes of rectangular, circular or dumb-bell shape.

BRIQUETTING WITH BINDER :

Bituminous coals, anthracites and coal chars are briquetted with binder. Briquetting with a binder is a very useful method of utilising small waste high rank coals in a covenant solid form. The principal types of binders can be categorised in four groups namely :

- Inorganic binders: sodium silicate, sulphate lye,clays, magnesum oxychloride, cement, etc.,
- Cereal and carbohydrate binders: Starches, ground cereals, maize flour, molasses etc.
- Heavy hydrocarbons or asphalts: coal tar pitch, bitumen, etc.
- Synthetic organic binders: Phenolic resins, and epoxides.

Inorganic binders have the obvious disadvantage of increasing the ash content of the briquettes, but the simplicity of the briquetting process may sometimes offset this disadvantage.

Cereal binders in small proportions,3-8% make satisfactory briquettes. Unfortunately such briquettes disintegrate under moist or tropical conditions. When using flour paste the large quantity of water required necessitates drying the briquettes at a temperature of 120°C before they are suitable for marketing. The use of very small additional proportion of water resistant organic substances improves the water resisting properties.

Petroleum asphalt and coal tar pitch are the most preferred binders. These have good cementing strength, water resistance and toughness. The usual weight percentage of these binders to coal in 5-7%. However, these type of briquettes produce smoke and soften as they become heated.

The type of presses in general use for briquetting with binder are the rotary-table press and double-roll press. The pressure applied is generally within the range of 60-300Kg/cm^2. Briquettes from roller presses have always the shape of eggs, pillow, tear-drops or similar forms.

The briquetting of coal involves five different steps of drying, grinding, mixing and pressing of coal and cooling the briquettes. For each of these stages there are optimum levels of size grading, moisture content, temperature etc., and these vary from coal to coal. Because the percentage of binder used is usually quite low, therefore, for its uniform distribution,the mixing techniques of powdered coal or char with binder is very critical. When increased density and strength of briquettes are required, a reduction in size is mandatory.

HOT BRIQUETTING :

Another way of getting good hard briquettes from bituminous coals is

hot briquetting. The temperature required is around 400°C, at which these coals are near plasticity stage.

The pressure applied is within a range of 300-1500 Kg/cm.^{2} The optimum conditions for briquetting vary according to the nature of the coal, its palsticity, coking power and volatile matter. The briquettes so made possess considerable mechanical strength and a calorific value greater than that of the original coal. They are weather resistant, ignite easily, burn well and are less smoky than the coal from which they are made. The briquettes made at temperatures below the point of incipient plasticity have a granular structure whereas those, made at high temperatures from coking coals have a fused structure and are more dense.

BRIQUETTE QUALITY :

Briquette quality is assessed on the basis of some property that is peculiar to the briquettes or the way they are used. The strength of the briquette is of prime importance and for many purposes the most useful measure of briquette quality is density.

Tests more generally applicable are those that measure the mechanical properties of briquettes. Crushing strength determines whether the briquettes can with-stand the wieght of the overburden if the briquettes are stored in bins or silos. A drop shatter test determines whether the briquettes have sufficient resistance to withstand repeated drops encountered in bulk handling. A tumble test determines whether the briquettes are abrasion resistant enough to be transported in bulk without undue loss in weight. All of these tests measure certain aspects of briquettes quality but the results must be interpretted with care as they are influenced by the size and shape of the briquettes as well as by the properties of the material from which the briquettes are made.

NEED FOR BRIQUETTING :

Considering the scarcity of fuel and energy resources, increasing demand of fuel due to population growth, rapid industrial and the quality of indigenous coals, the necessity of utilizing processed briquetted coal has been felt. The factors responsible for putting emphasis on coal briquetting can be enumerated as under:

Energy Position :

The total primary energy consumption in Pakistan is currently (1985) estimated at 24.6 million tons of oil equivalent (MTOE) of this, about one third is met by consuming conventional indigenous resources like firewood, charcoal, cow-dung, etc. The primary commercial energy consumption of 16 MTOE is largely based on the use of fossil fuels i.e. oil, gas and coal. Natural gas, which was the leading source of energy for about 10 years in the country, now occupies second postion.

At present oil, natural gas and hydel power meet almost all the country's commercial energy requirements, the percentage contribution of each source for the fiscal year 1984-85 being oil 38.6 gas 34.8 coal 7.4, Hydel 19.3 Nuclear and LPG 0.4

Increase in economic output and population are the main causes of growth in energy demand. The present growth rate of energy calculated on the basis of GDP and population growth rates come to 11.5%. The consumption of individual commercial sources of energy for the

years 1983 to 1985 are given in 000tons oil equivalent in Table: 1.[6,7]

TABLE : 1

ENERGY SUPPLY BY SOURCE

in 000 tons oil equivalent
(percentage)

Source	1983	1984	1985
			Year Ended June 30
Coal	862 (5.52)	1218 (7.39)	1270 (7.37)
Oil	5888 (37.75)	6436 (39.08)	6862 (39.82)
Gas	6054 (38.82)	5630 (34.18)	5560 (32.26)
Hydel	2701 (17.31)	3046 (18.49)	3378 (19.60)
Nuclear	90 (0.58)	65 (0.39)	80 (0.46)
LPG		72 (0.43)	80 (0.46)

Coal is the second major energy source after oil in the world but is playing a minor role in the energy picture of Pakistan at the moment as is evident from the Table:1 This fact had led to the realization that the development and utilization of this source of energy be given priority to fill-up the energy gap atleast partially.

Indigenous Coal Resources :

The geological coal reserves in the country are estimated to about 2 billion tons. Out of this nearly 160 million tons are proven reserves. During 1984-85 Pakistan's coal production was 1.985 million tons. This figure does not include the unreported production from some private mines, for which authentic information is not available. At present the largest use of indigenous coal is in brick kiln (95%). The remaining 5% is utilized in domestic sector and to a small extent in

electricity generation. These coals are mostly of low rank i.e. lignitic to sub-bituminous, non coking, largely high in ash and sulphur contents, friable and often liable to spontaneous combustion. They are characterized by marked physical and chemical variations both within individual beds and from one coal field to another The coal found in the Sharigh field processes medium coking characteristics.

Environmental Aspect :

Pakistan coals appear an attractive substitute for firewood and kerosene which are dominent domestic fuels and which are increasingly in short supply. Indigenous coal burns with smoke and sulphurous fumes that makes it undesireable as domestic fuel. This demands that some means for neutralizing the sulphur and driving off partly the volatiles be devised. Due to the friability and susceptibility to weathering and spontaneous combustion of these coals it is also necessary that it must be briquetted before putting it to domestic use. Moreover, there is now a fundamental need to reduce cutting of wood as it is resulting in deforestation, and causing environmental problems at the same time. The introduction of coal briquetting is therefore, one of the alternatives to come out of this critical situation.

Status of Coal Briquetting in Pakistan :

Only small quantity of briquettes are produced in Pakistan and supplied to army. These are made in a plant at Quetta which is run for three to four months (Nov.-Feb.) and produces about 5000 to 6000 tons of briquettes each year. Weakly coking, run of mines Sharigh Coal with 26 to 35% ash is used for making briquettes without using a binder. These are made with the help of super-heated steam and pressure. It is claimed that super-heated steam causes the coal to release its inherent tar which acts as binder.

500 tons of briquettes are produced at a cost of Rs.300/ton in a working day of about 8 hrs. 4 tons of coal is used in the boiler per day per shift. These are sold at a rate of Rs.500/ton.

TABLE : 2.

ANALYSIS OF LAKHRA COAL SAMPLES RECEIVED FROM VARIOUS SOURCES.

		U.S AID	PMDC	M.AMIN. (private miner)
Moisture	(as received)	37.3	16.3-30.3	12.9-33.5
Moisture	(air dried)	9.2	4.6-14	12.3-23.3
Ash	"	24.1	11.4-39.3	5.3-43.3
Volatile Matter	"	35.0	21.9-39.8	37.3-5.83
S (total)	"	5.51	3.41-5.99	1.9-5.83
Higher Heating Value K Cal/Kg.	"	4,930		4,620-5,970

STUDIES ON BRIQUETTIBILITY OF PAKISTAN COALS :

Studies on various coals were undertaken in Fuel Research Centre of PCSIR The emphasis however was laid on Lakhra coal being the largest deposit. Its reserves are estimated to be about 240 million tons. It is lignitic in nature and has relatively high sulphur and volatile matter. It is friable and liable to spontaneous combustion. The wide variations in the composition of this coal are evident from Table:2. These variations and are worth considering while making briquettes.

BRIQUETTING OF LAKHRA COAL :

Raw Materials :

a) Coal:

Lakhra Coal was crushed on a tooth-crusher and ground in a disc mill so that 80% of it passed through a 20 mesh sieve. The average analysis of this sample is given in Table :3

TABLE : 3

	As received	Moisture Free
Moisture	11.6	-
Ash	11.9	13.46
Volatile Matter	38.6	43.67
Fixed Carbon	37.9	42.87
Sulphur (Total)	3.34	3.78
Gross Calorific Value, KCal/Kg.	5,290	5,990

b) Char: Char was obtained by carbonising the coal at different temperatures in an electrically heated steel retort.

TABLE : 4

YIELD AND ANALYSIS OF CHARS.

Carbonization Temperature.	Yield of Char.	Moisture	Ash	V.Matter.	Sulphur (Total)
450°	72%	22.7	15.9	29.5	4.51
		Moisture Free	16.34	30.32	4.64
500°	58%	2.4	17.2	24.1	4.77
		Moisture Free	17/62	24.44	4.77
550°	63%	2.5	17.8	17.5	4.43
		Moisture Free	18.25	18.94	4.54
600°	57%	3.1	18.4	13.00	4.50
		Moisture	18.98	13.14	4.64

The yield of char and their characterstics are depicted in Table :4.

Char obtained at 500°C, was used for experimental work, as at this temperature the volatile matter was around 25%, the calorific value of this char was about 6,100 KCal/Kg. At higher temperature the yield of char is low and the production cost is increased which adversely effects the economics of the process.

c) Additive:

Lime: Quick lime available from local shops was slaked and was ground to pass a 60 mesh sieve (ASTM).

d) Binder:

The following materials were used as binders.

1. Clay : Powdered kaolin and pottery clay.
2. Cement : Portland cement.
3. Starch : Commercial grade starch.
4. Molasses: Molasses (of density 1.46 g/ml.)
5. Synthetic Binders : Polyvinyl alcohol solution

Briquetting Procedure:

The charge for briquetting was prepared by mixing first the solid ingredient then adding liquid material/paste to it and homoginising them. The briquettes were then produced on a small manually operated hydraulic press. The cylindrical briquettes were made at different pressures maintaining it for 15 seconds. The briquettes were cured for 3 days. The charge for each briquette was 25 gm.

The change in volume of charge after briquetting at various pressures were determined. The calculated compression ratio (Initial volume:Briquette volume are given in Table:5

TABLE : 5.

COMPRESSION RATIO OF COAL AND CHAR.

Material	Pressure Kg/cm2	Compression Ratio.
Coal	320	1:0.58
	640	1:0.55
	960	1:0.51
	1280	1:0.48
Char	320	1:0.63
	640	1:0.55
	960	1:0.52
	1280	1:0.50

Testing of Briquettes:

The briquettes were tested for their strength and resistance towards water after curing for 3 days.

a) Strength : The strength of the briquettes was determined by dropping these from a height of six feet on a steel plate and observing the resultant condition of the briquettes.

b) Water Resistance: The briquette was considered satisfactorily water resistant if it did not disintegrate after remaining in water for 24 hours.

c) Sulphur Retention : After combustion in a muffle furnace, the ash of the briquette was carefully weighed, then analysed for sulphur content. By comparing the weight of sulphur in the unburned briquette with the weight of sulphur in the ash, the percentage of sulphur detained in the ash was determined.

RESULTS AND DISCUSSIONS:

Briquetting without Binder:

Coal powder was briquetted as such without additive or binder and the moisture content of coal was maintained at 15%. The briquettes were made at various pressures. The results are given in Table:6.

TABLE :6

BRIQUETTES WITHOUT ADDITIVES OR BINDER :

Pressure Kg/cm^2	Briquette	
	Strength	Water Resistance
320	Weak	Non-resistant
640	Weak	Non-Resistant
960	Satisfactory	Resistant
1280	Good	Resistant.

The strength and water-resistance of briquettes at higher pressures were good and these burned smoothly but with smoke and obnoxious fumes.

In another series of experiments lime was added to coal in the stoichiometric ratio of 1:1 on the basis of sulphur in coal, 8 parts of slaked lime was added to 100 parts of coal with a sulphur content at 3.34%. The characteristics of the briquettes thus produced are shown in Table :7.

TABLE :7.

BRIQUETTES WITH LIME BUT WITHOUT ANY BINDER

Pressure Kg/cm^2	Briquettes	
	Strength	Water Resistance
320	Weak	Non-resistant
640	Weak	Non-resistant
960	Satisfactory	Resistant.
1280	Good	Resistant.

As indicated in Table:7 the addition of lime produced little effect on the strength and water resistance,but when burned less smoke and sulphurous fumes were emitted. The analysis of ash produced by burning these briquettes has shown that about 50% of the sulphur in coal was fixed in the ash.

Experiments were carried out by increasing the ratio of lime from the stoichiometric ratio of 1:1 to 1:2 on the basis of sulphur. Little effect was observed in the fixation of sulphur.

A few more experiments were carried out with a little quantity of inorganic salts in association with lime and it was observed that the fixation of sulphur in ash was increased to an appreciable extent. Further study in this direction is in progress to maximise the fixation of sulphur in ash.

Briquetting with binders:

1) Coal : Numerous experiments were carried out with lime and binders, in different proportions and at different pressures. No appreciable improvement in strength and water resistance was observed. On the other hand, with the addition of clays and cement, the ash content of the product increased proportionately thereby reducing the heating value.

2) Char: Briquettes were produced with the addition of lime and binders like clays,cement, starch molasses and PVA. The properties of those produced with molasses and starch are given in Table :8 and 9. The ratio of lime to sulphur in char was taken as 1:1.

TABLE : 8

CHAR BRIQUETTES WITH LIME AND MOLASSES.

Molasses	Pressure Kg/cm^2	Strength	Water-resistnace
15%	320	Weak	Non-resistant
	640	Weak	Non-resistant
	960	Satisfactory	Non-resistant
	1280	Good	Non-resistant.

TABLE :9

CHAR BRIQUETTES WITH LIME AND STARCH:

Starch	Pressure Kg/cm^2	Strength	Water-resistance
7.5%	320	Weak	Non-resistant
	640	Weak	Non-resistant.
	960	Satisfactory	Resistant.
	1280	Good	Resistant.

The briquettes produced with clays and cement were weak. Briquettes made with 5%,10% and 15% of molasses were produced. Only the briquettes with 15%molasses were satisfactory. With starch as binder 7.5% of starch on the basis of coal was sufficient to bind the char but with less proportions the briquettes were weak.

The briquettes produced from char and PVA, at 320 Kg/cm^2 were very good with repect to strength and water-resistance.

ECONOMICS OF BRIQUETTING:

The cost of fuel in terms of energy per million Btu is given in Table:10. It is evident that of all the fuels the coal, coal-lime and the smokeless briquettes are the lowest in cost. But due to the inherent drawbacks of coal being high in sulphur the use of coal briquettes in domestic as well as industrial sectors is difficult.

The processed coal briquettes which give off only 50% of sulphur present in the original coal in the flue gases can be a marketable commodity acceptable to consumers——domestic as well as industrial.

TABLE : 10

PARTICULARS OF VARIOUS SOURCES OF ENERGY :

	Briquettes Coal	Briquettes Char	Wood	Charcoal	Indigenous Coal	Furnace Oil	Kerosene	LPG	Gas.
Price/million Btu, in Rs.	22	35	68	80	15.00	49.00	86.00	34.00	40.00
Price/Unit in Rs.	420/ton	750/ ton.	750/ ton.	2000/ ton.	300/ ton.	1.8/lit	2.75 lit.	1.8/ lit.	140/ lit.
Calorific Value, KCal/Kg.	4,860	6,110	2,780	6,280	5,000	10,270	11,100	12,220	19,610

In comparison to the coal lime briquettes the smokeless briquettes are more expensive and require a lengthy processing but even the compares favourably with the dominant fuels used presently.

The coal lime briquettes can be burnt in the specially designed stoves meant for smokeless burning of the coal/processed coa briquettes or in the conventional charcoal stoves, popularly known as **"ANGITHI"**.

CONCLUSION :

It has been reported that 100% stoichiometric additions of sulphur seldom followed the theoritical postulates and that most coals often require twice or more of the theoetical quantity of lime to achieve about 100% fixation. But addition of more lime adversely affects the strength and quality of the briquette. The studies conducted at Fuel Research Centre reveal that:

i) by the addition of lime in the stoichiometric ratio of 1:1, 50% sulphur can fixed.

ii) further addition of lime had no or little effect on the sulphur retention.

iii) fairly strong and water resistant briquettes can be produced at a pressure 1280 Kg/cm^2.

iv) these briquettes can be burned in specially designed stoves with much reduced smoke and obnoxious sulphur and fumes.

v) the production of smokeless briquettes from coal-char is about 50% more expensive than the briquettes from coal. The production of coal-lime briquettes is an economically more attractive proposition.

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DEVELOPMENT OF MANPOWER FOR THE COAL MINES LAKHRA (SIND) ATTACHED WITH TWO 350 MW THERMAL POWER PLANTS.

RANA M. SULTAN
Chief Inspector of Mines, Punjab. (Pakistan). and
President Institute of Mining Engineers. (Pakistan).

HISTORY

The coalmining industry in Pakistan is nearly one century old. The traditional method of extracting coal by employing manual labour is in practice since beginning. The quality of coal generally is sub-bitumenous in the areas of Punjab and Baluchistan, while Ligitic type of coal is abundantly available in Sind. Due to presence of Sulphur and Ash contents the coal has not been able to find its utility in the industry. Presently the coal is being used in the brick kiln industry, which is mostly located in Punjab, NWFP and Sind. Due to thin coal seams, the coal cutting has not been mechanised. Some aspects of mining such as loading, transportation, roof support etc. have been mechanised while the rest of the processes are still being managed through the use of manual labour.

The coalmines which are being managed by the Public Sector Corporations are adequately mechanised while the coalmines of the Private Sector are mostly un-mechanised.

The various categories of personnel who are vital in coal raising have been trained by the industry itself, while working on the jobs. Although there is a net-work of Technical Training Centres and Vocational Training Institutes spread all over the country which impart training in various mechanical, electrical and Auto skills, but none of the training institutes cater for mining disciplines.

INTRODUCTION

The Lakhra Mine Development Project is going to be the first of its kind in Pakistan having a production capacity of 4.3 mt per annum. The successful operation of this project depends upon the availability of trained manpower as well as machinery. The Lakhra Mine Development Project is to act as feeder to the planned Thermal Power Plant, Lakhra. The Power Plant is going to produce 700 MW of electricity based on Lignitic Coal of Lakhra (Sind). The Lakhra Mine Development Project shall develop 2 surface mines at Lakhra namely the Western Block and the Eastern Block and one underground mine in the centre of these two blocks. The mining operations shall be fully mechanised so as to raise the desired production of coal economically.

There is no other coal mining project in Pakistan which will equal this project. For purposes of manpower distribution the project has been bifurcated into the following categories:-

1. Surface Mines (Western & Eastern Block).
2. Underground Mine (In between the Surface Mines).
3. Common Facilities i.e. Coal-Platform, Washing Plant etc.
4. Infrastructure facilities.

SURFACE MINES

According to the consultants two surface mines spread over 22.70 square kilo Meter area shall be developed in Lakhra to produce 4.0 . t of coal annually. The Western and Eastern blocks shall each produce 2.0 mt./annum. To manage the surface operations . services of Mining Engineers, Mechanical Engineers, Geologist and Industrial Engineers shall be needed besides their supporting staff. (Annexure I) The other major constituent of surface mines shall be the deploy ment of heavy machinery. The type of machinery which shall be used in these operations is exhibited in Annexure - II.

These heavy duty machines would require experienced and trained personnel for their operations. Estimated distribution of manpower on the surface mines is exhibited at

Annexure- III. . Except for personnel dealing purely with the mining aspects, the other categories of technicians and operators locally trained through the Technical Training Centres and Vocational Institutes of the Labour Departments are readily available.

UNDERGROUND MINE

It is planned to produce 0.3 mt. of coal annually through underground mining operations in an area of 3.204 SKM. Long-wall advancing method is proposed to be implemented . The type of personnel required for underground mines and machinery to be deployed are exhibited at Annexure- IV & V respectively.

Extensive drilling has been carried out in Lakhra over an area of 26 Square Kilo Meter in order to prove the extent and thickness of different seams of coal tabulated as under.

TABLE I.

Coal Seams thickness at LDMP & area under dev.

Name of Coal Seam	Western Pit 10.68 Sq. K.M.	Central Block Underground 3.204 Sq.K.M.	Eastern Pit 12.02 Sq.K.M.
Ist Seam	2.14 m		1.6 m
2nd Seam	1.71 m	1.91 m	2.14 m
3rd Seam	0.84 m	-	0.66 m
4th Seam	0.63 m	-	-
5th Seam	0.70 m	-	-

The requirement of different categories of personnel for surface as well as underground mines shall vary. In the pre-development stage the requirement shall be limited while with the progress in the development process additional trained hands of different skills shall be needed in accordance with the nature of the jobs. The manpower strength indicated in the Annexures indicate the estimated number of manpower when the Lakhra Mine Development Project was initially planned for 1.4 mt. of coal production. Latest report of the consultants based on 4.3 mt. production was not available at the time of writing this paper therefore reliance has been placed on the old report so far use of designations, categories and disciplines of manpower are concerned.

Lakhra Mine Development Project envisages to produce 2 mt. of coal from the Western Pit, 0.3 mt. from the underground central block and 2 mt. from the Eastern Pit. As equal quantity of coal shall be raised from the two Open Pits, therefore, the employment potential at the surface mines (Open Pits) and underground mines shall be as under:

TABLE 2.

Distribution of manpower at the Mines of Lakhra Mine Development Project.

Mine	Expatriates	Domestic	Total
Western Pit.	16	490	506
Central Block underground.	0	516	516
Eastern Pit.	16	490	506

COMMON FACILITIES

The section of Lakhra Mine Development Project which is to deal with the common facilities of surface and undergroun mines include Coal Platform, Coal Washing Plant, Coal Sample Testing Laboratory etc. All the coal which will be raised from the surface and underground mines shall be transported to the Coal Platform through Trucks and Conveyor Belts. A list of personnel required at this Section is exhibited in Annex-VI

INFRA-STRUCTURE FACILITIES

The infra structure facilities are supposed to consist of:-

1. Office;
2. Housing Colonies;
3. Roads
4. Schools
5. Hospital
6. Transport
7. Water Supply
8. Electricity
9. Gas
10. Stores etc.

The management and successful operations of these facilities require the availability of experienced and qualified workforce.

Comfortable living conditions shall attract experienced people to work at the project. The type of personnel needed to manage the above mentioned facilities can be perused from Annexure VII.

According to the consultants the break up of the manpower in broad terms viz a-viz expatriates and domestic employees have been given as below in table-3.

TABLE-3

Statement of Manpower Required during development

	Expatriates	Domestic	Total
Surface Mines.	32	980	1012
Underground Mine.	0	516	516
Common Facilities (Coal Platform. Coal preparation etc).	16	175	191
Infrastructure.	1	428	429
	49	2099	2148

The mining trades which are missing in the country and vitally needed for the surface and underground mines at Lakhra Mine Development Project are enlisted as under:-

1) Mining Sirdar
2) Coal Cutter
3) Shot Firer
4) Mines Rescue Crewmen
5) Mine Ventilation Assistant
6) Mine Sample Collector.

Mining Sirdar.

A certificated miner who has practical underground coalmining experience of atleast 3 years and have passed the examination conducted by the Board of Examiners under the Mines Act, 1923 of Pakistan. The existing Mining Sirdar Certificate holders working in the coal mines all over the country are mostly illiterate. Incidently there is no institution in the country which imparts training in this discipline of mining. To be eligible to sit in the Sirdar Certificate Examination, one has to work underground on various jobs such as coal cutter; timberman, katcha worker (work in the country rock). Ventilation Assistant etc. atleast for 3 years. Normally Sirdar examinations are conducted twice a year by the Board of Examiners of each Province. At an average 50 persons qualify each time.

In other words each province of Pakistan except NWFP turn out 100 Sirdar Certificate qualified persons annually. This means 300 Mining Sirdars Certificate Holders are available annually. Such qualified persons find jobs readily in the coal mines in their respective provinces. Failure to find jobs in their own provinces they move out and find jobs in other provinces. A Sirdar in fact is incharge of a section of a mine under the Mines Act. In a section of a mine normally 20-50 miners work. On the same analogy it would be safe to persume that each section of Lakhra Mine Development Project shall be supervised by a Mining Sirdar Foreman or a person of equivalent status. Considering the proposed layout of the longwall mining method the requirements of Mining Sirdars/ Foremen workout in table-4 as under:-

TABLE-4.

	1st. Shift		2nd Shift		3rd Shift		Total	
	W	F	W	F	W	F	W	F
MD (5 entries).	7x5	5	35	5	35	5	105	15
PD-1 (2 entries).	10	2	10	2	10	2	30	6
PD-2 (2 entries).	10	2	10	2	10	2	30	6
PD-3 (2 entries).	10	2	10	2	10	2	30	6
LW-1	22	2	22	2	22	2	66	6
LW-2	22	2	22	2	22	2	66	6
LW-3	22	2	22	2	22	2	66	6
	131	17	131	17	131	17	393	51

The type of Mining Sirdars/Foremen required for the coal mines of Lakhra Mine Development Project are different from the quality of sirdars available in the field. Literate persons/sirdars shall have to be recruited and specially trained through short courses. There will be other workers engaged on underground work but not directly involved in the production. However they shall continue to be considered on the roll of the underground mining operations. The services of Mining Sirdar/Mining Foreman are equally useable in the underground as well as on the surface mines. On the surface a quarry face of 200-500 meters can safely be placed under the charge of a Mining Sirdar/Mining Foreman.

Coal Cutters.

A coal cutter in Pakistan is a skilled worker who has learnt the trade while at the job after spending 3-5 years underground on the job of coal cutting. Usually he is an illiterate person coming from Swat, Kohat (NWFP) and Azad Jammu & Kashmir. He works with hand picks and cuts the coal from the thin seams from the face. Usually his Output Per Manshift (OMS) ranges between 0.25 to 0.5 tonnes. His working instrument is his pick. Due to migration trend of this labour to the Middle East there is always dearth of mining labour force. The private mine owners advance money to the Mates/Jorisars to bring labour for their mines. These coal cutters work on piece rate basis. A very few sects of locals are involved in this trade of coal cutting. The existing labour force of coal cutters in Pakistan works mannually and cut the coal with hand pick.

The type of coal cutters required by Lakhra Mine Development Project are quite different from the conventional coal cutters. These coal cutters shall be regularly employed on whole time basis and required to operate the coal cutting machinery. Therefore, mechanically trained coal cutters are not available at all and shall have to be trained by the Lakhra Mine Development Project from the time preparation/construction phase of mining starts.

Shot Firers.

Shot Firers or Blasters are very essential for rock blasting for surface mining as well as for underground mining. There is no institution in the country which imparts training on regular basis to the Shot Firers/Blasters. M/s Wah Bofors at Wah, Hassanabdal dealing in explosives, organizes one week course every year in Advance Rock Blasting Techniques for Engineers. Shot Firers/Blasters as such are learning the techniques of blasting while on the job. Most of these Shot Firers/Blasters are without any certificate granted by any recognized institute in the country. Those experienced persons who apply to the Chief Inspector of Mines, for the grant of certificates are given a test and thereafter granted certificates by the Board of Examiners under the Mines ACt. Skilled workers in this trade shall have to be specially trained by the Lakhra Mine Development Project for its surface and underground mines.

Shot Firers shall be needed for the underground coalmine as well and the estimated number shall vary according to the number of panels being developed. To train these Shot Firers it would be advisable to organise a short course of 6-8 weeks during the planning phase at site. As an alternative experienced Shot Firers of required number can be recruited. Shot Firers/Blasters shall be certainly available to join Lakhra Mine Development Project on better emoluments and facilities. The training facilities of the Training Centre and Training Mine at Choa Saidan Shah (Distt Chakwal) (Punjab) can be utilized by getting specialized courses arranged for Shot Firers/Blasters meant for Lakhra Mine Development Project. All these personnel selected for the job would be recommended to be referred to the Board of Examiners of Sind Government for test and issue of statutory certificate of Shot Firing.

Mine Rescue Crewmen.

Establishment of a Mine Rescue & Safety Station near Lakhra would be very essential on account of the fact that the Lakhra Mine Development Project is going to produce 4.3 mt. of coal annually with an employment of 2148 personnel. The project shall be producing 4 mt. of coal from the surface mines while 0.3 mt. shall be produced from the underground mines. Heavy machinery shall be deployed at the surface mines and similarly underground mining operations shall be mechanised to their maximum extent. 516 personnel shall be engaged for underground operations while 1,012 shall be engaged on the surface mines. To deal with the mine accidents of Lakhra Mine Development Project and other private sector mines it is imperative to have a Mine Rescue and Safety Station either established by the Lakhra Mine Development Project itself or by the Govt. of Sind at Lakhra. The establishment of such a Rescue Station is inevitable keeping in view the quantum of work to be carried out at the mines and also the type of hazards anticipated during mining. The Rescue Station is supposed to function on the international standards with a round the clock service. Rescue Brigades shall all the time be available at the Rescue Station awaiting calls of accidents from the coal mines of the area.

The Rescue Crewman is a specially trained person on breathing apparatus. Trained and experienced crewmen are not available in the country, because it is only very recently that Mines Rescue Safety Service has been introduced in the Provinces of Punjab & Baluchistan by establishing one Mine Rescue & Safety Station at Khushab (Punjab) and the other at Sinjidi(Baluchistan) near Quetta.

Besides above, two Sub-Stations are being established in Punjab one at Makerwal(Mianwali, Punjab) and the other at Choa Saidan Shah (Chakwal, Punjab). The Government of Baluchsitan have established two Sub-Stations, one at Duki and the other at Narwar.

Under the circumstances it would be the need of the time that specially selected personnel having underground experience, physically and medically fit to work as Rescue Crewmen should be got trained at the already established Mines Rescue Stations in the country by arranging special courses for Lakhra Mine Development Project.

Mine Ventilation Assistant.

The underground mining operations shall require middle line supervisors who are experienced and trained to work as Mine Ventilation Assistants. The type and size of underground mine being planned by Lakhra Mine Development Project is non-existant in Pakistan. These personnel shall have to be selected out of those persons who are already engaged in the Coal Mining Industry of Pakistan. Their further polishing by Lakhra Coalmining Project would be considered essential. Short courses of 4-6 weeks is considered adequate to train a team of Mine Ventilation Assistants.

Mine Sample Collectors.

At the moment there is no agency in the country which collects samples from the mines except the Mine Sample Testing Laboratory Khushab (Punjab) under the Inspectorate of Mines, Punjab. The Laboratory has been established very recently. The Lakhra Mine Development Project may recruit personnel of middle line supervisory level having underground experience in coal mines. These selected persons can initially be got trained at the Mine Sample Testing Laboratory, Khushab. Concurrently a small Testing Laboratory shall have to be established near the project to constantly monitor the underground operations by collecting samples of dust and gas and by testing them for the prevention of hazards and occupational diseases.

SPLITTING OF MANPOWER FOR TRAINING PURPOSES.

The manpower required at the Lakhra Mine Development Project can be bifurcated into the following broad categories:-

I. Engineers, Managers, Officers;
II. Sub-Engineers, Foremen, Supervisors, Section Incharge;
III. Technicians, Skilled Trademen, Craftsman.

ENGINEERS, MANAGERS, OFFICERS;

The personnel who deal with the planning of the operations are the Engineers, Managers and Officers. There will be no visible dearth of Mining, Electrical, Mechanical, Chemical Engineers, Geologists and Officers. (Annexure-VIII). Fresh graduate engineers from Universities can be recruited while experienced engineers already serving in other country projects can be attracted through attractive terms of employment. Professional Managers, Geologists and Officers experienced in their trades of Accounts and Administrative matters can be engaged through attractive terms. After engagement of top brass of the project, short term courses can be got arranged through NIPA, PIPA, WPIM & WAPDA specially for the employees of Lakhra Mine Development Project. Alternatively Engineers, Managers and Officers can be nominated in batches to attend regular courses of these Management Institutes just to fresh their managerial and engineering skills.

SUB-ENGINEERS, FOREMEN, SUPERVISORS, SECTION INCHARGE.

These are the middle line personnel and a very vital link in the management herrarchy. Normally a group of 8 to 10 workers is supervised ideally by a qualified and experienced Foreman/Supervisor. The types of Middle Line Supervisors needed have been enlisted as below:-

i) Mining Sirdar/Foreman,
ii) Electrical Foreman

iii) Mechanical Foreman
iv) Civil Overseer
v) Chemical Foreman.
vi) Industrial Foreman.
vii) Accounts Assistant.
vii) Labour & Legal Assistants
ix) Administration & Management Assistants etc. etc.

The engineering skills are taught at the polytechnics with 3 years course under the Education Departments of the Provincial Governments. Except for Mining Engineering skills other disciplines are on the regular curricula of the Polytechnics.

Lakhra Mine Development Project is a project of the Federal Government and being implemented with the help of WAPDA. P.M.D.C. and the Private Sector. also with the active financial assistance of USAID, World Bank, Asian Development Bank etc. As this project shall be located in Lakhra (Sind), it would be obligatory on the part of the Government of Sind to assist the project in respect of provision of its infrastructure facilities. The major field in which the Provincial Govt. can contribute is the availability of trained manpower for the various aspects of coal mining. Where ever the Provincial Govt. shall be lacking, trained manpower from other Provinces shall have to be encouraged.

MINING POLYTECHNIC SIND.

In any case the Government of Sind has to expedite the establishment of their approved project titled "Mine Polytechnic and Polytrade Training Institute, Khanote". This Polytechnic when ready shall be turning out the trained skilled men in the disciplines of :-

1. Mining Technology (3 years course).
2. Shot Firer (1 year course).
3. Metal Mining Proficiency(1 year course).
4. Ventilation (1 year course);
5. Timberman (6 months course);
6. Mine Haulage
7. Mine Mechanic;
8. Mine Electrician.

EDUCATION DEPARTMENT AND DIRECTORATE OF MANPOWER AND TRAINING SIND.

The Education Department, Government of Sind runs Government Polytechnics/Technical Colleges with 3 year's Diploma Courses in electrical and mechanical trades etc. Likewise Directorate of Manpower and Training Sind runs training centres and vocational institutes. The graduates from these institutes are the suitable persons to be engaged on various jobs to work as Middle line Supervisors. Annexure IX&X give the details of such institutions in the province of Sind including their seating capacity and the trades, alongwith other centres in Pakistan.

MANPOWER BY PUNJAB GOVERNMENT.

The Government of Punjab under the Directorate of Technical Education is managing Government Colleges of Technology and Polytechnic Institutes wherein Electrical, Mechanical Engineering trades are being taught on a 3 years regular course basis. During evening technical extension programmes of different durations are taught. The morning courses produce middle line supervisors while the evening extension programme produce skilled manpower which is in fact the base of the related industries. Various training courses being taught at the Government Colleges of Technology/Polytechnics in Punjab are exhibited at Annexure XI

AGENCY FOR BARANI AREAS DEVELOPMENT (ABAD) (PUNJAB).

This agency has established training institutes of certificate level at all the district levels The skills taught are listed hereunder:-

TABLE 5.

Trade Training Course Provided by the Agency for Areas Development.

Sr. No.	Trade	Seating Capacity	Course Duration (Months)	Minimum Entrance Qualification.
1.	Auto Farm Machinery.	128	12	No minimum qualification has been fixed. However preference is given to literate persons.
2.	Machine Shop	128	12	
3.	Wood Working.	128	12	
4.	Welding	128	6	
5	Electricity	128	6	
6.	Tailoring	128	6	
7.	Masonry/Radio Mechanics/Motor Winding.	128	6	
8.	Buldozer Operator.	30	5	
9	Buldozer Mech	20	12	
	Total	946		

COOPERATIVE DEPARTMENT, PUNJAB.

The Provincial Cooperative Department is running an institute at Chak No.5 Fatz, Multan primarily for assistance in the Agricultural field. The out-turn of trained manpower in different trades is given hereunder at Table-6.

TABLE-6.

Training Courses Provided by Pakistan German institute of Cooperative Agriculture, Multan.

Sr. No.	Trade	Seating Capacity	Course Duration (Months)	Minimum Entrance Qualification
1.	Tractor and Auto Mechanic.	25	24	Matric
2.	Carpenter.	15	24	Middle Pass Matric preferable
3.	Tractor Operator.	80	6	Middle Pass. Matric preferable.
	Total:	120		

A cursory look on the trades being taught at different institutes reveal that these trades are very much relevant to the Lakhra Mine Development Project. In other words no special training schools or centres are to be established for the project in question

TECHNICIANS, SKILLED TRADEMEN & CRAFTSMEN.

This deals with trained manpower which is the base of every industry . The Provincial Governments have launched exhaustive programmes for the training of skilled and semi skilled manpower in the respective provinces. The Directorate of Manpower and Training in Punjab is responsible for the management and administration of Technical Training Centres having the seating capacity of 4,044 and impart training in 26 trades grouped under mechanical, electrical, auto and construction trades. There are three Apprenticeship Training Centres and 13 Vocational Institutes having seating capacity of 620 and 2,786 respectively

TRAINING CENTRE & TRAINING MINES CHOA SAIDAN SHAH

The Government of Punjab has also established a Training Centre and a Training Mine for Mine Supervisors and Mining Technicians at Choa Saidan Shah, District Chakwal. A three years course is planned for the matriculates in the following disciplines:

- Coal Cutting
- Timbering
- Blasting/ShotFiring/Use of Explosives
- Mine Electrical Technicians.
- Mine Ventilation
  Labour Management & Mine Legislation
  Mine Mechanical Technician.

The first batch of 40 students is scheduled to be admitted on 1.9.1986. Besides above different classes of 40 more shall be imparted training through short courses during each year. These short courses shall be in different disciplines and the duration shall be 3-4 months.

MANPOWER BY NWFP GOVERNMENT.

The Directorate of Technical Education, NWFP has established 44 institutions in all and 8 Vocational Institutes are under construction and will be ready shortly. Six Polytechnic Institutes, one each at Peshawar, Haripur, D.I. Khan, Nowshera & Swat for males and one at Peshawar for women. These institutions offer 3 years diploma courses in mechanical, radio electronics, Civil, Electrical, Chemical and Auto Technologies. The seating capacity of these polytechnics is 2,170.

The Directorate of Labour Welfare, NWFP is responsible for the manpower training in various disciplines such as Electrician, Mechanical, Auto Diesel Mechanic etc. Apprenticeship Training programmes are in addition to the Technical Training Centre programmes. Total distribution of seating capacity is enlisted as under:-

TABLE-7.

Tradewise Training Facilities in NWFP in Training Centres under Provincial Labour Department.

Sr. No.	Name of Trade	Seating Capacity TTCs	ATCs	Total
1.	Draughtsman,Mechanical.	58	-	58
2.	Draughtsman, Civil Engineering.	10	-	10
3.	Electrician.	113	-	113
4.	Radio Mechanic.	24	-	24

5.	Television Mechanic.	10	-	10
6.	Machine Shop Worker/ Turner. Machinist.	125	20	145
7.	Bench Fitter. Millwright Fitter.	10	15	25
8.	*Air-conditioning/ Refrigeration Mechanic.	15	.	15
9.	Auto Mechanic.	103		103
10.	Farm Machinery Mechanic.		20	20
11.	Textile Machinery Mechanic.		15	15
12.	Welder/Plumber/Sheet Metal Worker.	83	20	103
13.	Pipe/Sanitary Fitter.	20		20
14.	Foundry Worker.	24		24
15.	CAbinet/Pattern Maker. Carpenter.	75	20	95
16.	Mason , Brick Layer.	20	.	20
17.	Tailor, Garment Maker.	20	.	20
	Total:	710	110	820

MANPOWER PROGRAMME BY FEDERAL GOVERNMENT.

From the perusal of the training programmes pursued by the different pro incial Govt; Governments; it is revealed that the trades being taught at the Technical Training Centres, Vocational Institutes , Polytechnics and colleges of Engineering are relevant to the requirements of Lakhra Mine Development Project.

It is understood that 70% of the success ful students find jobs with n 6 months of their passing out while the balance 30% seek jobs either within a span of 1 year, or proceed to Middle East. In other words 30% skilled manpower without jobs shall be available for engagement at the Lakhra Mine Development Project.

In order to promote vocational/technical training facilities in various fields, an Ordinance namely; "National Training Ordinance. 1980" was promulgated by the President of Pakistan. Under this Ordinance National Training Board as well as Provincial Training Boards have been constituted at the Federal and Provincial level respectively. It is imperative for the National as well as Provincial Training Boards to prepare annual training plans.

Currently various technical training programmes are under implementation in the country for the supply of skilled and semi skilled manpower to the industries in Pakistan as well as in Middle East. The programmes are as under

1. National Vocational Training System.
2. Other Public Agencies.
3. Private Institutions.
4. Apprenticeship Programme.
5. Informal Systems.
6. Returning Migrants.

Although these programmes do not include the different specialised trades of mining even then these programmes are helpful for Lakhra Mine Development Project for all skills other than mining. In order to make these programmes more useful towards the mining industry of the country in general and Lakhra Mine Development Project in particular the mining skills can be got introduced if not in all technical training centres of the country, at least for the Technical Training Centres and Vocational Institutes located in Distt. Dadu, near Lakhra (Sind). It is for the sponsors and the Sind Government or the Federal Government to look into this aspect seriously and that too immediately.

The Table below gives the statistics of out turn of the above mentioned training schemes:

TABLE VIII.

Supply of skilled and semi skilled Manpower 1984 & 1995

Source	1984		
	Skilled Mannower	Semi skilled Manpower	Total
National Vocational Training System.	3.100	3.320	4.500
Other Public Agencies.	7.410	111.440	117.650
Private Institutions.		20.000	20.000
Apprenticeship Programme.	1.110	.	1.100
Informal System.	3.000	7.600	10.500
Returning Migrants	9.310	10.380	19.890
Total (1984).	24.010	151.940	175.950

TABLE VIII (Contd).

Source	1995		
	Skilled Manpower	Semi skilled Manpower	Total
National Vocational Training System.	7,740	11,640	19,400
Other Public Agencies.[1]	8,500	116,230	124,130
Private Institutions.[2]	.	30,000	10,000
Apprenticeship Programme.	2,700		2,700
Informal System.[3]	4,000	11,000	15,000
Returning Migrance.[4]	14,240	11,390	26,110
Total (1995).	37,200	180,760	217,960

Source: Provincial Training Boards. ARTEP (1984) Report. NTB and Boards of Technical EDucation.

1. These include the various Provincial Departments of Social Welfare, Education, Technical Education, Rural Development and Local Government, dealth, the Provincial small Industries Corporations/Boards, and the Overseas Pakistanis Foundation.

2. Based on information gathered from the Boards of Technical Education (Sind and Punjab).

3. Based on information gathered from the NTB and the Provincial Training Boards.

4. Based on Survey by the Overseas Pakistanis Foundation in 1980 which reports that over 60% of returning migrants interviewed upon return intended to move into business and trading activities and about 15% wanted to go into the agricultural sector. Since 78.99% of those returning are production workers, these results show that most returnees rather than go back to their original skills would rather go elsewhere. Results of a PID study show that 23.1% of skilled and semi-skilled returnees do the jobs commensurate with their skills classification while 13.8% are still looking for the job. In Turn, 60% & the 13.8% are still lacking for work which can offer higher wages. For our purposes, therefore, we take 23.1% as the percentage of returning skilled and semi-skilled workers who do skilled and semi-skilled jobs.

EMIGRATION OF SKILLED WORKERS FROM PAKISTAN FROM 1971 TO 1984.

Name of Occupation	Emigration from 1971-82	1983	1984	Total
Welders.	11184	2145	1163	14492
Mason.	58571	1116	7389	87076
Carpenters.	63580	7783	4621	75984
Electricians.	29637	4428	3162	37227
Plumbers.	12281	2102	1478	15861
Steel Fixer.	30278	4576	3379	38233
Painters.	15332	2862	1837	20031
Mechanics.	28771	3319	2467	34557
Cable Jointers.	2111	212	194	2517
Operators.	13431	1501	1200	16132
Fitters.	29550	794	992	31336
Total:	314726	30838	27882	373446

Currently the Coal Mining Industry of Pakistan is employing 40,000 workers to produce 2.00 mt. approximately annually. The number of coal mines is 1600 approximately ranging from 5 tonnes/day production to 500 tonnes/day. More than 80% of the coal mines are in the private sector which are responsible for nearly 90% of the coal production. Most of the mining industry is non mechanised and the demand of trained skilled men have never come from the mining industry. Therefore, no special effort had been made in the past for developing mining skills except one centre recently established by the Government of Punjab at Chua Saidan Shah Distt; Chakwal.

According to a survey carried out by the study group of the Government to assess the requirements of the trained manpower for the mining industry during the sixth 5 year plan (1983-88), it was revealed that 108 new mining projects shall be established besides grant of 1170 new mining leases. The requirement of various categories of trained manpower are truly reflected in Annexure-XII. Against a demand of 303 Mining Engineers during the plan period an estimated out turn of graduate Mining Engineers stand at 425.

In other words 122 Mining Engineers shall be in excess to the actual requirements. If we account for the retirements rate and exodus of Engineers to Middle East and other countries, and employment by the private sector, then there shall be a very nominal number of graduate Mining Engineers who would be on the surplus list. Besides above the other demanding skills are Geologists, para Geologists, other Engineering Technicians and para mining Engineering skills.

TOP MANAGEMENT.

In the foregoing explanations it has been made clear that trained manpower of the top level management shall be readily available for the Lakhra Mine Development Project.

MIDDLE LINE SUPERVISORS.

Middle line supervisors level, personnel of all trades except mining are readily available on account of their regular 3 years courses being conducted at the Government Engineering colleges/Polytechnics. Inclusion of mining disciplines in the Government Polytechnic Institutes/Colleges of Technology at Sukkur and Hyderabad Sind shall be of immediate helpt to Lakhra Mining Development Project. Meanwhile the Mining Polytechnic at Khanote and the Training Centre and Training Mine at Choa Saidan Shah, Distt; Chakwal. Mine Survey Institute Makerwal shall be able to meet the future requirements of the Lakhra Mine Development Project.

SKILLED AND SEMI SKILLED MANPOWER.

The skilled manpower, which is trained through the net-work of Technical Training Centres and Vocational Training Institutes and Apprenticeship Training Institutes in the country shall be adequately available in all trades for engagement at the Lakhra Mine Development Project. Annexure- IX & X give the data of TTC, ATC AND VTI in the country alongwith their trades and seating capacity . A look on the Annexures exhibiting the technical training centres and the vocational institutes in Pakistan gives the annual turnout of 7247 and 3304 respectively of trained skilled workmen of different disciplines. There is hardly any trade except for mining whose skilled workers needed at the Lakhra Mine Development Project is not available in these training centres/institutes.

The tradesmen would prefer to change jobs on better terms of employment hence there will not be any visible shortage of manpower to Lakhra Mine Development Project. A separate programme under the National Training Board is therefore recommended to be formulated during the construction phase of the Lakhra Mine Development Project to meet shortfall if any.

To meet the deficiency of para mining Engineering skills, the Inspectorate of Mines, Punjab has started short courses in these skills and have been successful in imparting training to 243 Shot Firers, 49 Ventilation Assistants, 48 Timbermen, 395 First Aiders and 267 Mine Sirdars during the first half of the sixth five year plan. (1983-84. 1984-85. 1985-86).

The annual turn out of various skilled workmen of mining from different agencies/ Institutes is exhibited at Annexure -XIII

APPRENTICESHIP PROGRAMME.

Apprenticeship Training Ordinance requires of every industry upon which the provisions of the Ordinance have been made applicable. to recruit and train 20% of the strength of each category of employees. Keeping in view the volume of manpower required in the Lakhra Mine Development Project the provisions of the Ordinance are recommended to be extended to Lakhra Mine Development Project. This will facilitate the Lakhra Mine Development Project to have trained and skilled manpower all the time available with it.

The conspicuous trades of mining in which skilled workers shall be required are enlisted as under:-

1. Mechanical Coal Cutter.
2. Manual Coal Cutter.
3. Shearer Operator.
4. Longwall Coal Operator.
5. Roof Bolter.
6. Timberman.
7. Track Layer.
8. Ventilation Assistant.

9. Conveyor Belt Operator.
10. Rescue Crewman.
11. Electrician.
12. Dust Sample Collector.
13. Backhoe Operator.
14. Dozer Operator.
15. Safety Supervisor.
16. Dragline Operator.
17. Shovel Operator.
18. Truck Drivers.
19. Shot Firer/Blasters.
20. Mine Surveyor.

RECOMMENDATIONS.

In conclusion the strategy designed for the development of manpower says that:-

1) There will be no specific effort required in training the engineers of different disciplines. They will be available as the out turn from the Technical Universities is encouraging. Specialized courses can be organized of specified duration with the collaboration of Training Institutes of higher learning for management and Administrative skills.

2. The operations as planned at the surface and underground mines are comparatively of a larger volume as compared with the mining operations of the existing coal mines in Pakistan. The staff responsible for these operations should enjoy the designations which do not conform with the nature of jobs/ otherwise are likely to be viewed with disinterest and the management may find difficulty in engaging competent and experienced staff to get them attracted for employment in Lakhra Mine Development Project.

The designation of Foreman has been used for very important positions in the hierarchy of the management at the surface and underground mines. As a solution to this problem, it is proposed that instead of using the word Foreman, the nomenclature of Manager or Superintendent may be used in preference to Foreman. The name of Foreman in Pakistan is considered to be incharge of a group of 8-10 workers and that too semi-literate. Under the circumstances and keeping in view the volume of work involved and the extent of the project, the designation of Foreman is recommended to be replaced with some prestigious designation.

By changing this designation, it shall be possible to engage Engineers on these jobs who would be too willing to accept such responsible assignments.

3) Availability of middle line supervisors of all disciplines except mining is assured through the Government Technical Colleges/Polytechnics. Early completion of Mining Polytechnic Khanote (Sind) and Training Centre & Training Mine.Choa Saidan Shah (Punjab) and Mine Survey Institute (Makerwal) is recommended.

Regular conduct of Examinations by the Board of Examiners under the Mines Act by the Provincial Governments are necessary, so that Mining Sirdars, Shot Firers, 2nd Class & 1st Class Mine Managers and Mine Surveyors are available in the field.

4) For the training of skilled manpower in disciplines of mining, the platform of NTB must be utilized by organising training courses at the Technical Training Centres Vocational Training Institutes, and Apprenticeship Training Centre at Sukkur, Hyderabad, Kotri (Sind) in collaboration with WAPDA.

5) The Apprenticeship Training Ordinance be made applicable on the operations of Lakhra Mine Development Project. This will facilitate continued supply of skilled manpower of all categories during construction phase as well as development phase.

6. Literate persons/Sirdars are recommended to be recruited and specially trained through short courses to make them competent enough to supervise the underground and surface mechanized operations. Such training is recommended to be arranged at the Training Centre and Training Mine, Choa Saidan Shah and Mining Polytechnic, Khanote (Sind).

7. Coal Cutters with underground experience are recommended to be engaged on regular basis and imparted training on the machines to be used at the surface and underground coal cutting operations. Recruitment of coal cutters through Jersars/Mates shall have to be dispensed with.

8. The Chief Inspectors of Mines of all the Provinces should arrange Shot Firer's Examinations on regular basis and may grant certificates of competency in Shot Firing to the successful candidates.

9. The Government of Sind should expedite the establishment of Mines Rescue & Safety Station near Lakhra so that the rescue service is available to the workers engaged at Lakhra Mine Development Project.

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ANNEXURE - I.

DISCIPLINEWISE DISTRIBUTION OF TRAINED PERSONNEL FOR THE SURFACE MINE (WP) DURING DEVELOPING PHASE.

i) GENERAL SUPERVISORY OFFICE.

Civil	Mechanical	Electrical	Mining	Misc. Skilled	Misc.Semi-Skilled.
2 Road Maintenance Foreman.	2 Maintenance Supervisors.		1 Deputy Manager.		2- Warehouse clerks.
1 Reclamation F/m.	2 Welding F/m.		1 Chief Mining Engineer		2- Secretaries.
2 Field Maintenance Foreman.	3 Shot F/m.		2 Assistant Mining Engr.		
	3 Warehouse		1 Geologist		
			3 Shift F/m.		
			4 Stripped		
			1 Bank shooting F/m.		
			2 Lignite Load Haul F/m.		

ii) OVERBURDEN DRILLING AND BLASTING.

	6 Maintenance Mech.	3 Maintenance Electrical.	3 Drillers.	1- Dozer Operator.	3- Drillers Helpers.
			1- Shot Loader.		
			1- Asstt. Shot Loader.		
			1- Shot Firer.		

iii) INTERBURDEN DRILLING AND BLASTING.

	1 Maintenance Mechanical.		1- Driller.	1-Dozer Operator.	1- Driller Helper.
				1-Maintenance Misc.	

iv) OVERBURDEN REMOVAL SHOVEL/TRUCK.

	2 Shovel Operators.			14-Truck Drivers.	
	2 Shovel Oilers.			2 Dozer Operators.	
	14-Maintenance Mechanical.	6-Maintenance Electrical.		1-Grader Operators.	
				4-Water Tank Drivers.	
				4-Maintenance Misc.	

(Contd). ANNEXURE-I.

v) OVERBURDEN REMOVAL - DRAGLINE.

Civil	Mechanical	Electrical	Mining	Misc. Skilled	Misc. Semi-skilled
	4-Dragline Operator.	-	-	4-Dozer Operator.	-
	4- Dragline Operator.	-	-	-	-
	4-Dragline Groundman.	-	-	-	-
	12-Maintenance Mech.	6-Maintenance Elec.	-	3-Maintenance Misc.	

vi) INTERBURDEN & LIGNITE LOADING.

	2-Maintenance Mech.	2-Maintenance Elec.	-	2-Dozer Operator	
				2-Backhoe/FEL Operators.	
				2-Maintenance Misc.	

vii) LIGNITE HAULAGE AND ROADS.

	=	=	=	8-Truck Drivers.	
				2-Grader Operator.	
				2-Scraper Operator.	
				2-Dozer Operators.	
				2-Front End Loader Operators.	
				2-Dump Truck Operators.	
				2-Water Tank Driver.	
	3-Maintenance Mech.			1-Crusher Operator	
				2-Maintenance Misc.	

viii) RECLAMATION AND DRAINAGE.

-			-		
				3-Scraper Operator.	
				1-Grader Operator.	
				3-Dozer Operator.	
				1-Backhoe Operator.	
	3- Maintenance Mech.			2 Maintenance Misc.	

ix) MISCELLANEOUS MINE SERVICES.

				1-Backhoe Operator.	
		5 Power Distribution Maintenance.	1-Exploration Drill Operator.	6-Pumpmen.	
				6-Utility men.	
					1-Exploration DRill Operator Helper.
			13 Misc. Un-assigned people.	8 Service/Lub Truck Driver.	
				6 Mech/Welding Truck Driver.	
				6-Fuel Truck Driver.	
				6-Service Supply TruckDriver.	
5	67	22	34	116	9

ANNEXURE - II.

STATEMENT OF THE MAJOR DRILLING, STRIPPING, LOADING, HAULING AND SERVICE EQUIPMENT TO BE DEPLOYED ON THE SURFACE MINE.

OVERBURDEN PREPARATION.

1. Overburden Drill BE-55R.
2. Interburden Drill BE-35R..
3. Rubber Tire Loader Cat. 980C. or equivalent (201 KW).
4. Powder Truck.
5. Supply Truck.

DRAGLINE STRIPPING.

1. Electric Walking Drgaline Model 1370 W or equivalalent delivered and erected with spare Bucket (4400 KW).
2. Buldozer. D-9 or equivalent (343 KW).
3. Water Truck (425 KW.).

SHOVEL / TRUCK STRIPPING.

1. Electric Shovel P&H 2300 or equivalent with 20 C.M. Bucket. Delivered and Erected.
2. End Dump Truck 136 Tonne Cap. (963 KW.).
3. Buldozer Cat. D 9 or equivalent (343 KW.).
4. Grader Cat. G 16 or equivalent (186 KW.).
5. Water Trucks (425 KW).

INTERBURDEN LIGNITE LOADING.

1. Backhoe O & K RH.20 or Equivalent DEL & Erected (870 K.W).
2. Buldozer Cat. D 9 or Equivalent (343 KW.).
3. Front End Loader Cat. 992 or equivalent (515 KW.).

LIGNITE HAULAGE AND ROADS.

1. End Dump Trucks 136 Tonne Cap. (963 KW.).
2. Grader Cat. G 16 or equivalent (186 KW.).
3. Scrapper Cat. 631 D or equivalent (336 KW.).
4. Water Trucks (425 KW.).
5. Buldozer CAt. D 9 or equivalent (343 KW.).
6. FRont End Loader Cat. 988 or equivalent (280 kw).

MINE POWER DISTRIBUTION

1. Main Mine Substation 132 KV 11KV (30MKV).
2. Surface Facilities Transformer 11KV 440 V.
3. Pit Substation SKID MTD. for Dragline 11KV 7.2 KV.
4. Pit Substation SKID MTD. for shovel 11KV-6.9 KV.
5. Two Load 8 KV Breaker House.
6. Cable Connectors.
7. Cable Tools.
8. Dragline CAble (11 KV).
9. Shovel CAble (8KV).
10. Miscellaneous Connectors/Switches etc.

RECLAMATION AND DRAINAGE.

1. Scraper cat. 631-D or equivalent (336 k.w.).
2. Grader CAt. G-16 or equivalent (186 kw.).
3. Buldozer Cat. D-9 or equivalent (343 k.w.).
4. Utility Backhoe 2 C.M. (101 K.W).
5. Water Truck (425 KW).

GENERAL PURPOSE EQUIPMENT.

1. Mobile Crane 100 Ton. cap. (416 k.w.)
2. Mobile Crane 40 Ton Cap. 183 K.W.).
3. Lowbed end Tractor (KW).
4. Forklift (KW.).
5. Tire Forklift (K.W).
6. Fuel Trucks 6000L . Cap. (140 KW).
7. Service/Lube Trucks (140 KW.).
8. Welding/Mechanical Trucks (140 KW).
9. Utility Dump Trucks (336 K.W).
10. Electrician s Truck (140 KW.).
11. Geophysical Logging Truck (149 KW.).
12. Supply Trucks 5 Ton Cap. (65 K.W).
13. Portable Air Compressor.
14. Pickup Trucks (50 K.W).
15. Supervisor s Vehicles (58 KW.).
16. Surveyor Vehicle (108 KW.).
17. Exploration Core Drill (362 KW).
18. Tow Truck (140 KW).
19. Light Plants (8 KW.).
20. Ambulance (55 KW.).
21. First Aid/Safety EQuipment.
22. Fire Truck (140 K.W).
23. Communication Equipment.
24. Road Compactor (231 K.W).
25. Engineering EQuipment.
26. Personnel Busses (140 K.W).
27. Lignite Laboratory and equipment.

ANNEXURE III.

STATEMENT OF ESTIMATED NUMBER OF TRAINED MANPOWER REQUIRED AT THE SURFACE MINE DURING DEVELOPING PHASE.

		Westren Pit	Eastren Pit	Total
1.	Drillers.	5	5	10
2.	Driller Helpers.	5	5	10
3.	Shot Loader.	1	1	2
4.	Assistant Shot Loader.	1	1	2
5.	Shot Firer.	1	1	2
6.	Dozer Operator.	15	15	30
7.	Maintenance Mechanical.	58	58	116
8.	Maintenance Electrical.	18	18	36
9.	Maintenance Misc.	18	18	36
10.	Shovel Operator.	2	2	4
11.	Shovel Oiler.	2	2	4
12.	Truck Driver.	48	48	96
13.	Grader Operator.	4	4	8
14.	Water Tank Driver.	6	6	12
15.	Dragline Operator.	4	4	8
16.	Dragline Oiler.	4	4	8
17.	Dragline Groundman.	4	4	8
18.	Backhoe/FEL Operator.	4	4	8
19.	Scraper Operator.	8	8	16
20.	Front End Operator.	2	2	4
21.	Dump Truck Driver.	2	2	4
22.	Crusher Operator.	1	1	2
23.	Pumpmen.	6	6	12
24.	Utility Men.	6	6	12
25.	Power Distribution Maintenance.	5	5	10
26.	Misc. Unassigned People.	13	13	26.

ANNEXURE-IV.

DISCIPLINEWISE DISTRIBUTION OF TRAINED PERSONNEL FOR UNDERGROUND MINE DURING DEVELOPING PHASE.

Mining	Mechanical	Electrical	Misc. Skilled	Misc. Semi-skilled.
i) Administration.				
1 Mine Superintendent.				2-Office Clerks.
1 General Mine Foreman.				
II) Mine Supervisor.				
3 Shift Foreman.	1 Belt Move Foreman.			
30 Section Foreman.	3 Maintenance Foreman.			
2 Mine Inspector.				
3 General I/s F/m.				
iii) General Outside.				
	5 Diesel Vehicle Repair man shop.		1 Transport Driver.	6-PickingT Table workers.
			1 Blacksmith.	1-General Labour.
			3 Lamp man and Bath house.	
iv) General Inside.				
	3-Mechanics.		3-Mechanics Helper.	9-Utility.
	1 Belt Repairman.		1 Conveyor Belt Repairman helper.	
			6-Brattice & overcast construction.	
7-Roof Support.	3 Ploeman.		21-Conveyor Belt cleaner & Petrol.	
6-Supply men & Rock Duster.	4-Conveyor Belt mover.			
	3 Buffourmen.		1-Roadway Maintenance.	
v) General Inside.				
27 Roof Support.	63-Loaders.			
27-Coal Cutters.	9- Boom Operators.			
12 Scooptrain Loader Operators.				
63-Roof Support.				
63-Coal Cutters.				

ANNEXURE - V.

STATEMENT OF MAJOR MINING EQUIPMENT TO BE USED IN THE UNDERGROUND MINE OF LAKHRA MINE DEVELOPMENT PROJECT

GENRAL SURFACE FACILITIES.

2- 4-wheel drive vehicles for supervisory use.

2- Pickup trucks. 4-wheel drive.

1- Flatbed truck.

1- Auxiliary Diesel generator. 1000 kw.

MINE PORTALS.

1- Mine Incline. 668 m. length. 4.27 m. width. 4.27 m. height. complete. w/belt conveyor.

2- Ventilation fans. exhaust type. 1.83 m. diameter. 150 kw. motor.

MINE POWER.

1- Mine distribution panel w/4 circuit bar. 11 kv.

1- Lot surface high voltage distribution cable. 3000m.. 11kv.

1- Lot underground high voltage distribution cable 7600 m.. 8 kv.

1- Lot high voltage i distribution cable. 2700 m. 8 kv. 3 cond.

14-Switchhouses. single vacuum breaker. w/relays and feed through.

3- Ongwall conveyor power centres. 30 kva.

8- Belt power centers. 100 kva.

6- Belt power centers. 50 kva.

2- Transformers. 200 kva. 11 kv/2300 v.. for mine fan.

1- Transformer. 750 kva.. 11 kv/440 for offices shop. warehouse and bathhouses.

1- Transformer. 500 kva. 11 kv/440 v. for incline belt.

1- Transformer. 150 kva. 11 kv/440 v.. for picking belt and crusher.

WATER SUPPLY AND TREATMENT.

1- Lot 500 m.. 100 mm. raw water line including excavation. valves bedding. and installation.

1- Lot 500 m.. 75 mm. potable water line including excavation. valves. bedding. and installation.

1- Sewage system. w/septic tanks and sewage pits.

OUTSIDE LIGNITE HANDLING FACILITIES.

1- Portable crushing plant. 400 tph capacity w/hopper. feeder. picking belt. screen. roll crusher. on rubber tire trailer.

1- Radial stacker. 107 cm x 38m. w/adjustable boom and motorized carriage.

1- Refuse truck. 10 tonne capacity.

MINE HAULAGE AND SERVICES.

3- Diesel tractors for transporting supplies.

6- Diesel scooptrains. 2.5 cu. m capacity.

1- Road a maintenance machine.

6- Diesel Personnel Vehicles 6 passengers rubber tired.

5- Diesel personnel carriers. 24 passenger. rubber-tired.

6- 914 mm belt conveyors. w/head and tail sections. drives. motors. starters 3600 m. conveyor belt 7200 m structure. 37 kw drives.

8- 914 mm belt conveyor. w/head and tail sections drives motors. starter 5600 m conveyor belt. 11.200 m structure. 75 kw drives.

6- 6.4 cu. m/min. electric air compressor 6.900 kpa.

4- 10.3 cu. m/min. electric air compressor 6.900 kpa

1- Lot 7600 m. fresh water pipe. 75 mm diameter w/hydrants.

FACE EQUIPMENT.

50 Pneumatic picks with lines couplers. and tools.

4 Longwall conveyors 60 tph 11 kw motor. starter

1 Lot 500 hydraulic props w/link bars feed system. and power pack.

MISCELLANEOUS UNDERGROUND EQUIPMENT.

2 Welding sets w/ tools

3 Auxiliary face fans 5000 cfm.

1 Lot ventilation tubing 450 m.

3 Pnuematic drills w/accessories.

1 Set bulk rock dusting equipment rubber tired.

1 Lot winches and miscellaneous tools.

SAFETY EQUIPMENT.

1 Lot First Aid equipment.

1 Lot 550 mining helmets safety toe shoes. and mining belts.

1- Lot 550 electric cap lamps with charging racks.

40- Flame Safety Lamps.

15 Anemometers.

1- Lot 550 personal self rescuers.

1- Lot breathing apparatus and gas masks.

MISCELLANEOUS.

Spare Parts and supply inventory.

ANNEXURE- VI.

STATEMENT OF PERSONNEL CONNECTED WITH COMMON FACILITIES AT LAKHRA MINE DEVELOPMENT PROJECT.

LMDC GENERAL ADMINISTRATION.

Staff:	Number Required
Genral Manager	1
Chief Engineer	1
Mining Engineer - Surface Mine	1
Mining Engineer - Underground Mine.	1
Electrical Engineer.	1
Industrial Engineer	1
Assistant Mining Engineer - (Surface Mine).	1
Assistant Mining Engineer - (Underground Mine).	1
Senior Geologist.	1
Financial Officer(Comptroller).	1
Deputy Comptroller	1
Chief Purchasing Agent.	1
Assistant Purchasing Agent.	2
Chief Training Officer.	1
Deputy Training Officer.	1
Training Instructor.	6
Chief Safety Officer.	1
Deputy Safety Officer.	1
Safety Inspector Surface	1
Safety Inspector Underground.	3
Director of Employment/Personnel	1
Chief Surveyor.	2
Survey Crew.	4
Draftsman.	2
Director of Building Maintenance	1
Janitorial Services.	20
First Aid Technicians.	3
Director of Security.	1
Clerical/Secretarial	10
Director of Transport Services.	1
Total:	68
Workers:	
Building Maintenance Crew.	3
Security Guards.	18
General Transport Operators.	15
Total:	36

COAL HANDLING AND RAILROAD LOADOUT.

Staff:	Number Required
Chief Lignite processing Officer.	1
Deputy Lignite Processing Officer.	1
Shift Foreman.	2
Lignite Quality/Haulage Coordinator.	1
Lignite Analytical Lab. Director.	1
Lignite Analytical Lab. Technician.	3
Total:	8
Workers:	
Stationery Equipment Operator - ROM	3
Stationery Equipment Operator (Radial Stackers).	3
Stationary Equipment Operator (Railroad Loadout).	2
Mobile Equipment Operator	3
Lignite Sampler	3
Maintenance Mechanical	2
Maintenance - Electrical	2
Maintenance Helpers	2
Laborers/Hand Pickers.	10
Total:	30

OPTIONAL PREPARATION PLANT FACILITIES.

Staff:	
Manager.	1
Shift Foreman.	6
Laboratory Supervisors.	1
Laboratory Technician.	1
Total:	10
Workers:	
ROM Operators.	6
Plant Operators.	4
Radial Stracker Operator.	5
Endloader Operator.	2
Buldozer Operator.	2
Refuse Truck Operator.	2
Loadout Operator.	3
Maintenance Mechanics.	12
Electricians.	2
Samplers.	4
Laborers.	15
Total:	57

ANNEXURE VII

STATEMENT OF PERSONNEL DIRECTLY AND INDIRECTLY CONNECTED WITH INFRASTRUCTURE FACILITIES AT LAKHRA MINE DEVELOPMENT PROJECT

INFRASTRUCTURE - PERSONNEL.

	Number Required
Chief Administrative Officer	1
Clerical/Secretarial.	3
	4

BUILDINGS AND GROUNDS:

Management:

Colony Superintendent.	1
Assistant Superintendent.	1
Foreman.	3
Chief Constable	1
Subtotal Management.	6

Labour:

Clerks.	3
Mason - Grade 1.	1
Mason - Grade 2	2
Mechanic-Grade 1.	1
Mechanic - Grade 2	2
Waste Disposal Collectors.	5
Waste Disposal Drivers.	3
Recreation and Civic Facilities	14
Equipment Operators.	1
Assistant Operators.	2
Constables.	19
Driver Light Truck.	2
Gardeners.	4
Helpers.	9
Bus Drivers.	5
Electrician - Grade-1	2
Electrician - Grade-2	3
Subtotal - Labour.	78
Total Buildings & Grounds.	84

WATER, ROADS, AND STREETS.

Management:

Foreman.	1

Labour:

Assistant Foreman.	4
Water Attendants.	10
Assistant Water Attendants.	8
Equipment Operator.	1
Assistant Operator.	1
Truck Driver.	3
Helpers.	6
Subtotal Labour.	33
Subtotal Water, Roads and Streets.	34

Schools:

Management:

School Superintendent.	1
School Principal	3
Sub total Management.	4

Labour:

Teachers.	25
Housekeeping	3
Clerk	1
Subtotal Labour.	29
Subtotal Schools.	33

Hospital:

Management:

Medical Doctor Chief of Staff.	1
Medical Doctor.	3
Subtotal - Management.	4

Labour:

Nurses.	18
General Technician.	2
Technicians.	1
Housekeeping.	9
Clerks.	2
Subtotal Labour:	32
Subtotal Hospital:	36

ANNUAL TURN OUT OF GRADUATE ENGINEERS (4 YEARS) OF VARIOUS DISCIPLINES FROM THE TECHNICAL UNIVERSITIES/COLLEGES OF PAKISTAN

ANNEXURE-VIII.

Sr. No.	Name of University	Civil	Electrical	Mechanical	Mining	Chemical	Industrial	Metallurgy	Petroleum	Electronic	Fuel	Computer	Archi-tecture
1.	University of Engineering and Technology. Lahore.	185	207	193	47	54	-	47	17	-	-	-	-
2.	Faculty of Chemical Engineering. University of Punjab. Lahore.	-	-	-	-	120	-	-	-	-	-	-	-
3.	N.W.F.P. University of Engineering & Technology Peshawar.	74	78	72	20	-	-	-	-	-	-	-	-
4.	N.E.D. University of Engineering & Technology Karachi.	212	141	211	-	-	-	-	-	-	-	70	-
5.	Dawood College of Engineering & Technology. Karachi.	-	-	-	-	76	20	30	-	210	-	-	40
6.	College of Engineering & Technology. Nawabshah.	78	81	74	-	-	-	-	-	-	-	-	-
7.	Mehran University of Engineering & Technology Jamshoro.	76	55	55	18	25	20	25	-	34	20	-	-
8.	College of Engineering and Technology Taxila.	76	70	69	-	-	-	-	-	-	-	-	-
	TOTAL :-	701	632	674	85	275	40	102	17	244	20	70	40

VOCATIONAL INSTITUTES IN PAKISTAN AND VARIOUS TRADES

ANNEXURE-IX.

Sr. No.	Name of the Institution	MACHINIST	BENCH FITTER	WELDING	SHEET METAL	AUTO MOTIVE MECH.	PLUMB & PIPE FITTER	CARPENTER	ELECTRIC WIRING	RADIO SERVICING	T.V. SERVICING	MASON/BRICKLAYER	RAC MECHANIC	TRACTOR MECHANIC	AUTO ELECTRICIAN	AUTO BODY REPAIR	TURNER	INSTRUMENT MECHANIC	MOTOR WINDING	ELECTRO PLATING	D/MAN MECH	D/MAN CIVIL	TAILORING	LEATHER WORK/WOOD	SURGICAL EQ. MECH.	TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1.	Punjab A.T.C. Kot Lakhpat Lhr.	16	48	12	-	12	12	-	24	12	-	-	12	-	-	-	12									160
2.	A.T.C. Sailkot NEW.	16	-	10	-	-	-	-	16								12			8				24	24	110
3.	T.T.C. Islamabad NEW	12	48	16	16	16	16	32									32									188
			50																							
4.	A.T.C. Faisalabad.	16		12		16		24									12									160
5.	A.T.C. Ferozewala	16	36	12		12		16							6		12									110
6.	A.T.C. Gujranwala	16	36	12		10		24									12									110
7.	G.V.I. Bahawalpur	16	16	12		-	16	12	32	16							12				12	16				160
8.	G.V.I. D.G. Khan	-	-	14		12	16		16	12																70
9.	G.V.I. Faisalabad	16	-	10					24	12							12				12	12				98
10.	G.V.I. Gujranwala	16	16	12					16	16							12		16		16					120
11.	G.V.I. Gujrat	16	16	12					26								12		12		16					110
12.	G.V.I. Jauharaba	-	12	12			12	12	24	14																86
13.	G.V.I. Jhang.	-	12	12	12	12		12	16	12					12						12					100
14.	G.V.I. Jhelum	16	32	8					24								10									90
15.	G.V.I. KHanewal	-	12	12			12	12	16	12							12									100
16.	G.V.I. Multan	16	24	8					24								10	8			12					90
17.	G.V.I. Sahiwal	-	12	-					16	16			14	14			12				12	16				100
18.	G.V.I. Sargodha	-	-	12			12		16	16			14									16				98
19.	G.V.I. Sheikhupura	-	16	12			16		16	16			-				12									100
20.	Sind A.T.C. Landi Karachi New	12	40	40	16	30	16	30	16	16			16				16					20				300
21.	T.T.C. Sukkur Extended		-	10	-		10	10	16	16		10	16	16												104
22.	A.T.C. Hyderabad		16	16	16								16	16		16	12									140
23.	T.T.C.(GVI) Karachi A.H			16		16		16	32	16							16									112
24.	NWFP A.T.C. Mardan New	12	16	16				16						16												92
25.	T.T.C. Khalabat	12	-	16		20	16		16			16											20			113
26.	T.T.C. D.I. Khan	20	16	16		16		20	16	16											16	20				156
27.	T.T.C. Mingora	-	16	16		16	16	16	16			16					16									128
																										3,304

ANNEXURE-X.

TECHNICAL TRAINING CENTRES IN PAKISTAN AND THEIR TRADES.

S.NO.	NAME OF THE INSTITUTION. / NUMBER OF PLACES PER TRADE PER CENTRE — TRADES	MACHINIST	BENCH FITTER	WELDING	SHEET METAL	AUTOMOTIVE MECH.	PLUMB & PIPE FITTING	ELECTRICAL WIRING	CARPENTER	ELECTRICIAN	RADIO/TV SERVICING	MASON/BRICKLAYER	RAC MECHANIC	AUTO/FARM MECHANIC	AUTO ELECTRICIAN	AUTO BODY REPAIR	TURNER	INSTRUMENT MECH.	ARMATURE WINDER	D/MAN MECH.	D/MAN CIVIL	TRACER	PAINTER	TAILORING	MOULDER	MILL WRIGHT FITTER	TRACTOR MECH.	TOTAL	TOOL KIT COST PER CENTRE
1.	T.T.C. LAHORE(GULBERG)	52	112	80	-	-	-	-	64	118	128	-	84	-	-	-	81	-	-	75			16	-		-	-	814	138276
2.	T.T.C. LAHORE (MUGHALPURA).	36	48	74	-	96	78	-	-	112	64	-	84	-	12	-	84	-	-	98	28	-	-	-	-	56	-	870	138868
3.	T.T.C. MULTAN	24	96	60	-	88	84	-	64	112	84	-	48	-	-	-	42	-	-	78	-	-	-	-			-	780	137832
4.	T.T.C. RAHIM YAR KHAN	20	96	60	-	-	72	-	-	112	32	-	20	84	-	-	62	-	-	84	-	-	-	-	-	-	-	638	100200
5.	T.T.C. GUJAR KHAN.	-	80	28	16	58	48	64	44	-	48	36	-	-	36	-	48	-	48	56	-	-	36	60	24	-	-	730	103540
6.	T.T.C. PESHAWAR.	40	40	39	-	78	39	-	55	78	49	-	30	-	-	-	40	-	-	78	-	-	-	-	-	-	-	566	96545
7.	T.T.C. KARACHI.	56	56	46	15	70	-	-	50	60	46	-	46	-	-	-	56	-	-	50	60	-	-	-	-	-	-	621	96828
8.	T.T.C. SUKKUR.	-	-	10	-	-	10	-	10	16	16	10	16	16	-	-	-	-	-	-	-	-	-	-	-	-	-	104	20800
9.	T.T.C. QUETTA.	-	-	32	-	-	-	-	-	-	32	-	32	-	32	32	-	-	-	32	32	-	-	-	-	-	-	224	31040
10.	T.T.C. KOTRI.	56	56	46	16	82	44	-	20	60	-	-	-	-	-	-	-	-	-	56	60	-	-	-	-	-	-	496	69838
11.	T.T.C. SAHIWAL.	12	12	24	-	-	32	-	24	32	24	-	20	24	-	-	24	-	-	24	-	-	-	-	-	-	-	252	44856
12.	T.T.C. MIANWALI.	12	12	20	-	-	32	-	24	32	24	-	20	-	-	-	24	-	-	-	-	-	-	-	-	-	-	200	39116
13.	T.T.C. BAHAWALNAGAR.	-	12	16	-	-	32	-	24	32	24	-	20	24	-	-	-	-	-	-	-	-	-	-	-	-	-	200	38240
14.	T.T.C. SARGODHA.	12	12	24	-	-	24	-	24	32	30	-	20	24	-	-	24	-	-	24	-	-	-	-	-	-	-	250	44486
15.	T.T.C. KASUR.	12	12	24	-	-	30	-	24	32	24	-	32	24	-	-	24	-	-	-	-	-	-	-	-	-	-	252	47606
16.	T.T.C. DIPALPUR.	-	16	-	-	-	16	-	16	18	16	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	16	120	25480
17.	T.T.C. PINDI GHEB.	-	16	-	-	-	16	-	16	18	16	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	18	120	25480
	TRAINEES TOTAL	332	676	583	48	472	557	64	459	846	657	46	512	196	80	32	512		48	590	180		68	60	24	56	36	7247	1199031

ANNEXURE-XI.

TRADE TRAINING COURSES OPERATED BY GOVERNMENT COLLEGES OF TECHNOLOGY/ POLYTECHNICS IN PUNJAB.

Sr. No.	Trade	Seating Capacity	Course Duration (Months).	Minimum Entrance Qualification.
1.	Electrician.	463	6/12	Middle Pass/Matric (Science).
2.	Electrical Supervisor.	217	9/12	Middle Pass/Matric (Science).
3.	Electrical Engineering.	43	12	Matric (Science).
4.	Refrigeration/Air Conditioning	171	6/12	Middle Pass/Matric(Science).
5.	Tracer.	400	6/12	Matric (Science).
6.	Draftsman (Civil).	135	6/12	Matric (Science)
7.	Quantity/Civil Surveyor.	478	3/6/12	Matric (Science)
8.	Radio Mechanic.	62	6/12	Middle Pass / Matric (Science).
9.	Television Mechanic.	12	12	Matric (Science).
10.	General Fitter.	8	6	Middle Pass.
11.	Welder.	21	12	Middle Pass.
12.	Auto Servicing Mechanic.	121	6/12	Matric (Science).
13.	Auto Electrician.	28	12	Matric (Science).
14.	Armature Winder.	16	12	Middle Pass.
15.	Turner.	16	12	Middle Pass.
	Total	2,191		

TRADES IN T.T.Cs. G.V.Is. & A.T.Cs. PAKISTAN.

T. T. Cs.

1. Electrician.
2. Radio/TV.
3. Ref. & Air Cond.
4. Draftsman (Mech).
5. Draftsman (Civil).
6. Wireman.
7. ARmature Winder.
8. Auto Mechanic.
9. Auto Farm Mach.
10. Auto Electrician.
11. Plumber/Sanitary.
12. Welding.
13. Turner.
14. Machinist.
15. Millwright.
16. Bench Fitter.
17. Sheet metal.
18. Moulder.
19. Carpenter.
20. Painter.
21. Tailoring.

G. V. Is.

1. Electrician
2. Radio/T.V
3. Draftsman (Mech).
4. Draftsman (Civil).
5. Ref. & Air Cond.
6. Instrument Mech.
7. Armature Winder.
8. Auto Mechanic.
9. Auto Electrician.
10. Tractor Mech.
11. Fitter.
12. Turner.
13. Machinist.
14. Welder.
15. Plumber.
16. Carpenter.

A. T. Cs.

1. Fitter.
2. Turner.
3. Machinist.
4. Welder.
5. Electrician.
6. Textile Fitter.
7. Ref. & Air Cond.
8. Radio/TV.
9. Plumber.
10. Surgical Instrument Mech.
11. Leather/Wood work (Sports goods).

ANNEXURE - XII.

STATEMENT SHOWING MANPOWER REQUIREMENT FOR THE SIXTH FIVE YEAR PLAN FOR THE MINING INDUSTRY.

Sr.No.	Name of Department/Institution.	No. of Projects	Geologists	Mining Engineers	Drillers	Other Engrs/ Technical	Para Engineers	Para Geologists	Other and Unskilled
1.	Pakistan Mineral Development Corporation. Baluchistan.	30	12	33	-	6	120	-	-
2.	Resource Development Corporation (Federal).	1	1	6	8	99	14	-	-
3.	Geological Survey of Pakistan (Federal).	18	38	6	11	4	-	16	-
4.	Pakistan Industrial Development Corporation (Federal).	2	5	8	5	7	70	12	-
5.	National Fertilizer Corporation (Federal).	1	1	6	-	-	14	-	100
6.	Gemstone Corporation of Pakistan (Federal).	8	31	10	-	25	23	11	160
7.	Sarhad Development Authority (NWFP).	9	25	24	-	-	347	-	340
8.	Directorate of Mineral Development (NWFP).	100(more Leases)	10	10	-	5	475	-	2000
9.	-do-	Consul-tants work.	10	5	-	-	10	15	60
10.	Punjab Mineral Development Corporation (Punjab)	7	8	22	-	105	40	-	470
11.	Directorate of Mineral Development (Punjab).	1	-	6	-	2	8	-	-
12.	-do-	800(more Leases)	10	30	-	10	200	-	1500
13.	Chief Inspector of Mines (Punjab)	9	-	24		-	60	-	-
14.	Directorate of Mineral Development (Sind).	2	8	2		-	8	6	-
15.	Chief Inspector of Mines. (Sind).	2	1	10	-	-	19	2	40
16.	Chief Inspector of Mines. (Baluchistan).	2	-	10	-	-	44	14	28
17.	Directorate of Mineral Development (Baluchistan).	5	2	2	-		-	-	1000
18.	Directorate of Mineral Development (Baluchistan).	270 (Leases)	-	54	-	-	900	-	-
19.	State Cement Corporation.	11	1	7	-	102	7	-	23
		108	163	275	24	365	2359	76	5721
	Add. of 10% for agencies having not responded.	11	16	28	2	37	236	8	572
	Grand Total	119	179	303	26	402	2595	84	6293

STATEMENT OF OUT TURN OF VARIOUS MINING TRADESMEN FROM THE INSTITUTES/ AGENCIES IN PAKISTAN.

ANNEXURE - XIII.

Name of Institute/Agency	1986	1987	1988	1989	1990
1. Training Centre & Training Mine for Mine Supervisors Choa Saidan Shah District Chakwal (Punjab.	-	10-VA 10-Shot Firer 10-T.M. 10-MMT 10-MET 10-MGE	10 VA 10 SF 10 MT. 10-TM 10-MET 10-MGE	20-MT 10 VA 10-SF 10 TM 10-MET 10 MGE 10 MT	20 MT 10 VA 10-SF 10 TM 10-MET 10 MGE 10-MT
2. Mines Rescue & Safety Station. Khushab(Punjab).	80-RCM	80-RCM	80-RCM	80-RCM	80-RCM
3. Mine Survey Institute Makerwal District Mianwali (Punjab).	-	-	-	20-MSU	20-MSU
4. Chief Inspectorate of Mines. Punjab. Lahore.	100-SC 5-FCM 5-SCM 20-MCS	100-SC - - -	100-SC 5-FCM 5-SCM 20 MCS	100 SC - 	100 SC 5-FCM 5 SCM 20 MCS
5. Mining Polytechnic & Polytrade Khanote (Distt. Dadu) Sind.		Project is in the planning stage and is likely to be completed by 1989-90.			
6. Mines Rescue & Safety Station Lakhra (Distt. Dadu) Sind.		The project is under construction stage and shall take 3-5 years before starts operation in full swing.			
7. Chief Inspectorate of Mines. Sind . Karachi.	50-SC	50-100 SC	50 100 SC	50 100 SC	50 100 SC
8. Mines Rescue & Safety Station. Sinjidi . Baluchistan.	100-RCM	100-RCM	100-RCM	100 RCM	100 RCM
9. Chief Inspectorate of Mines. Baluchistan. Quetta.	100-SC -	100-SC 5-FCM 5-SCM 10-MCS	100-SC -	100 SC 5 FCM 5 SCM 10 MCS	100 SC
10. Chief Inspectorate of Mines. NWFP. Peshawar.	-	-	-	50-MMS	50 MMS
11. PMDC Survey Institute. Khewra. Jhelum (Punjab).	40-MSU.	40-MSU	40-MSU	40-MSU	40-MSU.

SF- Shot Firer.	SC	Sirdar Certificate	MGE-Mine Gass & Explosives.
TM- Timber Man.	FCM-	First Class Certificate.	VA- Ventilation Assistant
RCM- Rescue Crewman.	SCM-	Second Class Certificate.	MMT Mines Mechanical Technicians.
MSU- Mine Surveyor.	MT-	Mining Technicians.	MET-Mines Electrical Technicians.
	MCS-	Mine Competent Surveyor.	MMS-Metalliferous Mine Sirdars.

MANPOWER DEVELOPMENT TO SUPPORT INCREASED COAL PRODUCTION AND UTILIZATION IN PAKISTAN POLICY AND INFRASTRUCTURE PRIORITIES

Donald W. Meals, Ph.D.
Arthur D. Little, Incorporated
25 Acorn Park, Cambridge, MA
02140 U.S.A.

INTRODUCTION

Can coal be extracted without the hands and minds of people? Can it be made to benefit man without human intervention? Unless we believe in magic, the answer to both questions is a confident no! Not even a tentative "maybe" or a cautious "perhaps" is acceptable. The fact is, growth and change in any business or social enterprise, including those of government, are conceived by people, planned by people and operated by people. Their success or failure depends upon people.

It is fitting and proper that this conference reckon with the human resources needed to combine financial, technological, and material resources to increase the production and utilization of coal. We are all aware of the need to recognize that the right people must be in the right jobs when they are needed. We also know that it is important to train the people who operate new equipment, those who maintain that equipment and, indeed, those who supervise and manage the people using and maintaining new equipment. But that is not enough. Our questions and answers must go beyond the allocation of time and money to create the human skills that implement all plans. Who does the training, how is it accomplished, and where it takes place are as important as concerns about blending coal to improve combustion or mine safety--for these also depend on human skills. My aim, therefore, is to share with you two concerns that grow out of first-hand observations of manpower development in Pakistan and seven other rapidly developing countries. How well technical and financial discussions cope with these manpower development issues can make or break any high hopes and ambitious programs that grow out of this conference. They are:

- What is the best place to train? At home or abroad?
- How should training be managed?

BACKGROUND: TRAINING TECHNOLOGY

Before considering these two issues, a brief examination of what has been happening to training will be helpful. In brief, we are experiencing technological developments as rapid and significant as those found anywhere. There is a modern training technology. It is as different from that of the 1940s as the miners pick is from a continuous miner or modern shuttle car. Three complementary developments account for ongoing revolutionary changes in training and educational technology.

- Improved understanding of the learning process.
- Application of visual and control technologies.
- New course design techniques.

The Learning Process

While the physical scientists have given engineers new knowledge to apply to new physical technology, behavioral scientists have given teachers new knowledge that makes teaching more efficient. Today's well trained teacher is a better skill-building engineer than his or her predecessors fifty years ago. And as understanding improves, teaching and training get still better. In addition, we can give the trainers much better tools.

Visual and Control Technologies

By far the most evident change in training and education is the application of modern media and computer technologies to the teaching-learning process. We are all familiar with the rapid transition from the printed picture to the projected image, to the motion picture, broadcast video, and now the video cassette that is invading homes everywhere. We are aware that the power of the computer has been harnessed by teachers and trainers. Rapid technological advances in computing have lowered costs while increasing power. The result: computers in classrooms and training centers providing drill and practice. They simulate complex processes to help trainees learn to control them. These developments have been expanding the capability of trainers just as modern mining equipment has been expanding the productivity of workers

Within a remarkably short time, both the range and power of teaching tools and their adaptability to individual trainees has increased. There now is solid evidence that the use of these technologies increases the productivity of the teaching and learning process. For example:

- *Since 1978, the public schools of six towns close to my home have been using computers for part of the instruction given in language and mathematics. Their carefully maintained and analyzed records show that this mode of instruction has been superior to conventional instruction. Learning goals are achieved more quickly too. Small low cost computers are entering classrooms in great numbers--even as budgets for public education diminish.*

- *A 25 million dollar grant by IBM to the Carnegie-Mellon University has produced a set of computer programs or software for higher education. A reviewer has stated that "... it will make educational applications as portable as textbooks."*

Training technologies also enforce quality control. Most important, they are mobile. They can move across national boundaries, they can move into industrial training centers, onto the factory floor.

The Design of Training

The revolution in training hardware technology has been widely reported. Meanwhile, there has been a quiet but equally significant development of a technology for combining what we know about how people learn with the new hardware, called by some Instructional System Design (ISD). It focuses on trainee needs, teaching only what the individual needs to know. Built-in techoiques prevent the waste of time and effort. Its products are called "software" if a computer is involved but, more generally, they are referred to as "courseware" or "validated instructional materials."

Lest Instructional System Design appear to be an esoteric activity of university professors, one example of its use is necessary. The International Telecommunications Union (ITU) in Geneva, Switzerland, has taught hundreds of trainers in developing countries to design efficient instructional materials. Such materials now teach telephone employees in Singapore, Kenya, and elsewhere to install and repair telephones. The ITU has also developed teaching materials for modern switching equipment. The process is being used in both developed and developing countries simply because it saves time and money.

Concurrent Development: Training and Other Technologies

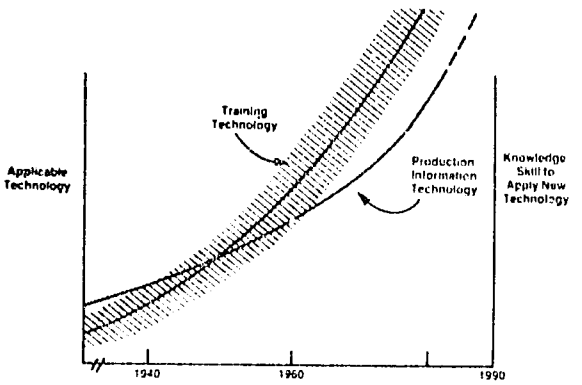

FIGURE 1 CONCURRENT GROWTH OF TRAINING AND OTHER TECHNOLOGIES

The significance of the new technologies of training for Pakistan begins to be evident when we place them in the broader context of technological developments generally. Figure 1 portrays the growth of technology as accelerating. As it does, the demand for knowledge and skill to apply the new technology increases. Many say this requirement increases at a faster rate than the technology *. But, even if technology and the associated demand for expanded human capabilities grow at about the same rate, the general demand for training increases very rapidly. Development that uses competitive technologies, therefore, can be expected to increase the demand for training and retraining. This suggests that investments in capital equipment should be matched by investments in human capital.

*New projects such as a steel mill or vastly expanded coal extraction generate sudden surges in the demand for new skills rather than the steady growth shown in Figure 1. This intensifies the need to produce new skills as efficiently as possible.

Once it is recognized that satisfying technology-driven demands for human skills is a necessary cost of development, finding ways to reduce those costs becomes important. Training technologies promise to cope with those demands.

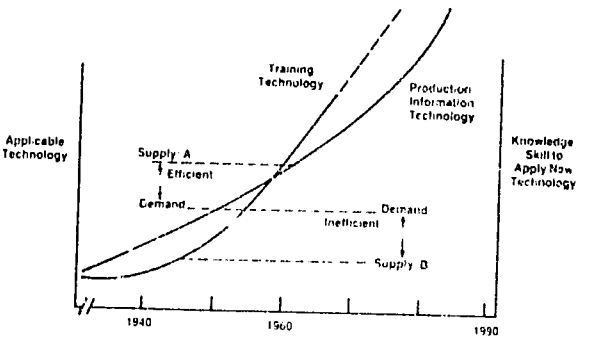

Figure 2: Impact of Alternative Training Technologies on Manpower Development

How important it is in the long run to make use of modern training technologies is suggested by Figure 2. If less advanced training methods are employed to cope with new technologies, as at "B", the use of new technology or even the growth of an established one will be hindered by inadequate, delayed, or costly manpower development. On the other hand, as shown at "A", if training technology matches or exceeds production technology, the demands for worker skills and knowledge are more easily met. Inferior training technology is likely to be less efficient, cost more. The inference is that in both the short-run and the long-run, training technology must keep pace with growth and technological change.

We simply cannot efficiently grow, or expand a 1975 technology, with 1935 training. This is the message of the parallel development of training and other technologies. It has special meaning for those who decide where training is done and how it is managed.

THE LOCATION OF TRAINING

We have argued here and elsewhere that modern training technology is needed to produce efficient solutions to the human resource problems created by rapid growth and technological change. Unfortunately--and incorrectly--many leap to the conclusion that much of the training that supports growth and change should, therefore, take place in the West. The unexamined assumption seems to be that the trainee must go where the training technology is best. Apart from the cost penalties of doing so, offshore training is a bit like sending your raw materials to be manufactured abroad because the production technology there is more modern, more efficient. A better solution is to move the technology to the raw materials and basic manpower resources. Like investments in the production and communication technologies, bringing training technologies to the workers creates self-sufficiency and independence. Moreover, doing so builds a balanced developmental capability.

Three arguments for keeping the maximum amount of manpower development at home are especially important:

- o Training Is Continuous
- o Training Is Adaptive
- o Training Technology Is Mobile

Continuous Training

The need to train workers to cope with new machines and processes does not end on the day a factory opens or when coal production exceeds seven million metric tons a year. Turnover, promotions and retirements create a constant internal flow of human resources into different jobs with different demands. As management learns to adapt the organization and its equipment to the local environment and customs, there will be changes in the organization and, consequently, changes in job responsibilities. Incremental changes in technology will impose further needs to acquire new skills. Retraining for redeployment will make continuous training support as essential as the maintenance of equipment.

Failure to provide for continuing support is an all too common cause for low productivity. It happens this way:

> *A successful equipment vendor agrees to train X operators and Y maintenance personnel in his own "modern" training facilities thousands of miles away. Although cost is substantial, it is hidden in the price of the equipment. To the buyer the numbers to be trained seem large in comparison with the available supply of skilled workers. In practice, the numbers to be trained have been set at a minimum level by the vigorous price competition encouraged by the tender.*
>
> Two years after delivery of the equipment several trainees are supervisors, several more have used their training to find better jobs, and one or two have been assigned elsewhere. Inadequately trained employees fill the slots as negotiations get underway for the vendor to train more employees -- this time, perhaps several trainers as well. The price will no longer be hidden in equipment costs.

Building a modern local training capability helps avoid costly dependence on foreign sources of training or the use of inefficient methods of developing human resources. Moreover, manpower development can respond to continuous requirements for training and retaining.

Adaptive Training

A basic principle of modern Instructional Systems Design that is consistent with what we know about how people learn insists that training begin with what the trainee knows at the start of training. The training builds from that to produce just those skills and knowledge needed to do the job well. That is, training adapts to the trainee and the job. How then can a manager be sure the foreign trainer with programs

designed for his largest market will accommodate his needs? Will the programs of the foreign supplier change as his jobs and trainee populations change? Will the foreign trainers be able to cope with trainees with different cultural values?

There are some trainers who can adapt to changing and diverse needs. But, few adaptations can be as sensitive and complete as those the manager makes himself. The more training he does at home, the better able he will be at adapting to his own special needs.

A Mobile Technology

Emphasis on training within one's own country would be fanciful and impractical if up-to-date training technology were not mobile. The fact of the matter is that the essential elements are highly mobile and are widely disseminated.

An example of the mobility of a key part of training technology, course design, is the work of the ITU mentioned above in training course designers who now apply these techniques in a dozen countries. Another example is typical of such transfers.

> *Forty members of a staff responsible for creating educational and training programs in a developing country learned to apply the Instructional System Design techniques. Within a year they were producing first-rate instructional programs employing television, teaching machines and special textbooks. During the second year, this group trained an equal number from another developing country.*

What about the hardware? It too, is mobile. Overhead projectors, video cassette players, and microprocessors, for example, are on the move. They are penetrating training environments because they behave like all good capitol investments: They yield good returns on investment. Market growth and rapid technological change are driving prices ever lower. Both video and computer based instruction cost less than a tenth of what they cost a decade ago--and their benefits are greater. time gives the owner of the hardware or delivery device control of the training process. It is necessary to own a safety razor in order to take advantage of available blades of low cost and high quality.

Before moving beyond hardware as a source of mobility and local control, a comment on resistance to training hardware is in order. Our idealization of the teaching-learning process makes it a highly personal matter: teacher and student working together, chalk and chalk board, lectures and exams. Resistance is the natural desire to hold on to the old and familiar. Fears of excess cost and complexity are the last defense, just as they were for the internal combustion engine.

The truth is, the hardware is not the key feature of the revolution in training technology. It is just the delivery and control device for modern courseware. If one encounters resistance to training technology, back down the curve we examined earlier, use a lesser technology for a while. Improved training, mobility, access to courseware and, above all, ownership will hasten the transfer of training technology--and expand the local capability for matching human skill to the demands of new technology.

Conclusion:

The parallel growth of production technology and training technology is a phenomenon that cannot be ignored. A better understanding of learning and the design of courses have been combined with technological adaptations that increase training efficiency and make it more mobile. These are the tools for learning that now must be continuously and ever adaptive. To buy or rent but never own these tools is to delay an understanding of them and a control of their power. This means that those creating a new enterprise must insist on the transfer of training technology along with other technologies. A commitment to the maximum possible amount of in-country training supported by modern training technology enables management to own and control the key tools for development. Learning to use them will increase the capability for future

But the major benefit is not in the hardware; it is in the courseware. Just as the radio and home video enable the owner to have access to multiple sources of information, educational hardware makes courseware highly accessible, i.e., mobile. Through the courseware he creates, a single master trainer can be in five classes in Sind while at the same time "teaching" three groups in Baluchistan.

Hardware makes courseware portable and therefore mobile. It enables the trainer to use learning materials produced thousands of miles away or to produce his own in Karachi for use in Lahore. Such portability expands mobility and at the same development--enable human resources to keep pace with technological change and growth. The answer to my question of where to do the training:

Do as much training as possible at home with the best training technology that can be acquired, owned and used.

MANAGING TRAINING

The most damaging aspect of off-shore training is the associated complacency about the management of human resource development. It is as if the vendor, by taking trainees into his school, has assumed total responsibility for manpower development. Yet, he cannot do more than a small piece of the strategically important job of developing human resources. There are just too many related activities that determine whether manpower goals will be met.

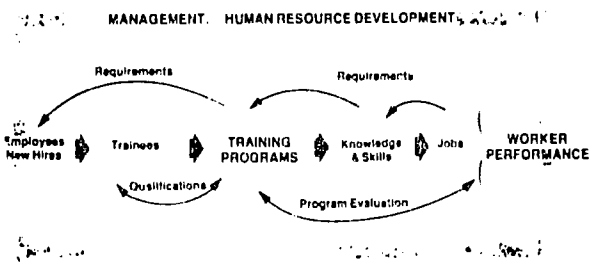

FIGURE 3 TRAINING MANAGEMENT: MORE THAN SCHEDULES AND FACULTY

Consider some of the activities that determine whether money spent on training will be wasted. We begin with a training program at the center of Figure 3. It makes no difference whether it takes place in a classroom or on-the-job. Apart from the level of technology involved, the reason for training is to provide knowledge and skill. But for what? Obviously, the knowledge and skill are intended to enable the trainee to perform his job. This means that the program is related to one or more jobs. If the job changes, the training may need to change. Some one must make that happen.

Next we must have trainees. They may be current employees or newly hired ones. Not all of them will enter training programs at the same time. Nor, will all trainees enter the same course. Some one must control the selection of trainees.

Without further complicating the need for coordinated actions and process control, it is evident that there are a number of critical points where things can go wrong--and often do.

- The wrong trainees are selected to attend the training program.
- The skills produced by the program are not those needed on the job.
- The program is too long.
- Trainees get assigned to jobs not specifically related to their training.

Every time one of these familiar events occurs; there is waste--not just of time, money, and opportunity, but of human resources. Meanwhile, excellent management talent may be controlling finance and transportation with finesse. It would appear at first to be simply a matter of diverted attention. In most cases, it is that, but much more. Very often the techniques and technologies of human resource management are just not in place. There is no infrastructure. For example:

- The wrong trainees may be selected because:

  - Objective measures of aptitude and trainee potential are not used; performance appraisal is missing or evaluates unimportant employee qualities.

  - The trainer has not specified the capabilities the trainee must have to succeed in his course.

  - The wrong employees we.e hired. Few qualify for the training program.

Screening instruments are not in use while performance assessment is unrelated to the job. We have management without measurement--a fatal flaw.

- The skills produced are inappropriate because:

  - The job has not been analyzed.

  - The course has not been evaluated to determine whether it produces what it intends--correctly or incorrectly--to produce.

The techniques of job analysis have not been applied.

- The program is too long because:

  - Much has been added to compensate for the lack of certainty about what the job requires.

  - It has not been designed for efficiency and the appropriate use of teaching techniques and materials.

Modern course design is lacking:

- Trainees are assigned to other jobs because:

  - The jobs for which they were trained are filled or not yet established.

  - The placement process begins when the trainee graduates rather than before training starts.

Manpower planning is lacking.

Such deficiencies lead to a gross wastage of human resources. Training is not linked to what the trainee later does on the job--his performance. From this focus on job performance and its associated measurements comes the information managers need. To avoid wasting human resources, there must be a plan and the means of controlling a complex set of activities: recruiting, selection of trainees, the design of courses, the assignment of trainees to jobs, and others. To succeed in a new venture will require managerial skills applied to money and equipment. Developing human resources calls for equal or better management of a similarly complex set of activities. Without a supporting infrastructure and adept management, more money can be wasted on training than on anything else.

The waste of money on inappropriate training will be greatest for those training courses co.ducted off-shore. Here is an example. It is typical of six training contracts I have recently examined in detail.

> *The tender for very expensive modern equipment was carefully prepared by engineers who drew up tight technical specifications. They were based on careful analyses of operational requirements that took account of maintenance and interfaces with other components of the system. Bids were evaluated carefully and a winner declared, the contract negotiated and signed.*

Along the way, almost casually, and without any analysis, the tender called on the contractor to provide training. The number of trainees was specified without any manpower planning. The pre-training qualifications of those to be trained by the contractor and the results of training were vague--far from the precision of the hardware specifications.

The negotiations were instructive as well. Almost all of the negotiation effort was devoted to clarifying and enforcing specifications--of the hardware. Very little negotiation time was spent on the training, for there were no specifications to worry about. From the record it is apparent that the winning contractor liked that. There would be no careful inspection and measurement of what he had agreed to deliver. Moreover, there was a good possibility that there would be a separate contract for more training--a late discovery that both trainers and replacements would need to be trained.

Unnecessary--often blind--dependence on off-shore training is frequently the result of inadequate analyses of manpower needs and the absence of the supporting human resource development capabilities. Training is but one segment of the continuous manpower development required by both growth and change. Without the allied capabilities, it is small wonder that the development of people gets little management attention. The ability to make effective use of expensive off-shore training is limited by inadequate management support.

If a lack of a manpower development infrastructure limits the value of off-shore training, it places local training at an equal or greater risk. Training that is not supported by a well managed human resource infrastructure is like an expensive piece of equipment with uncertain input, unplanned use of output, and no maintenance. Moreover, well managed manpower development will be capable of detecting and adjusting to changes in input and new demands for adapting to changes.

Conclusion:

Well managed manpower development will:

- o Demand training programs that produce the skills needed; enforce requirements that only Instructional Systems Design can meet.

- o Call for the best techniques available for delivering training; insist on the application of the best available technology to hardware.

Taken together, such training, well supported and managed as part of the development of human resources can help make expanded coal extraction a success. What is more, it will prepare the way for other and later developments as coal producers and users own and use modern capability for increasing your most important resource. Thus, the answer to my second question: "How should training be managed" ? is:

Create a human resource management infrastructure of which training is a part and manage it with as much or more talent as that applied to the management of equipment and money.

Summary

We have examined the technology of training--found it an important means of coping with the demands of growth and new technology. The potential value of this technology and its effective application to the developmental challenges of Pakistan argue for its application here. In the final analysis, however, the effectiveness of all training--at home or abroad--depends on the integrated management of all human resource development of which training is a part. It adds up to just this:

- o Develop and own the best training capability possible--it will serve development better than using training designed for other people and places.

- o Above all, provide the human resource management capabilities that support training. Manage it well.

Keep as much training at home as possible. Begin now to adapt, use and own modern training technology. Manage this technology as part of a strengthened and vigorous manpower development capability.

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THE CONVENTIONAL ENERGY TRAINING PROJECT: COAL AND LIGNITE TRAINING OPPORTUNITIES

S. Ebbin, Ph.D.
Institute of International Education
1400 K Street, NW, Suite 650
Washington, DC 20005-2403

Abstract

Many developing countries are in the exploration and production phase of the commercialization of domestic coal resources. Often the coal is low rank and lignite. Since the coal industries are newly emerging, a critical need is to train local personnel in every aspect of the industry, from upper management through engineering staff, supervisory personnel, to production workers.

The Conventional Energy Training Project (CETP), which is conducted by the Institute of International Education (IIE) under contract with the United States Agency for International Development (USAID), has broad experience in energy training. We have found that formal courses in the coal industry in the United States are scarce. New courses will have to be designed especially for Pakistan and other countries with emerging coal and lignite industries.

The IIE/CETP staff is currently in the process of designing a sixteen-week course involving lignite and low rank coal utilization by industry and utilities. The course is practical and will be held in lignite-burning plants.

We have also developed training programs in coal mine engineering, coal chemistry, coal briquetting, geology, geochemistry, plant efficiency, and coal use in utilities.

Introduction

Established in 1981 by the United States Agency for International Development (USAID), the Conventional Energy Training Project (CETP) trains working engineers, geoscientists, managers, planners, economists and other energy professionals from developing countries to better use their oil, gas, coal and non-nuclear electric power resources.

Emphasizing the development of job skills for working professionals, AID's Office of Energy (S&T/EY) Energy Training Project has recently entered its fifth year. CETP has already trained over five hundred energy specialists from forty-five countries worldwide. We have trained seventeen for Pakistan. Previously exclusively funded by S&T/EY, more and more missions have added their own funds to the CETP to assure the availability of training slots in what they view as a highly effective training program. CETP has earned a reputation as a no-nonsense, hands-on, practical training program which requires participants to work a minimum of forty-hour weeks throughout the period of training. Each participant signs a contract agreeing to this; the participant's employer is asked to review and endorse the terms of training and stipulate that they will continue to pay salary and employ the participant for the period of study and upon return home. Each participant's progress is carefully monitored by CETP staff.

Since September of 1981, the CETP has been administered by a special energy training staff of the Institute of International Education (IIE). Founded in 1919, IIE is the oldest and largest not-for-profit private sector institution whose sole mission is the international exchange of persons. Since 1948 the Institute is best known as administrator

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of the Fulbright Fellowship program, the Humphrey Fellowships, and the UNESCO Fellowships.

IIE administers programs for over one hundred sponsors, facilitating the exchange of nearly 10,000 students, faculty and citizens. Among the sponsors are the United States Government, the United Nations, World Bank, Ford Foundation, private corporations, and several foreign governments.

CETP combines highly regarded training offered by the energy industry with the best that academic institutions can contribute. We have provided professionals from developing countries an opportunity to receive the same training that U.S. energy professionals receive. Roughly two-thirds of CETP graduates have received their training with either industrial institutes, as interns with United States energy companies, or in special courses created by the IIE staff and operated by selected training companies or institutions (see appendix).

CETP has, since its inception, involved the U.S. private sector energy industry with U.S. foreign assistance and has proved that providing technical training can pay great dividends for the country receiving the training as well as for U.S. industry. The host country receives skilled manpower prepared to do their job better. The measure of success for the CETP is that its graduates can make a contribution the first day they return to work. U.S. industry becomes more aware of international marketing opportunities.

Although the energy crisis has abated in the United States, AID-assisted countries are still economically devastated by high energy prices. Oil must be purchased with scarce hard currency. CETP is based on AID's assessment that energy is basic and essential to all economic and social development. Trained energy manpower is essential to achieving these goals in agriculture, industry, health, and other vital sectors.

Training in Coal and Lignite

For a substantial number of developing countries recent discoveries of indigenous coal and lignite reserves provide an opportunity to gain some measure of energy independence. For many countries, the development of indigenous coals and lignite provides the possibility of creating an entirely new industry, as well as a range of ancillary enterprises.

We are currently conducting an exhaustive survey of U.S. energy training institutions for all forms of energy. We have found a severe lack of relevant courses in the coal industry. Unlike petroleum, the coal industry in general has no support industry that regularly provides training. Most of the training is conducted within companies for their own personnel exclusively and is primarily for production workers. We found coal companies reluctant to train outside personnel, particularly non-Americans. Coal operators usually work closely with the mine unions to assure harmonious relations and are therefore sensitive to their concerns about the exportation of coal technology or expertise. Moreover, we found the coal industry sensitive about high unemployment and fearful that people are being trained to supplant American production workers at lower salaries. Mining engineers, geologists, petrologists and other upper level people, with university degrees usually receive their practical experience on the job and are not as concerned about outside competition.

Several colleges and universities carry on limited skills training in coal through continuing education programs and consortium arrangements. However, we have found no comprehensive programs offered on a regular basis to meet the needs of developing countries starting an emerging coal industry. Some sources suggest that training in lignite operations would be similar to those needed in bituminous coal operations, especially if the lignite was to be surface mined. We have found no existing lignite training programs and there is strong evidence that there is no organized training in either bituminous or sub-bituminous coal operations. The capability does exist to develop useful training, but unlike the petroleum industry, these capabilities have not been organized in any cohesive manner to assist developing countries to develop their domestic resources. The reason for this is that skills training has never been important in coal production in the United States, except in health and safety areas. This concern has been mandated by U.S. national law for more than ten years but is only now emerging on a regular basis.

The mandating of specific safety training did more than protect the safety of mine personnel. Mine owners who had fought the imposition of training programs for a long time have now begun to see a positive relationship between training and productivity. Training is now being applied to an increasingly broad range of activities, beyond safety. More enlightened coal companies provide orientation training for new hires, training for existing personnel in new equipment and technologies, task training for greater efficiencies of effort, and supervisory training for all promising personnel. Mine owners involved in other industries such as petroleum or steel have been more willing to implement training programs and have moved to do so more rigorously than smaller, more traditional coal operators, since they have seen the benefits of such programs in their other industrial activities.

The lack of an organized training industry to support coal development activities of developing countries means that creativity is a critical factor for an organization such as ours. In order for us to make available training opportunities to developing countries, we have had to piece together elements of existing capabilities, assess them, alter them and develop new program components, and coordinate these elements to meet participants' and their companies' needs.

For example, a chemist from Costa Rica, a country with newly discovered coal reserves, studied as an intern with a coal testing firm. She spent four months on-site learning (by doing) coal and coal ash analysis. She learned all the required ASTM procedures in the field. She recently established the most modern coal laboratory in Costa Rica.

Because of this lack of existing training, three years ago we developed a training program for the Lakhra Jamshura project. We defined the basic training requirements and identified sources that could fulfill these requirements to implement a full-scale training program that would provide the necessary manpower training for both mine development and power plant construction.

Working with Stone and Webster, we developed a program that addressed the needs of the various functions of the Lakhra Jamshura project. We identified

the functional training needs and potential training sources, as well as the professional criteria for the following positions: project director; chief financial officer; chief engineering officer; chief construction engineer; chief procurement and contracts officer; chief support services officer for cost estimating, scheduling, control and auditing; chief resources officer for manpower development training, recruiting, spare parts, maintenance, personnel and operational services; liaison officer; project officer for transportation; project manager for power plant; project manager for fuel supply; and project manager for infrastructure. For each position the specific training area, the type of training needed and the projected length of training were identified.

Subsequent phases of training were created to facilitate the plant becoming operational, and to create an on-going training facility and program. At each phase the number of trained people was to increase until the continuous flow of trained manpower necessary for continued plant operations could be provided. Besides the operational aspects of the project, we recognized the need to integrate the Lakhra Jamshura project into other existing considerations. As a result, CETP's program provided for issues of funding sources, organizational involvement of Pakistan institutions and technology transfer approaches.

Useful training requires practical hands-on experience. This is why we believe that practical training must take place outside of a purely academic setting. While academic programs can augment training for specific applications, a real training setting is of great importance. Training involves more than just skills development; it includes improved attitudes regarding the work ethic and work habits. These can best be provided by practitioners in the field. Our own experience strongly supports this in petroleum, power systems and coal. This experience was a major element in our design for the Lakhra Jamshura project. Certainly, for a major project such as Lakhra Jamshura, training must include such subjects as: mining, transportation, beneficiation, combustion, carbonization/gasification, fuel substitution, siting, electric power generation, and industrial applications; but, in addition, the training needs to address issues such as company structure, human resources development and utilization, economics, management, contracts and negotiations, procurement, accounting, funding strategies, health and safety, and environmental issues. Years of our own efforts and the evaluations of those efforts show that this life-cycle, hands-on practical approach works.

Recently, we were requested to develop a practical training course on the use of low-rank coal and lignite. The sixteen-week course is for in-plant engineers and managers in countries with new coal industries. It combines classroom training with in-plant engineering. As a first step, we canvassed large lignite-burning utilities and coal consulting companies to provide the required training. One major utility with lignite burning facilities has emerged as an ideal site for this training.

The course to be offered for the first time will take place in the United States over a sixteen-week period to a competitively selected group of trainees from the ASEAN countries. It is specifically designed for mid to upper level technical managers of utility and industrial plants which do now or may plan to

use low rank coal in the near future. It is understood that participants will include plant engineers, technical managers of power plants, and supervisory engineers who are to be trained to understand the overall scheme of lignite and subbituminous coal utilization.

The first eight weeks will take place in a classroom, but will be practically oriented, stressing experiential learning methods. Operating lignite-fired generating plants will be used during this period to substantiate the classroom portion of the course and will afford maximum opportunities for hands-on applications.

The final eight weeks of the course will be spent in internships at two generating plants. Participants will be placed in these facilities to specialize in applications of special interest to them. All activities during the internships will be job oriented. Each participant will be placed under the tutelage of an assistant foreman or supervisor. Training at this level will insure that the participant will be exposed to real-life plant operating conditions rather than textbook examples, It will also afford each trainee with management experience.

Participants will be encouraged to bring with them specific problems relating to plant operations in their home countries. The training staff will work with each participant to solve these problems either individually or in teams. Problems will be addressed on a theoretical basis during the classroom portion of the course and practical solutions confirmed during the internship period. Each participant will document his/her problem in a written course project which will be judged by instructors.

Below is the outline of the first eight weeks or classroom portion of the course. Internships are expected to be negotiated individually with the training staff.

It is entirely practical for the CETP to provide a similar course for the Pakistan coal development effort. Once the course is in place it will be applicable to all lignite-based power operations.

The impact of the CETP has recently been evaluated by an independent team of training specialists which visited twelve countries and interviewed 209 participants, supervisors and U.S. officials. The conclusion of this report is that "participants learned critical new skills and knowledge and have begun to apply them in their employing organizations... [they] experienced personal growth, leading them toward greater self-confidence, assertiveness and initiative in taking action... Participants, their employers and their countries are receiving a diverse range of benefits from both academic and nonacademic training in an overall program that has been almost universally praised."

Preliminary Course Outline

0. Course Orientation
   A. Introduction to Solid Fueled Power Plants
      1. Physical Plant
      2. Manpower Requirements

I. Coal Preparation
   A. Sampling Techniques
      1. Core Analysis/Geological Mapping
      2. Fuel Samples
   B. Fuel Analyses
      1. BTU Content
      2. Ash Content
      3. Sulfur
      4. Moisture
   C. Blending
   D. Quality Control

II. Coal Handling
   A. Mining Overview
   B. Transportation
      1. Heavy Wheeled Equipment
         a. Front-End Loaders
         b. Haulers
         c. Railroad
      2. Mechanized Pit Equipment
         a. Cross Pit Conveyors
         b. Standard Conveyors
   C. Storage
      1. Short Term
      2. Long Term
         a. Required Long-Term Storage Characteristics
         b. Drainage Requirements
         c. Spontaneous Combustion
      3. Equipment Requirements
      4. Operator Skill Requirements
   D. Processing
      1. Feeders and Conveyor Systems
      2. Grinders and Pulverizers
      3. Mill Maintenance

III. Combustion
   A. Powerplant Boilers
      1. Fuel Characteristics and Handling
      2. Burr Controls
      3. Boiler Operations
      4. High Speed Blowers - Forced Draft and Induced Draft
      5. Boiler Cleaning Systems
      6. Sootblowing Systems
      7. Specialized Instrumentation and Control
      8. Fly Ash/Bottom Ash Handling and Disposal
      9. Simulator Training
      10. Powerplant Chemistry
   B. Other Industrial Boilers

IV. Boiler Design and Modification
   A. Boiler Sizing
   B. Boiler Cleaning Systems
   C. Sootblowing Systems
   D. Compressor Systems
   E. High Speed Blowers - Forced Draft and Induced Draft
   F. Fly Ash/Bottom Ash Handling and Disposal
   G. Control System Upgrading
   H. Data Acquisition Upgrading
   I. Enhanced Operator Interface
   J. Maintenance

V. Environmental Control Technology
   A. Precipitators
   B. Wet Scrubbers
   C. Bagging Systems
   D. Dust Suppression
   E. By-Product Disposal
   F. Economic Considerations

VI. On-The-Job Training
   Trainee will arrange for an appropriate placement in his/her field of specialization.

Tentative Time Schedule

I. Coal Preparation
   40 hours
II. Coal Handling
   72 hours
III. Combustion
   132 hours
IV. Boiler Design and Modification
   40 hours
V. Environmental Control Technology
   36 hours

PRIVATE SECTOR COAL MINING INDUSTRY IN PAKISTAN.

Saifullah Khan Paracha
Minister for Planning & Development, Government of Baluchistan, Quetta, Pakistan.

After graduating from University of California at Berkely in June 1954 I joined Habibullah Mines Limited, which was and still is the biggest producer of coal in Pakistan, initially as a mining engineer, later as its chief mining engineer and lastly as its managing director. I have 30 years experience of coal mining. This resume on the subject of Private Sector Coal Mining in Pakistan is based on my personal coal mining experience and knowledge. The subjects discussed in my paper are (i) introduction, (ii)evolution in mining methods and mechanisation in coal mines, (iii) technical problems in coal mines, (iv) future of coal mining in Pakistan, (v) what needs to be done by private sector, (vi) what needs to be done by Government of Pakistan and (vii) conclusion.

I. INTRODUCTION:

Pakistan utilizes over fifty percent of its entire annual export earnings on the import of oil. Other countries who were in similar condition have either managed to reduce or are in the process of reducing their dependence on imported oil by developing indigenous sources of energy and fuel. The success in this direction of the developed countries has resulted in lesser worldwide consumption of oil and its lower selling price.

So far Pakistan has not succeeded in mobilising its own known resources of energy and fuel. Heavy dependence on imported oil continues. Local oil production has increased but the demand for oil has also jumped up. Gas fields are being developed to yield more natural gas but the gas consumption is also increasing. The gap between electric power generation and demand is widening steadily. Power shutdown has become a usual feature and such frequent load-sheddings have resulted in lower agricultural and industrial production.

This picture, though looks dismal, is the resultant of a growing national economy. During 1984-85 growth rate of GDP was 6.4 percent, for agriculture 9.9 percent and industry 8.6 percent. If the fuel and power supplies were sufficient to meet the requirements the growth rate of the national economy would have been higher.

Under the far sighted and able helmsmanship of Dr. Mahbubul Haq, Pakistan dynamic Minister for Finance, Planning & Development, the Government of Pakistan has for the first time realised the ability of indigenous coal to substitute for imported oil as well as for gas, which could then be reserved for higher value uses. At present the international price for oil is dropping but with the revival of global economy the consumption of oil will again go up and this in turn will hike the selling price of oil. Pakistan is already groaning under unfavourable import-export imbalance and cannot afford to earmark more of its foreign exchange for the import of oil. At the Federal Government Cabinet level it has been accepted that indigenous coal should be used for power generation in thermal power plants but the public sector agency responsible for power generation, Water and Power Development Authority (WAPDA) is still half hearted in its efforts to use indigenous coal for power generation.

The proposal for making use of indigenous coal for power generation was put forward in the Provincial Assembly of West

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Pakistan in Lahore in 1965. Consequently the Government of Pakistan accepted the assistance of Poland towards the preparation of feasibility reports on the subjects of mining of coal in Lakhra Coalfield and generation of electric power through Lakhra coal fired thermal power plants. The Polish reports were completed and submitted to Government of Pakistan in 1966. As imported oil was readily available WAPDA took little notice of these favourable feasibility reports and the subject of substitution of imported oil with indigenous coal received no support from government of Pakistan.

Even during 1973-76, when the world was engulfed by the oil crisis, Pakistan continued to import oil under concessional conditions because of its unusual good relations with the oil producing countries in the Middle East. That was the time when Pakistan should have made all possible use of its known indigenous coal resources and also should have under taken an elaborate programme for proving its coal reserves in all the known coalfields. It was known that Lakhra could be a very big coalfield and the underground mining conditions in that field were favourable comparatively with other coalfields but no funds were provided by the Government for drilling for the purpose of proving the coal reserves or for determining the chemical and other qualities of Lakhra coal. As imported oil and Sui Gas were so conveniently available, even imported coal was not seriously considered as a substitute in thermal power plants. Imported coal would have proved as a cheaper fuel compared to imported oil. Some generation of power in Karachi area could have been based on imported coal keeping in view the existing port facilities at Port Qasim and the option of using sea water for cooling in the thermal plants. But this aspect never received meaningful support from Karachi Electric Supply Corporation (KESC). The end result of all this was that valuable time was lost, which could have been used in proving the extent of known coalfields, their coal reserves, coal qualities and suitability of indigenous coal for power generation in coal fired thermal power plants.

On September 22, 1985 the Government of Pakistan through its Economic Coordination Committee of the Cabinet (ECC) considered the induction of private sector in the power generation and took a number of decisions. Firstly it was felt that inadequate investment in power had been the principal reason for recent power shortage. As funds for public sector investment would continue to be less than the requirements, in the foreseeable future, it appeared desirable to mobilise private resources for development of power network. Secondly WAPDA was burdened with manifold responsibilities and was examining ways of decentralisation. Private operated generation units would relieve WAPDA of some of its future day to day responsibilities. Thirdly, power generation was a convenient point for inducing private participation. In the light of experience gained, the role of private enterprise in the development of the power system could be enlarged. The ECC took a number of decisions on how to induct private sector in the power generation. With setting of coal fired thermal power plants it would be possible to use indigenous coal in big quantity for power generation. The Government's decision of September 22, 1985 has laid a sound foundation for establishing a modern coal mining industry in the near future.

During the last thirty eight years since 1947 coal mining industry has been treated as a neglected orphan child. Whatever attention was given was showered by the Government on its own public sector organisations, specially Pakistan Mineral Development Corporation (PMDC).

Inspite of this step-motherly treatment the private sector proved vigorous enough to account for 87 percent of the total national annual coal production during 1984-85 & the public sector organisation including FMDC, were able to produce the remaining 13 percent.

The Government of Pakistan and the Provincial Governments have been investing millions of U.S. dollars on public sector coal mining over the past twenty five years but failed to even provide bank financing on easy terms to private sector mining industry. This forced the private sector to stand on its own feet, without financial support from industrial development banks, such as Pakistan Industrial Credit & Investment Corporation (PICIC) and Industrial Development Bank of Pakistan (IDBP). The private sector however took loans at heavy interest rates from commercial banks against pledge and hypothecation of their stocks of mined coal and also materials including mining timber.

The entire private sector coal mining industry was self-financed. The extent of self-financing can be appreciated by realising that today it requires an investment of Rupees 18 to 24 millions to develop a coal mine which can produce one hundred tonnes of coal per day. This includes expenditure on development of the permanent mine workings such as adits, tunnels, inclined or verticle shafts, haulage roads, ventilation ways and levels, mining machinery and equipment, buildings for housing installed machinery, offices and residential purpose buildings and shingled roads.

The chief reason for the government's neglect was that indigenous coal had only one industrial use of being the fuel for burning clay bricks in brick kilns. Over 82 percent of the entire national annual coal production is being used for this purpose. Fortunately for the coal mining industry the baked clay brick continues to be the cheapest and most desired building material for the construction of houses and buildings. But there is a limit to how much coal can be consumed for burning clay bricks, thus the coal mining industry has not progressed much, as can be seen by noting that 1.5 million tonnes of coal was produced during 1964-65 and last year the figure was 2.2 million tonnes.

The other industrial use of indigenous coal is the consumption of a few thousand tonnes annually in 2 x 7.5 Megawatt coal fired thermal power plant of WAPDA at Sheikh Manda near Quetta, which was established in 1965 and continues to function even today inspite of its defective cooling system. This is the only coal fired thermal power plant in Pakistan and it has proven one point that indigenous coal can be used for power generation.

A few thousand tonnes of coal are consumed annually for winter heating in houses and office buildings, specially in Quetta. As Sui Gas has now been made available in Quetta the use of indigenous coal for this purpose is declining. Utilisation of indigenous coal in 1980-81 is given below:-

Brick Industry	= 82.3 percent
Power	= 1.3 percent
Household	= 1.3 percent
Others	= 12.8 percent
Distribution losses	2.3 percent
	100.0 percent

The importance of coal mining industry has shot up under the Sixth Five Year Plan. WAPDA was directed to plan for the establishment of a 500 Megawatt Lakhra coal fired thermal power plant to be established at Jamshoro near Hyderabad in Sind Province. FMDC was instructed to plan for the production of 1.4 million tonnes annually of coal from its mining leases in Lakhra Coalfield under joint venture between FMDC and private sector. Assistance was taken from USAID for the preparation of feasibility report on the use of Lakhra coal in coal fired thermal power plants and for

proving sufficient coal reserves in PMDC area in Lakhra Coalfield, which would ensure coal supply to WAPDA's 300 Megawatt power plant for 30 years of operation. The entire picture of the coal mining industry both in public and private sectors is expected to change in the near future.

II. EVOLUTION OF MINING METHODS AND MECHANISATION IN COAL MINES:

i) In Baluchistan.

Mechanisation and modernisation of coal mines are carried out not for philanthropic but for economic reason only, that is for mining large quantity of coal most inexpensively and under safe mining conditions. The chief limitations are marketing of mined coal and extent of investment available to the mining industry. In 1948 the national annual coal production was only 200,000 tonnes. As Pakistan started developing this called for more construction of houses, buildings and civil works. Baked clay bricks were and are still today the cheapest and most desired building material in the country. Consumption of bricks rose steadily thus creating more demand for indigenous coal. The annual coal production rose from 200,000 tonnes in 1948 to 1.5 million tonnes in 1964-65 and by 1984-85 it has crossed 2.2 million tonnes. These figures should be considered remembering that the actual coal production is more than reported.

This rising coal demand encouraged the private sector to invest more money in the development and mechanisation of its coal mines. Not only most of the earned profits were ploughed back, fresh investments through establishment of partnerships were made to ensure increase in coal production.

In 1948 the method of mining was a primitive form of room and pillar. With the creation of Pakistan there was mass migration of Muslims from Bharat and the entire mine supervisory and engineering staff consisted of immigrants from Dhanbad, Kani Janj and Jharia Coalfields of Bihar and Bihar. Room and Pillar method of coal mining was practised there and it was understandable that this system would be introduced in Pakistan. Coal mining was practiced by using only human labour with no deployment of machinery or equipment. Coal was cut with hand picks, shovelled into gunny bags and carried on back by mine labour all the way to the mine mouth. The entire work of mining coal and transporting it to outside the mine mouth was entrusted to a gang of workers called a "jorhee" and the gang leader was called the "jorheesar". Each person of the gang was given a particular job and collectively the gang managed to mine coal and transport it manually to outside the mine mouth, from where it was loaded in trucks to be transported to brick kilns. This method proved economically satisfactory till the mine depth increased to over 500 feet and the "jorhee" consisted of over 30 persons.

The need for mechanisation was felt to cut down the number of workers of the "jorhee". It was realised that out of 30 workers 25 were employed for the manual transport of coal from the coal face to the mine mouth. A manually operated wooden haulage device was invented. This haulage device had a manila rope of about 100 feet length and was operated by using feet of the workers. Wooden planks were affixed in the haulage way and two bags of coal were hauled up at a time by the haulage device. This method reduced the jorhee strength from 30 to 18 persons.

Ventilation inside the mines continued to be relied on natural ventilation. If water was encountered inside the mine then first it was tried to remove the water manually by using buckets and if that did not succeed then that mine was shut down.

1960 was an important milestone in the history of coal mining development in Pakistan. At that time only 400,000 tonnes

of coal was being produced annually. The Government of Pakistan felt that by 1965 the country would need 1.5 million tonnes of coal annually. The government called both the private and public sectors coal mining concerns and assigned them annual coal production targets to be achieved by 1965. PMDC, which was then PIDC, was given the figure of 1.1 million tonnes and private sector coal mining firms were made responsible for the remaining 400,000 tonnes.

For the first time a number of incentives and tax concessions were provided by the government. Import licences for importing trucks for coal transportation and mining machinery were issued. The private sector rose to the occasion and invested heavily in its mining industry for importing and installing mining machinery & trucks While the Government allocated millions of US dollars for public sector mining, it failed to arrange bank loans on easy terms for private sector mining.

It was realised that to achieve more coal production the existing coal mines needed basic mechanisation. Diesel electric generating sets were needed to provide power to operate electric winches/haulages, air compressors, water pumping sets and ventilation fans. Steel rails were required for providing the rail track and mine tubs were to be employed for coal hauling from the coal face to mine mouth. Pneumatic picks and rock drills were introduced for coal cutting and drivage of mine workings. Coal mines were becoming deeper and the above mentioned form of mechanisation was essential to cut down the strength of the jorhee back to 12 to 15 persons. Adits were driven and hand tramming system was practised where possible inside the mines.

New mining methods were introduced to bring about higher coal production with employment of lesser mine workers. Initially retreating longwall method of mining with full packing of the "goaf" area in coal seams, from where coal had been extracted, was introduced. The Government Inspectorate of Mines was cautious and thus instructed the mining firms to pack all voids created by the extraction of coal with shale, free of carbonaceous content. Thus suitable shale had to be mined from outside the mines and transported to the longwalls. This method of mining proved successful but had two serious defects. First the retreating longwall method of mining was time consuming before regular coal production could start and second the full packing of goafs with shale from outside was too expensive.

By 1965 retreating longwall method of mining with no packing was introduced successfully. A retreat of 3 feet per shift was practiced. but this method still had the defect of being time consuming before regular coal production could be obtained. To prepare the retreating longwall face two level-ways, one above the longwall and the other below had to be driven to the full prescribed length of the longwall. These level-ways were kept maintained, for which regular repair work was needed as the roof support continued to be timber. The debris recovered from the drivage of the two level-ways had to be hauled out of the mine.

By 1965 coal production reached the target figure of 1.5 million tonnes. What was unusual was that the private sector, which had been assigned the annual production target of only 400,000 tonnes, was producing 1.1 million tonnes annually, while the public sector was producing 400,000 tonnes instead of the target of 1.1 million tonnes.

The increase in coal production was forcing the private sector to cut down on cost of coal production. To do so the private sector introduced advancing longwall method of mining with modification in the ystem and with no packing of

goafs. The modifications were firstly the longwall length was reduced to about 100 feet; secondly the debris removed from the drivage of the two level-ways, one above & the other below the longwall, was packed inside. The usual size of the level was 6 feet x 6 feet, but to accommodate the debris coal upto 6 to 8 feet was removed towards the dip direction in the seam and the debris was packed in the void created by the removal of this coal in the level-ways and thirdly to ensure good ventilation at the advancing 100 feet long longwall, pillars of 50 feet in length and 25 feet in width were maintained above the lower level-way. The passages of 5 feet x 5 feet between pillars were sealed when the longwall advanced ahead. One passage nearest to the longwall was kept open to permit removal of mined coal and flow of ventilation air.

To establish the modified longwalls, haulage roads in the dip direction of the coal seam were driven and the distance between haulage roads was kept at about 800 feet. The coal seam between the two haulage roads was divided in strips or panels, each 800 feet in length and 100 feet in width. This strip or panel accommodated two longwall faces. The mined coal from these faces was transported to the nearest haulage road by hand tramming, as rail tracks were provided in all level-ways.

After removing all the coal in the panel of 800 feet x 100 feet the panel next below was taken for establishing similar two modified longwall faces. The existing lower level-way of the exhausted face became the upper level-way and thus to establish the longwall face only one level-way was driven afresh to serve as the lower level-way. Advance of 3 feet per shift of 8 hours of the longwall face was maintained and steady coal production was ensured with reduced cost of production.

Irrespective of the coal seam thickness the mine outlay in the panels and the modified longwall faces remains the same. Level-way has to be 6 feet x 6 feet. Distance between two haulages is kept at about 800 feet. If the coal seam is thicker the cost of production is lower and vice versa if the coal seam is thinner the cost of production is higher.

ii) <u>In Punjab</u>:

Mining and marketing conditions are different than in Baluchistan. The dip gradients of the seams are much less and the seam thickness on an average is thinner. One very big advantage available to the coal mining firms in Punjab is the nearness of coal consuming brick kilns. Punjab being the most populated and prosperous province of Pakistan has also most of the brick kilns. Coal mined in Punjab does not have to be hauled over long distance thus cost of truck transportation between the mines and the kilns is considerably lower.

Because of these reasons the urge to modernise and mechanise the coal mines was not as great as in Baluchistan. Improvement in mining method and mechanisation lagged behind. Employment of Jorhee system is practised in some mines but there are mines where every worker is on his own. He is assigned a working place and is paid wages on coal production basis. Both room and pillar and modified longwall system are practised.

iii) <u>In NWF Province</u>:

There is little coal mining in the province of North West Frontier (NWFP)

iv) <u>In Sind Province:</u>

In Sind Province coal was mined from Meting - Jhampir Coalfield for many years. The coal seams here belong to Laki Formation . As far back as 1935 it was known that coal existed in Ranikot Formation in Lakhra. For the first time coal was mined commercially in Lakhra by Habibullah Mines Limited in 1959. Unlike coal of Punjab and Baluchistan, Sind coal is of brown lignite quality with low heating value and high moisture and sulphur

contents. Even though Lakhra coal is of inferior quality yet it is being successfully used for burning of clay bricks in brick kilns situated in the areas of Sind Province, Multan, Bahawalpur, Faisalabad and Lahore. The sale price of Sind coal is so low that it can compete with coals from Punjab and Baluchistan Provinces.

Mining conditions in Lakhra Coalfield are very favourable compared to those existing in the coal mines of Punjab and Baluchistan. There are 3 coal seams in Lakhra but at present mining is restricted to Lilian Coal Seam, which is the top seam and is only 80 to 150 feet below surface. The seam thickness is 4 to 9 feet. Though Lakhra is an anticline the seam at the axis is flat and both the sides of the anticline dip gently, thus for practical mining purpose the seam can be assumed as flat. Because of nearness of Lilian Seam to the surface little roof pressure exists in the mine workings underground. No mine gas or water is encountered.

These favourable conditions in Lakhra have resulted in steady increase of coal production and today, according to one estimate, over one million tonnes coal is being mined annually from Lakhra Coalfield alone. Room and pillar method of mining is practiced in the coal mines of Sind Province, including in Lakhra. The mining is mostly manual. Coal is mined by using hand picks and is loaded in gunny bags, which are manually transported to the hoisting verticle shaft, where a diesel engine powered hoist is installed near the shaft mouth. The steel rope of the hoist goes through a pulley, which is suspended from a tripod affixed over the mouth of the shaft and the end of the steel rope is hooked to a tub, which is then used for hoisting the coal up. No mine safety equipment is employed. Occasionally rail track is laid for hand tramming.

Same are the mining conditions in Meting - Jhampir area but the coal seams there are much thinner than Lakhra thus the cost of production of coal in Meting - Jhampir is higher. The method of mining is the same in all coalfields in Sind and the seam thickness affects the cost of production of coal. It is because of this reason that coal mines of Meting-Jhampir cannot economically compete with those of Lakhra.

No basic infra-structure has been provided in Lakhra. A metalled road is just being constructed to link Lakhra with the Kotri-Dadu Highway. Water has to be carted from Sind River to the mines in tractor hauled steel tanks. There is no telephone or telegraph facility. The nearest police station is over 21 miles away from the mines. WAPDA has as yet not extended its electric power lines to the coal mines. Same are the conditions at Meting-Jhampir coal mines.

Inspite of the lack of infra-structure, the mine labour at Lakhra is able to earn a decent wage because of favourable mining conditions, absence of machinery and equipment and lesser overhead expenses. Labour employment practice is the same as in Baluchistan and in Lakhra labour also works in a jorhee under the jorheesar's supervision but he can mine one tonne of Lakhra coal in one shift of 8 hours when a mine worker in Baluchistan can hardly mine a third of a tonne.

Because of these reasons the method of mining has not changed much and need for mechanisation has not been felt. If Lakhra coal is used for power generation in coal fired thermal power plants, which may be established by WAPDA or private sector, then the mining picture will change drastically. The deman of the power plants will enforce modernisation and mechanisation of coal mines. Heavy capital investments will have to be made and the cost of Lakhra coal

production will rise considerably.

v) Further evolution in mining methods and mechanisation will depend upon how much coal is required in the country. If annual coal consumption keeps on rising 10 percent per year, then the existing manual methods of mining will suffice. Progressive mining firms will adopt the modified advancing longwall method of mining with partial mechanisation, which means installation of diesel electric generating sets, air compressors, rail track and mine-tubs, haulage/winches, ventilation fans, water pumping sets, pneumatic picks and rock drills.

With installation of coal fired thermal power plants the requirement of indigenous coal will rise manifold, which will result in modernisation and mechanisation of coal mines. Proper advancing longwall method of mining will have to be introduced. The length of the longwall faces will have to be increased from 100 feet to over 300 feet. Hydraulic steel props will replace timber support. Mechanical coal cutters or shearers will have to be installed. Chain and belt conveyors will be employed where needed. Mining machinery & equipment already being used will continue to operate but these will have to be of bigger capacity and better quality.

In Punjab and Baluchistan permanent mine workings, such as haulage roads, levelways and ventilation roads will have to be of bigger sizes and safer from spontaneous combustion underground. The drivage of these workings will have to be done in a suitable stratum below the coal stratum. In Baluchistan a few mining firms have already started such drivage below the sandstone bed, above which the bottom seam rests. The size of these drivage is 7 feet in height and 8 feet in width. As the sandstone forms the roof of these drivages, there is no breakage of timber support owing to roof pressure. Mine workings of bigger sizes will permit better ventilation underground and installation of more efficient coal haulage system.

Modernisation of mines will call for better residential, recreational and underground working conditions for labour and staff. Labour wages linked with coal production will encourage labour to work harder. A training programme will have to be launched to train labour and staff in the use of modern mining machinery and how to repair and keep it in operational condition.

Mine safety will have to be much improved and all required mine safety equipment will have to be provided. All machinery and equipment installed underground will have to be suitable for use in gassy coal mines.

III. <u>Technical problems in coal mines</u>:

a) <u>In Baluchistan</u>:

Coal deposits in Baluchistan belong to Eocene age. They are existing in syncline or remains of synclines and because of geological disturbances the coal bearing areas are much folded and faulted. Mining conditions in the coal mines are unfavourable. The seams dip steeply. There is heaving of floor & considerable roof pressure underground in the mines, which calls for regular change of timber mine support. The underground roads and mine workings require continuous repairs. Dangerous mine gases exist in the mines. All mines are subjected to fire-damp gas, which because of its explosive nature cause many mine accidents. Black damp and carbon monoxide gas are also encountered. Water is present in almost all the mines, calling for water pumping.

As the coal mines in Baluchistan have been worked for a long period therefore these mines have become deep. Some of the mine workings are 3000 feet away from the mine mouth. The unfavourable underground mining conditions have

put limitation on economical mechanisation of mines.

Quality of coal varies from mine to mine within the same coalfield, which results in different sale prices for these coals. In Sore Range Coalfield the difference between the best and the poorest quality coals is as high as Rs.300/- per tonne. The mining concern which has better quality coal has tremendous edge over another firm with poor quality coal, even though they be neighbours in the same coalfield. The mining industry considers this variation of coal quality and of coal seam thickness as act of God. The coal deposits were created by nature as such.

There are usually two to three coal seams which can be mined economically. The variation in seam thickness is from mine to mine within the same coalfield. In Sore Range the thickness varies from 15 inches to eleven feet. Cost of coal production much depends on the thickness of coal seam because the expenses on creation of long-wall faces and coal getting places are the same. Thicker coal seam will result in more coal production and benefit both the concerned mining firm and the mine labour.

Government of Pakistan had as far back as 1948 engaged the famous consulting firm, Powell Dufferyn to advise on suitable methods of coal mining in Sore Range. Powell Dufferyn had advised that incline shafts in a suitable stratum below the coal seams should be established to provide entry to the the coal mines, haulage roads for mined coal transport and mine ventilation. All coal mining firms ignored the advice as drivage of inclines in another stratum other than the coal seam stratum was considered expensive. Powell Dufferyn also did not recommend establishment of adits. Time has proven that Powell Dufferyn was right. Incline shafts in the coal seam stratum are prone to spontaneous combustion causing mine fires. The mine ways are subjected to much roof pressure and floor heaving, resulting in heavy repair and mine timbering expenditures.

b) <u>In Punjab</u>:

Mining conditions in Punjab are not as bad as in Baluchistan, however there are many similarities. As mine modernisation and mechanisation is lagging behind compared to Baluchistan, this gives an advantage to the mining firms of Punjab. They can take benefit from the experience gained in Baluchistan. They can make selection in regards to mechanisation and improvement in methods of mining.

c) <u>In Sind</u>:

Favourable mining conditions exist in this province. The coal seams are flat or slightly dipping. While Meting-Jhampir has thinner seams, Lakhra has the right thickness of coal seam from 4 to 9 feet for easy mining.

In regards to technical problems the major set back at present is the lack of infra-structure, specially WAPDA's electric power supply, without which mines cannot be mechanised and modernised. Metalled roads are required to link the mines with the national highways, as the chief form of coal transport is by trucks. Telephone and telegraphic facilities are required. To maintain law and order in the coalfields police stations have to be opened at suitable places. Short supply of water is a serious problem, as water has to be transported from Sind River to the coal mines.

There are three chief underground problems in Lakhra Coalfield. The first one is that the floor level of the coal seam keeps on changing up or down, even though the coal seam is almost flat. These ups and downs create steps of six inches to eighteen inches and are frequently encountered every 100 feet or so. Surprisingly similar steps are not so much found in the roof of the coal

thus the thickness of the coal seam keeps on changing. If there is a down step the coal seam becomes thicker by as much as the depth of the step. Similarly if there is an up step the coal seam becomes thinner. At present this does not pose a serious problem as coal is mined manually. When these mines are mechanised and modernised then the coal cutting machinery installed at the longwall faces will have to accommodate these up and down steps in the seam.

The second chief problem is that above the coal seam there is a bed of loose silica sand. The distance between the coal seam and the silica sand bed varies from a few inches to a few feet. If the distance in-between is a few inches then loose silica sand pours down during coal cutting operation. ways and means will have to be found to check the sand flow at the longwall faces.

The third chief problem is that in the goaf area created by the removal of coal from the coal seam, the roof of the seam does not gradually sag down. Big blocks of the roofing come down suddenly, causing small air blasts and anxiety to mine workers. At present this problem has not caused many accidents as a primitive form of room and pillar method of mining is used and the width of the rooms is kept between 25 to 50 feet. With the introduction of mechanised longwall method of mining, protective measures will have to be taken against these falling blocks.

IV. FUTURE OF COAL MINING IN PAKISTAN:

As mentioned before there is a limit to how much indigenous coal can be consumed by the brick industry. Already over 82 percent of the annual coal production is used by this industry. If unreported coal production is kept in mind this percentage will rise to 90 percent. Brick consumption in Pakistan has slightly declined owing to reduction in remittances by overseas Pakistanis, which has resulted in lesser construction of houses. Cement industry is reluctant to use indigenous coal to replace natural gas or imported oil.

Besides the brick industry there is no major consumer of indigenous coal. Over production of coal has brought about active competition amongst coal producers. Coal mining firms of Baluchistan have suffered the most during the last one year. Selling price of coal is steadily going down and today the selling price is less than the cost of production. If this situation continues for long, many coal mines in Baluchistan will shut down.

Mining firms in Lakhra and Meting-Jhampir are also suffering. Their coal selling price is also below cost of production. Huge stocks of coal have accumulated near the mines. The public sector including Pakistan Mineral Development Corporation has also been hit. As Sind coal is of lignite quality and is prone to spontaneous combustion, these coal stocks are on fire. If this situation continues mining operations in Sind province will have to be curtailed.

Coal mining firms in Punjab are not that bad off. The nearness of brick industry is a very big advantage. Truck transportation between Quetta and the brick kilns in Punjab runs between Rs.400 to 500 per tonne, while in case of coal produced in Punjab the truck transport does not cost over Rs 100 per tonne. Coal mining will not get badly hit by the existing unfavourable marketing condition.

If this situation continues I foresee mining industry suffering financial losses over the next 5 years till brick consumption rises considerably or other industrial source of indigenous coal consumption is created.

The obvious new industrial coal

consuming source is the establishment of coal fired thermal power plants by WAPDA and private sector. As mentioned before Government of Pakisan has allowed private sector to come forward and establish power generation plants. It will be technically possible to generate 2100 Megawatt power through establishment of coal fired thermal power plants over the next ten years and this would call for annual indigenous coal supply of ten million tonnes, for which proven mineable coal reserves of 300 million tonnes would be required to guarantee coal supply for 30 years of power plant life.

Indigenous coal fired thermal power plants of 25 to 50 Megawatt can be established by private sector near Quetta, Mach, Harnai, Makerwal, Salt Range, Lakhra and Meting-Jhampir. WAPDA is planning to set up a number of 300 Megawatt coal fired thermal plants based on Lakhra coal. Government of Pakistan and private and public sectors have to get together and put up concerted efforts to bring about the establishment of these thermal power plants.

With the setting up of these power plants modern coal mining both in public and private sectors will get established on sound foundation. The widening gap between power generation and power demand in Pakistan will keep on calling for more such power plants and more coal production.

From the above it is clear that future of coal mining in Pakistan will depend on the policies adopted by Government of Pakistan. Private sector will continue to be the major coal producer but there is place for both private and public sectors in the field of mining industry.

V. WHAT NEEDS TO BE DONE BY PRIVATE SECTOR:

Private sector in coal mining industry will have to undergo a major change if demand for indigenous coal is created for power generation. Heavy investments would be required to mechanise and modernise the mines. Proper longwall method of mining will have to be introduced. Hydraulic props will replace timber mine support. Chain and belt conveyors for underground coal transport will also have to be introduced. Compressed air will be needed to operate pneumatic picks, rock drills and pneumatic equipment. Mine safety equipment will be required. Suitable mining machinery will have to be selected and installed.

At present the private sector consists of mostly of proprietorship and partnership firms with a few private Ltd. companies. To give sound financial base to the industry these will have to be encouraged to convert into public limited companies.

Small coal mining firms could exist without much change as long as they are not forced to conform to the full requirements of mine supervisory staff and mine safety standards dictated by the Mines Act. Coal produced by them using existing labour intensive methods will continue to be cheaper than coal produced by modern and mechanised mines. This situation could change if labour wages of mine workers rise manifold and the requirements of safety under the Mines Act are strictly enforced.

I am of the view that the private sector be allowed to go through evolution according to the dictates of the law of supply and demand and free marketing environment. To enable the private sector to produce needed coal for power generation Government of Pakistan should encourage the private sector and provide more incentives, tax concessions and facilities.

VI. WHAT NEEDS TO BE DONE BY GOVERNMENT OF PAKISTAN:

We continue to hear repeatedly that

Government should encourage the private sector and provide more incentives, tax concessions and facilities. These requirements need to be spelled out as follows:-

i) Government should realise the importance of private sector in coal mining industry:

Government of Pakistan is promoting private sector specially in the field of industry. The Government has realised that private sector in mining produces over 87 percent of the national annual coal production and that the private sector would continue to be the major coal producer for the next ten years.

ii) Bank Loans for Coal Mining Industry at 3 Percent Concessional Interest rate be Given:

In the recent past Government in national interest had provided bank loans to exporters of Pakistani goods at the concessional interest rate of 3 percent. This concession was given to promote exports to improve the export-import imbalance. Now national interest demands that indigenous coal fired thermal power plants be established, for which coal production in Pakistan needs to be increased. The private sector is requesting Government to provide bank loans for investment in mining at the concessional interest rate of 3 percent.

iii) Central Board of Revenue Should Amend Income Tax Rules to Allow 100 Percent Depreciation on Expenditure Made by Mining Firms on Construction Works on Buildings, Houses and Roads at Mine Sites:

Coal mines are located in wilderness far away from towns. Buildings at mine sites are valuable as long as mining operations continue and the mine is productive. While in towns land and buildings appreciate in value with time, buildings at mine sites have no resale value. Private sector feels justified to request Government to allow 100 percent depreciation as is allowed in case of machinery installed at the mines.

iv) Depletion Allowance:

At present 15 percent depletion allowance is allowed to mining companies but this is subject to the condition that the depletion allowance does not exceed 50 percent of the total invested money in the mining venture. The private sector has requested the Government to remove the condition and allow the depletion allowance to all coal mining firms. The private sector has further pleaded for increasing the depletion allowance from 15 to 20 percent.

v) To Encourage Coal Mining Firms and Private Limited Companies to Convert to Public Limited Companies:

At present 90 percent coal mining concers are partnership firms. A few are private limited companies. There is not a single public limited (coal mining) company in Pakistan. If sound financial foundation is to be provided then these mining concerns have to be encourage to convert into public limited companies with their share stock quoted on Karachi Stock Exchange.

As the situation exists today, owners of mining concerns have lot to lose financially if their concerns convert to public limited companies. The reason is that they have invested heavily in their coal mining ventures in the establishment of permanent mine workings such as tunnels, adits, verticle and incline shafts, level-ways, haulage roads and ventilation roads; but they had for simplicity of book keepin charged the expenditure as coal production cost and had not entered these expenses as mine development assets. This was permitted by the Income Tax Department as it made no difference towards assessment of income tax, but under this practice balance sheets fail to show all the mine development assets.

Private sector has requested that Government should permit them, as a special case, to revalue the mine development assets on present day value of these permanent mine workings and allow them to reflect the revalued figures in balance sheets as mine development assets against issue of "bonus shares", on the condition that these mining firms would convert to public limited companies. The private sector has proposed that a special committee of the Government (under the Ministry of Finance) may be formed to approve the revaluation of the mine development assets on present day value.

It is relevant to mention here that the Federation of Pakistan Chambers of Commerce and Industry (FPCCI), which is the highest body in the field of commerce and industry in Pakistan, has strongly recommended to Government of Pakistan to grant all the above mentioned incentives as requested by the private sector. These recommendations are under consideration of the Government.

At present mining industry contributes little in form of income tax. If the above mentioned incentives are given, Government will not have to lose any more than what it is getting from the mining industry. These requested incentives can result in the formation of modern mechanised coal mining industry in Pakistan.

vi) Proving Coal Reserves:

Besides the above, Government has to take a number of steps to determine enough mineable coal reserves in all known coalfields to enable coal mining industry to produce ten million tonnes of coal annually for 2100 Megawatt coal fired thermal power plants. By obtaining foreign aid and loans or from Pakistan's own resources, Government has to finance a major core collecting drilling programme for determining coal reserves and coal quality in all the known coalfields. Drill holes at one kilometer apart need to be drilled all over the coalfields, irrespective of whether the mining rights belong to private or public sectors. At least 200 drill holes per year should be drilled over a period of next ten years. By the end of this period drilling of 2000 drill holes will prove enough coal reserves to meet the requirements of much more than 2100 megawatt coal fired thermal power plants.

There is simply no way to avoid the drilling programme. It has to be done. The sooner the Government realises this, the better it will be for reducing the gap between power generation and power demand in Pakistan. Who should undertake this drilling programme, has to be decided by the Government. Geological Survey of Pakistan could establish a separate department for this, as long as Government provides the required financing. International tender could be floated and reputable companies, who are experts in drilling, could be given contracts to carry out the required job. Private sector in drilling field could be invited to come forward in this regard. It is for the Government to decide how this is to be done.

VII CONCLUSION:

I submit my conclusions as follows:

a) The policy now adopted by the Government will decide the fate of private sector coal mining. If indigenous coal fired thermal power plants are not established in sufficient number and capacity, the existing private sector coal mining industry will suffer tremendously and many coal mining firms in Baluchistan will close down with 5 years from today.

b) If the Government can encourage cement industry, both of private and public sectors, to convert from use of natural gas to indigenous coal that would create additional demand for coal

and will benefit the mining industry. The gas being used by the cement industry could be diverted for value added industrial use. It is my opinion that at present it would be difficult for the Government to force the cement industry to convert to coal, as the cement industry will be able to offer many excuses for not being able to do so.

c) Public sector coal mining should be able to co-exist with private sector coal mining, as the public sector has the advantage (over the private sector) of Government financing and foreign aid and soft loans, irrespective of whether the public sector makes profit or loss in its mining ventures. This has been so in the past. Healthy competion from the private sector will promote better efficiency in the the public sector organisations.

d) The private sector is capable of shouldering the responsibility of producing most of the coal, which will be needed by coal fired thermal power plants, as the private sector is versatile and vigorous, subject to the condition that the incentives requested by the private sector are given by the Government. I believe that the private sector coal mining will perform better than our present expectations. This has been the case in the past and similar performance can be expected from it in future.

Financing Lignite Projects in Thailand

by Aswin Kongsiri, Executive Vice President
Industrial Finance Corporation of Thailand

Project Financing in Thailand

Before considering the specific aspects of financing lignite projects in Thailand, it will be useful to look first at the overall situation regarding the availability of project financing in Thailand, as the approach to financing lignite projects has to contain all the basic elements of normal project financing. The different problems encountered in financing lignite projects will be brought out when we discuss the case of the Thai Lignite Mining (TLM) project.

The Financial System in Thailand consists of 16 domestic commercial banks, 14 branches of foreign commercial banks, over 100 finance companies of various types, and a number of specialised financial institutions established by the Government, namely the Bank of Thailand (the central bank), the Goverament Savings Bank, the Government Housing Bank, the Bank for Agriculture and Agricultural Cooperatives, and the Industrial Finance Corporation of Thailand. Many foreign banks have expressed a keen interest in opening branches in Thailand, but the Government's policy on this has been quite restrictive; nevertheless over 30 foreign banks have established representative offices in Bangkok. Other types of financial institutions, such as insurance companies, are of course well established in Thailand, and the stock market, the Securities Exchange of Thailand (SET), has been in operation since 1975. While foreign exchange transactions are supervised by the Bank of Thailand, Thailand's foreign exchange policy has been relatively relaxed and the raising of funds from abroad by both the private and public sectors for legitimate investment purposes has not been restricted. Therefore financing arranged by financial institutions based in neighbouring financial centers such as Hongkong and Singapore is fairly common, and off-shore sources of funds can be considered to be reasonably accessible for enterprises located in Thailand.

Thailand's financial system can be considered to be well developed and sophisticated in terms of commercial banking and trade financing services. The branch network of the commercial banks is extensive, and while there is a natural concentration in Bangkok, which is by far the largest city in Thailand, virtually all towns in the country are served by at least one commercial bank branch. Electronic banking services are already being provided to bank customers in Bangkok, although the transfer of funds to and from Bangkok and the provinces is still slow compared with more developed financial systems. The finance companies, however, have very limited branch networks as most of them concentrate their operations only in the Bangkok area and the major cities outside Bangkok.

The legal framework under which the financial system operates is essentially based on Western concepts, and the procedures and documentation for entering into financial transactions are relatively simple and well established. Mortgages on movable and immovable property, pledges or assignment of receivables or securities, and personal guarantees, are the most common form of loan security used. For financial institutions located outside Thailand which want to have a lien on the fixed assets of a borrower in Thailand, it is possible to enter into a security sharing agreement with a domestic financial institution which can act as security agent. It should be noted that intentionally writing a cheque on an account with insufficient funds can be treated as a criminal offense. Therefore the use of post-dated cheques as loan security and the discounting of cheques to raise funds has become a common practice in the Thai financial system. Another less developed area is lease financing; while leasing services are available in Thailand, the tax system, which does not distinguish between financial leases and rentals, makes the financial cost of leasing higher than for hire

purchase or other types of loans. With regard to taxation, remittances of interest and dividends abroad are subject to witholding tax, but this tax can be reduced or eliminated under double taxation agreements that Thailand has with many other countries.

Despite the number and variety of financial institutions mentioned above, Thailand's financial sector is dominated by the domestic commercial banks. Foreign bank branches account for less than 5 percent of total commercial banks' assets. The largest and most successful finance companies are controlled by Thai commercial banks. The only significant competitors to the Thai commercial banks are the specialised financial institutions set up by the Government which are by definition limited in their scope of activities. Furthermore most of the commercial banks, even the largest ones, are controlled by family groups whose interests extend beyond banking into commercial, trade and industrial activities. In other words the privately-owned banks are the centerpieces of extensive and powerful economic groupings. The exceptions are the two banks currently owned by the Government, the most important of which is the Krung Thai Bank which the third largest in terms of assets. This bank serves as the main commercial banker for the Government and its state enterprises.

Project Financing. The preceding paragraphs provide the setting against which we can consider the state and practice of project financing in Thailand. As can be expected, given the evolution of the Thai financial system, the concept of project financing has only been recently introduced and can be said have been practised only over the past 25 years in the private sector. As in most developing countries project financing was introduced by the World Bank after the Second World War for large infrastructure projects, such as power generation and irrigation, in the public sector. Project financing in the private sector was introduced on a systematic basis after the establishment of the Industrial Finance Corporation of Thailand in 1959. Even now only about 6 of the largest commercial banks and about 4 of the largest finance companies have any capability in project financing. Many medium to large scale projects in the private sector still have to rely on the services of foreign financial institutions to arrange project financing. This does not of course mean that projects are not financed by domestic financial institutions. However loans for projects are usually based on the collateral available and are often granted on an overdraft basis which is the most popular form of credit facility in Thailand. Credit facilities are also often granted on a 'clean' basis or against only a personal guarantee based on the reputation of a family group which reflects the business environment in which virtually all enterprises are family owned and managed. Poor accounting practices and the reluctance of family businesses to reveal information for tax and other reasons have been cited as causes for the lack of interest in project financing in most financial institutions.

Project financing in the public sector has usually been undertaken under the leadership of a multilateral financial institution such as the World Bank or the Asian Development Bank (ADB) or a bilateral aid agency, although other financial institutions are often involved through co-financing or the provision of suppliers' credits. Some of the larger domestic financial institutions also participate in these public sector project loans through their overseas branches, but generally do not play any role in the evaluation of the project. The various lignite projects undertaken by the Electricity Generating Authority of Thailand (EGAT) were financed by a combination of World Bank or ADB loans plus co-financing by the private sector project financing and sovereign risk financing as all projects in the public sector have either direct or indirect recourse to the Government. As Thailand's credit rating in the international capital markets is still quite good, many foreign financial institutions are eager to lend to Thailand under the guise of project financing, especially for state enterprises, while in fact the decision to lend is based on Thailand's creditworthiness and not on the viability of the project itself.

Arranging finance for projects in the private sector without recourse to the Government presents a greater challenge. As mentioned earlier, the Industrial Finance Corporation of Thailand was the pioneer institution in this field and continues to be the pre-eminent institution for project financing in the private sector. The Industrial Finance Corporation of Thailand (IFCT) was established under a special law in 1959 to operate basically as a private sector institution with a majority of private sector shareholders. The special law granted IFCT certain privileges which enabled it to mobilise long-term resources at relatively low cost. IFCT, however, retains its autonomy in its investment decisions and in determining its interest rates, and its shareholding structure, in which the Government directly and indirectly owns only 26 percent of the shares, while the remaining shares are spread over a large number of both institutional and individual shareholders, both Thai and foreign, enables the Corporation to be objective and professional in the conduct of its operations. IFCT's shares are listed and actively traded on the Securities Exchange of Thailand, and its steady record of profitability and regular dividend payments over the past 20 years have enabled it to increase its capital base to keep pace with the rapid growth of its operations. IFCT's other sources of funds were previously based mainly on loans from the World Bank and the ADB and the Thai Government, but now the Corporation has been able to diversify its funding sources into the international capital markets, as well as to raise domestic currency resources through debenture issues in the Thai financial system, in both cases without having to depend on a Government guarantee. IFCT can now make loans of up to US$ 20 million equivalent for a single project with a repayment period of up to 12 years at a fixed rate of interest, as well as take equity participations in the projects it finances. In 1985 the Corporation approved loans amounting to about US$ 113 million equivalent for 140 projects in a broad range of industrial enterprises.

The project financing methods used by IFCT are based on the techniques introduced by the World Bank and adapted for use by development finance institutions, many of which were established in developing countries in accordance with the World Bank 'model' during the 1950's. These methods included an economic analysis of projects using shadow prices for larger projects to ensure that they made a real contribution to the economy commensurate with the cost of the resources used. The techniques of economic analysis are still controversial and many question its usefulness. However the main objective of project financing must be to make the lending institutions as sure as reasonably possible that the project will be able to service its debt under a variety of assumptions, and at the same time to provide the project sponsors with the lowest cost financing available and on terms and conditions which are most suitable for that project. The various critical components affecting the viability of a project are well-known; the skill is in assessing the strengths and weaknesses of any particulr project with respect to these components, and making reasonable assumptions about how changes in these components can adversely affect the project's ability to service its debt. Project sponsors are often justifiably annoyed by bankers who through lack of understanding or experience overestimate the downside risks of a project and as a result require additional security from the project sponsors. Financial institutions in Thailand are no less conservative than in other countries and a number of project failures in the recent past has not helped them to become more aggressive.

One important aspect of project financing in developing countries must be mentioned here as it is particularly relevant to energyrelated projects. In larger projects the raw materials used or the products to be produced are often politically sensitive and may be subject to controls or restrictions which are difficult to predict. Even if assurances have been given in writing by the current Government, future Governments may for various political or other reasons follow a different policy. This kind of issue is often used by foreign financial institutions as an

excuse to require a Government guarantee. Thailand has correctly and successfully resisted this requirement by stipulating in its Government guarantee law that only enterprises in which the Government holds more than 70 percent of the shares can be guaranteed by the Government. As the trend is towards less rather more state enterprises, more projects will have to be based on non-recourse financing. Moreover, unlike many developing countries in Asia, Thailand has only one industrial development financing institution, namely the IFCT, so there are no fully Government owned industrial DFI's which can provide an indirect Government guarantee. The strict policy on the issuance of Government guarantees has been an important factor in protecting Thailand's creditworthiness, as well as in ensuring that project financing in the private sector is done on a realistic basis. Some good projects may have failed to be implemented or have been delayed as a result, but on the whole this policy has prevented a large number of bad projects from being financed under the protection of sovereign risk.

In summary a typical medium to large scale project in Thailand is financed by a combination of a fixed rate long term loan from IFCT and a medium term loan from a commercial bank on a floating rate of interest. The same commercial bank would usually provide the working capital funds and other trade financing facilities. Some projects may use a suppliers' or export credit which is guaranteed by the commercial bank. For larger projects a consortium of banks may be formed, both to provide direct financing and to guarantee off-shore sources of funds. For exceptionally large projects considered to be of national importance, the Government may request all the commercial banks to participate in the financing, but this politically motivated approach is cumbersome and has been increasingly resisted by the commercial banks. The International Finance Corporation (IFC) and other DFI's in developed countries have also financed a number of private sector industrial projects in Thailand in the form of both loans and equity. Their equity contribution in particularly important as equity finance continues to be the biggest constraint to project financing in Thailand. IFCT usually requires that at least 30-40 percent of the project cost is financed by equity; commercial banks tend to be less strict on debt-equity ratio requirements as they lend for a shorter term and place more emphasis on collateral coverage. Even when the project is a joint-venture with a strong foreign partner, the size of the investment is often limited by the ability of the local partner to raise equity financing.

Foreign Exchange Risk. One of the main reasons that financial institutions in developing countries are not more involved in project financing is their lack of access to sufficient long term funds. Capital markets in developing countries are usually oriented towards investments in short term securities. In Thailand the longest term fixed deposits of 3 years with the commercial banks account for only a small percentage of total deposits. Tax incentives and interest rate differentials are not sufficient to attract funds into bonds or debentures, nor is the secondary market developed enough to provide liquidity for investors in long term securities. The Government's domestic funding requirements absorb most of the institutional long term funds available. The main source of medium and long term funds for project financing is therefore foreign currency loans. While Thailand's foreign exchange policy remains relatively open and some projects are in a position to bear some foreign exchange risks, the commercial banks can provide projects with term loans by guaranteeing foreign currency loans. However under the recently introduced floating exchange rate regime fewer projects are able to bear the foreign exchange risks; therefore some mechanism for alleviating this problem was needed if a sufficient supply of long term funds was to be provided for project financing.

As Thailand's lending project financing institution IFCT was acutely aware of this problem and has developed a mechanism which may be of interest to other countries. IFCT mobilises most of its long term resources from abroad with repayment periods of at least 10 years and on-lends these funds to projects in Thailand without

passing on the foreign exchange risk. In order to protect its financial position against extreme fluctuations in exchange rates, IFCT has entered into an agreement with the Ministry of Finance under which IFCT has to pay a percentage of each foreign exchange loan into a reserve account on a monthly basis. If realised foreign exchange losses exceed the funds in the reserve account (which is accumulated from all outstanding foreign loans), then the Ministry of Finance will advance funds to IFCT which IFCT has to repay annually at a fixed minimum amount or as a percentage of its net profit, whichever is higher. Realised foreign exchange gains are paid into the reserve account. The key factor is the fixing of the percentage of each loan to be paid into the reserve account which is determined in accordance with the currency borrowed, its exchange rate trend vis-a-vis the local currency and the interest rate paid. The percentage can be adjusted if there are significant changes in these factors. This mechanism forces IFCT to be aware at all times of the real cost of borrowing foreign currency funds and this cost is passed on to the project in terms of a higher fixed interest rate rather than a highly uncertain foreign exchange risk. Furthermore IFCT is in a much better position than project borrowers to manage foreign exchange risks by diversifying currencies and obtaining long maturities. This mechanism has worked reasonably well over the past 12 years during which IFCT has only had to have recourse to an advance from the Ministry of Finance once for an amount of about US$ 1 million. If the foreign exchange risk is completely absorbed by the Government as in the case of most state-owned DFI's, the danger is that the real cost of foreign currency funds will not be reflected in on-lending rates with distortionary effects on the cost of capital.

The Importance of Lignite in Thailand's Economic Development.

Thailand is in a similar position to other oil importing countries which placed high priority on the development of domestic sources of energy following the oil crisis of the 1970's in order to reduce the greatly increased foreign exchange cost of imported oil. Potential domestic sources of energy included hydropower, solar power, oil, natural gas, oil shale, and lignite. Most of these domestic energy sources have been aimed at electricity generation and have been developed by the Electricity Generating Authority of Thailand (EGAT), one of Thailand's largest and most successful state enterprises. The domestic sources of energy which have achieved the best results have been hydropower, natural gas, and lignite. Thailand's hydropower resources have been developed on a large scale since the end of the Second World War and by 1985 EGAT was operating 12 hydropowered plants with a total installed capacity of about 1.8 million kilowatts, and has about another 28 possible hydroelectric projects with a total potential installed capacity of about 4.45 million kilowatts. The development of natural gas in the Gulf of Thailand has begun to bear fruit; four offshore gas fields are now producing 350 million cubic feet of gas per day, plus 17,000 barrels per day of condensate, and have the capacity to increase production by another 30 percent. EGAT has completed the construction of a natural gas/fuel oil-fired electricity generating plant with a capacity of 1.82 million kilowatts, as well as a number of other smaller natural gas-fired power plants, and has converted some of its existing plants from fuel oil to natural gas. It is estimated that at the end of 1985 49 per cent of electricity generation is based on natural gas, 26 percent on hydro energy, and 10 percent on lignite.

The share of lignite in electricity generation is still relatively low even though the development of lignite mining for this purpose had started as early as in 1955 at the Mae Moh mine in the north of Thailand. Greater emphasis had been put on the use of natural gas since the oil crisis of 1973, while the use of hydropower had peaked at a level of about 50 percent of electricity generating capacity in 1970 and gradually declined to 26 percent in 1985. The first real expansion of the Mae Moh lignite mine was undertaken in 1973, at the same time as EGAT

started the construction of the first 75,000 kilowatt unit of the Mae Moh lignite power plant. Since then EGAT has built 7 lignite-fired generating units at Mae Moh, the last of which was commissioned at the end of 1985. The first phase of the project was completed between 1973-77 during which 3 units of 75,000 kilowatts each were built. The mine had to supply 1.5 million tons of lignite per year for these 3 units. The second stage of the development of the Mae Moh lignite mine and power plant was completed in 1985 after 4 units of 150,000 kilowatts had been built for which the mine had to supply 5.5 million tons of lignite a year. The investment cost of the mine, including the cost of expansion over the years, is estimated to be about Bt. 7,665 million to supply sufficient lignite for 7 generating units with a total capacity of 825,000 kilowatts, and to substitute for more than Bt. 5,500 million in oil imports per year.

The third stage of development of the Mae Moh lignite power plant envisages the construction of 3 more generating units with a capacity of 300,000 kilowatts each. Work has already started on the first of these units, for which financing by the ADB of US$ 122.6 million has been obtained to cover part of the total investment cost of about Bt. 7,000 million. The other two units have been postponed due to the country's public sector financing constraints. Lignite reserves at the Mae Moh mine are sufficient to supply the planned expansion. While a 1971 study indicated that the total quantity of Mae Moh Lignite proven reserves was about 55 million tons which would be adequate to supply a generating capacity of 225,000 kilowatts for 30 years, a survey undertaken in 1980 using more advanced and efficient technology and equipment indicated that proven lignite reserves exceed 500 million tons. The mine can be developed so that by 1992 it can produce 12 million tons of lignite per year to supply 10 generating units with a total capacity of 1.725 million kilowatts.

Use of Lignite by Industry. From the time that lignite was first discovered in Thailand in the southern province of Krabi in about 1892, many efforts were made to use this domestic energy resource, apart from the production of electricity. Earlier this century an attempt to use lignite in railway steam engines was made, but the low heat value of the lignite and the inaccessibility of the deposits at that time made the project unfeasible. More recently, the early 1960's, the Government decided to use lignite from the Mae Moh mine in the production of chemical fertilisers. The Chemical Fertiliser Co., Ltd. (Chemferco) was established in 1963 and started operations in 1966. The plant was built by a consortium of German companies with an initial investment cost of about Bt. 300 million which was a considerable sum at that time. The bulk of the financing was provided by the KfW, a German Government export financing institution, under a Thai Government guarantee with a repayment period of 8 years at an interest rate of 6 percent per annum. The lignite would be used by a steam generating plant which had been originally used to provide electricity for the construction of the Bhumipol Dam, and in the gasification process for the chemical fertiliser plant. Unfortunately the process design of the plant was not suitable for the characteristics of the lignite available, resulting in chronic production problems, and the plant never achieved more than 50 percent of its production capacity. At the same time other raw materials, such as naptha and natural gas were being used to produce chemical fertilisers which were far more efficient and cost-effective. Chemferco's problems were further exacerbated by a change in the consumption pattern for fertilisers in Thailand away from the types of fertilisers it was producing. The Chemferco project can be considered to be a case where project financing was inadequately carried out, partly no doubt because the bulk of the financing was covered by a Government guarantee.

In 1970 the Government increased lignite production in the north of Thailand with the objective of encouraging the use of lignite for tobacco curing as a substitute for wood fuel. The use of wood fuel was seen as a major cause of the depletion of Thailand's forests. Other industries became interested in the use of lignite to replace

both wood fuel and fuel oil following the oil crisis of 1973. Lignite was considered to be particularly suitable as it had a low cost in terms of heat value and could thus result in considerable savings in energy costs, and it was relatively easy to convert fuel burning systems from fuel oil to lignite and at a low investment cost compared to other sources of energy. As a result many other types of industry, apart from tobacco curing, changed to lignite as their source of energy. These industries include cement, limestone, steel, paper, noodles, sugar, vegetable oil, canned foods, and mineral refining. In fact these industries also began to use imported coal in increasing quantities. In order to discourage this trend the Government has accelerated the development of lignite production in Thailand by encouraging the private sector to undertake lignite mining, and by recently increasing the tariff on imported coal. Nevertheless with the increasing availability of domestic supplies of natural gas, many industries are using natural gas as a substitute for fuel oil, although the use of natural gas for industrial purposes will be constrained for some time by the lack of access to a gas pipeline. Furthermore the Government places higher priority on natural gas for high value-added uses, such as the production of fertilisers and petrochemicals, than for fuel oil substitution in the industrial sector.

There are currently 12 lignite mines in operation in Thailand, of which 3 are operated by the Government and 9 by the private sector. Nine mines are located in the northern region, and one mine each in the north-eastern, western and southern regions. Annual production has increased from about 761,340 tons in 1976 to about 2,338,470 tons in 1984. In 1976 virtually all the production came from the 3 Government-owned mines, particularly EGAT's mine in Krabi as the expansion of the Mae Moh was still at an early stage. The first private sector mine, Phrae Lignite Co., Ltd., only began to start production in that year. In 1984 the Government-owned mines accounted for about 85 percent of total production, but there were now nine private sector mines opened, six of which were in operation and produced about 362,400 tons of lignite. After the implementation of its massive expansion program, the Mae Moh mine alone accounted for about 71 percent of total production. With regard to the import of coal and coke mentioned earlier, in 1976 about 36,766 tons valued at about Bt. 86 million were imported. By 1984 the volume of imports had increased to about 214,307 tons valued at about Bt. 364 million. It is noticeable that the unit cost of imported coal and coke has been on a declining trend in the past four years even in nominal baht terms, and is therefore becoming increasingly competitive with the cost of domestically produced lignite, especially as transportation costs are also declining in real terms. The Government has therefore taken steps to provide a higher level of tariff protection for domestic production.

In summary the Thai Government continues to place a high priority on the development and exploitation of domestic sources of energy despite the decline in world energy prices. Lignite is already playing a significant role in electricity generation, as a substitute for wood fuel in the tobacco curing industry, and as a source of energy in the cement industry. The potential for its increased production and use is great as the commercially exploitable reserves are estimated to be abundant, and as the technology required for its application in industry is relatively simple and inexpensive.

The Financing of Lignite Projects in Thailand

This paper will mainly consider the various factors related to financing a lignite project in the private sector, as most of the lignite projects in the public sector have been financed by the multilateral financial institutions who are well represented at this conference. Lignite projects in the private sector range from the exploration for lignite deposits and the estimation of probable reserves, the stripping of overburden before the start of lignite mining as in the case of the Mae Moh mine where EGAT subcontracted this work to the private sector, the mining of lignite itself, the storage, transpor-

tation and distribution of lignite to end-users, and the installation or conversion of industrial energy systems to use lignite. In this paper a lignite mining project financed by IFCT is used as a case study; the name of the project and the figures used have been changed to protect the confidentiality of the original information.

The Thai Lignite Mining Co., Ltd. (TLM) was established in the early 1980's with the objective of excavating lignite from an open cut mine located in the north of Thailand. The total project cost was estimated to be Bt. 60.5 million baht, for which the project sponsors were able to offer to raise Bt. 25 million in the form of equity. IFCT was requested to arrange financing for the project.

For mining projects the starting point for project evaluation is normally the size and cost of the ore reserves, in the same way as the availability and price of raw materials are evaluated in a manufacturing project. In the case of the TLM project the lignite reserves had been explored and surveyed by the National Energy Authority (NEA) which had offered for tender the mining concession rights for proven lignite reserves of 4-5 million tons located in an area of about 400 rai in the north of Thailand. The NEA also provided the results of a study of the soil structure of the concession area which can be summarised as follows:

Top layer, to a depth of 1-5 meters, is composed of clay and silts, with an occasional underlay of laterite in some areas,

Second layer, to a depth of 10 meters, is composed of sand and gravel with small quantities of lignite fragments.

Third layer is the lignite seam with a depth ranging from one to 50 meters or an average of 17 meters. The lignite seam has very little impurities, some white gray clay in parts.

Fourth layer is a rock layer consisting mainly of quartzite, slaty-shale and sandstone.

NEA's survey indicated that the average overburden depth is about 15 meters and the lignite seam depth is about 17 meters, giving an overburden to lignite ratio of 0.831 cubic meters of overburden to one ton of lignite. This represents a low cost of overburden stripping relative to the lignite reserves. However, as these estimates were based only on test drilling, a safety margin of 20 percent is added to the overburden to lignite ratio in calculating the cost of stripping.

In winning the bid for the mining concession, TLM had to enter into a contract with NEA with the following salient points:

- Life of the concession: 18 years
- Guarantee bond: Bt. 10.6 million
- Average annual payments to NEA for 5 years: Bt.1.429 million
- TLM has to procure 500 rai of land for NEA.
- Minimum production of 210,000 tons per year.
- At least 65 percent of TLM's output must be sold to tobacco curing plants, but TLM can seek NEA's approval if it has difficulty attaining this target.
- Lignite must be mined for at least 95 percent of the estimated reserves of 4 million tons.
- TLM has to pay the following fees to NEA:
  (a) A research fee of Bt. 500,000 per year.
  (b) A production fee of Bt. 40 per ton in the 1st and 2nd years.
  (c) A production fee of 15 percent of the value of production in the 3rd to 5th years.
  (d) A production fee of 17 percent of the value of production in the 6th to 9th years.
  (e) A production fee of 20 percent of the value of production in the 10th and subsequent years.
- TLM has to adhere to the following pricing formula for selling lignite:

Price at time of contract:

Lignite Size	Price Bt/ton
Over 1 inch	270
Under 1 inch	187
Average	241

Price adjustment formula: $P = K \times Po$

Where: P = the lignite price after price adjustment.

Po = the lignite price at time of contract.

K = the escalation factor.

The escalation factor is based on changes in the price of high-speed diesel oil as fixed by the Ministry of Interior. The high-speed diesel oil is given a weight of 45 percent and the minimum wage rate a weight of 10 percent.

In many mining projects the exploration and survey are done by the mining company and is usually financed solely by equity funds as it is too risky for debt financing. If sufficient ore reserves are discovered, the exploration and survey costs are amortised over a number of years together with other project development costs. In this case NEA recovers its exploration and survey costs through the payments and fees imposed on the mining company, which helps to reduce the initlal investment cost for the company. However the mining concession contract also stipulates that 65 percent of the lignite production must be sold to tobacco curing plants, as part of the Government policy to substitute lignite for wood fuel, and sets a formula for the selling price. An analysis of the feasibility of the project therefore requires a careful study of the demand for lignite in the tobacco industry as well as the trend for the high-speed diesel price and the minimum wage rate.

The market analysis showed that there were 452 tobacco curing plants in Thailand with over 16,000 kilns in Thailand at that time. Lignite consumption by this industry was about 170,000 tons per year and had increased at an average annual rate of 21 percent in the past 3 years. If the tobacco curing industry switched to lignite as its sole energy source, its consumption would be over 480,000 tons per year. Furthermore other alternative sources of energy are more expensive than lignite, and wood fuel was becoming increasingly scarce and expensive due to the severity of the Government's campaign against illegal logging. Future demand was therefore projected to be according to the past trend. An additional factor is that TLM had a well prepared marketing program for selling lignite to the tobacco industry which included sending trained personnel to advise and assist in the conversion of tobacco curing plants from wood fuel to lignite. A market survey indicated that about 130 tobacco curing plants with about 4,686 kilns and a consumption of lignite of about 138,000 tons per year were interested in using TLM's product. TLM was not therefore expected to have any problems in meeting its target of selling 65 percent of its production to the tobacco industry.

TLM's other target group was the cement industry. Thailand has three cement producing companies, one of which had started using a lignite/oil mix in its cement production in 1981. It was quickly found that this fuel mix not only reduced energy costs, but also improved cement quality. The other two cement producers began to use the lignite/oil mix in some of their plants soon afterwards. The consumption of lignite for this purpose is expected to reach 440,000 tons per year when TLM starts its mine production and to increase as other cement plants are converted to lignite.

At the time that TLM's project was being evaluated the supply of lignite for industrial purposes was still limited and a survey of potential new sources of lignite in the north of Thailand indicated that supply would continue to fall short of demand for many years, although because its relatively large size, TLM's market share in supplying the tobacco and cement industries would exceed 20 percent. Using IFCT's standard assumptions for the rate of increase of the price of high-speed diesel and the minimum wage rate, TLM's price as stipulated in the NEA contract compared favourably with the price of lignite produced by the other private sector mines. TLM's price in terms of heat value was also estimated to be lower than the price of lignite from other sources.

The technical aspects of the project are relatively simple and consists basically of stripping the overburden, removal of the upper layers of soil, excavation of the lignite, moving the lignite through the crushing and screening section, and storage of the lignite according to size. For quality control, samples are taken for every 100 tons of finished product and tested in a laboratory for heat value, moisture content, percentage of impurities, etc.

TLM's technical staff are well qualified and have sufficient experience in lignite mining; they will also be assisted by 3 coal experts from China during the start-up period. The machinery and equipment required is fairly standard and most of it will be acquired through competitive bidding. The project has an additional attraction for a development financing institution as some of the machinery was designed by Thai engineers and locally fabricated, and has proven itself as efficient and reliable. However about 44 percent of the total project is in foreign exchange. A contingency of 15 percent was added to the estimated cost of the construction and machinery and equipment to allow for inflationary factors and possible fluctuations in the exchange rate. A project of this size and level of technology would obviously not require a cost overrun facility or a completion guarantee. Standard mechanical guarantees by the equipment vendor would be sufficient.

At the time the project was evaluated, TLM had applied for, but not yet received Government promotional privileges, which include exemption from import duty on machinery and exemption from corporate income tax for up to 8 eight years. The promotional privileges offered in Thailand are similar to those in other Southeast Asian countries and have been an important tool in encouraging investment. Recently the Board of Investment has placed higher priority on export industries, domestic resource based industries, and industries located outside the greater Bangkok area. As lignite mining would very likely meet these criteria this project was appraised assuming that promotional privileges would be granted.

Based on the technical analysis and IFCT's experience from other projects, TLM's annual operating costs can be estimated. An important assumption is the capacity utilisation ratio which depends on an assessment of the technical complexity of the project. In this case full production can be expected to be reached very rapidly. Another important calculation is the working capital requirement for the projected level of production and the marketing strategy. In this case an inventory of 15 days and accounts receivable of 21 days plus a contingency of 15 percent were assumed. Underestimation of working capital requirements is a common cause of problems at the operating stage, especially when there are large seasonal fluctuations in either the supply of raw materials or market demand. Even when sufficient financing is provided for working capital, lack of control over the use of funds, especially when there are cost overruns at the construction stage, can result in the same problem occuring.

Based on the estimated project cost, the market analysis, the projected price trend and operating costs, and the equity financing available, a financing plan can be prepared. The estimated project cost can be summarised as follows:

	Bt. million
Construction	13.9
Machinery and Equipment	36.2
Office Equipment	0.1
Pre-operating Expenses	6.2
Working Capital	4.1
Total	60.5

IFCT looks at both the debt-equity ratio and the debt service coverage ratio in assessing how much debt a project can prudently bear. With the market and technical aspects fairly straightforward, as in this case, IFCT would use as a guideline a maximum total debt-equity ratio of 60 : 40, and a minimum debt service coverage ratio of 1.5. The proposed share capital of Bt. 25 million would therefore be sufficient to meet the debt-equity ratio requirement, while the repayment period of the term loans can be structured in accordance with the projected cash flow to maintain the debt service coverage ratio at above 1.5. An adequate grace period to cover the construction period and the first year of operation, when delays or other unforeseen problems may occur, is particularly important.

One major problem which affects the financing of most mining projects is the shortage of collateral. If the mining company has undertaken the exploration and survey work itself, then there may be large pre-operating expenses which are of little collateral value. The mine site, even if it belongs to the company, is also usually of little collateral value. The most valuable asset are the ore reserves, the loan security value of which will depend mainly on the terms and conditions under which the company can utilise these reserves. The remaining assets are the buildings, which cannot be used as collateral if the land on which they are located does not belong to the company, and the machinery and equipment. In the TLM project the exploration and survey were done by NEA, so the company has low pre-operating expenses, but as the mining concession and land belonged to NEA, it could not use the mine or the buildings on it as collateral. One of the objectives of project financing is of course to reduce reliance on collateral, but a favourable evaluation does not guarantee the success of a project, and it is sound banking practice to ensure that as much of the loan as possible can be recovered from the liquidation of the assets if the project does fail. As a development finance institution IFCT is relatively more generous in its collateral valuation and does not require 100 percent collateral coverage for its loans. In this case only the machinery and equipment can be used as collateral; the investment cost of the machinery and equipment is Bt. 36.2 million and the collateral value is estimated at Bt. 18.6 million, or about 51 percent. The amount of term loan required, however, is Bt. 31.4 million, given that the maximum equity available is Bt. 25 million and working capital finance is Bt. 4.1 million. In this case a solution was found as the project sponsors were able to provide a "directors' loan" of Bt. 10.4 million which would be effectively subordinated to the term loan. The term loan required would now amount to Bt. 21 million, giving a collateral coverage ratio of about 88 percent. In view of the fact that the project sponsors were willing to put up a subordinated loan, and the favourable results of the project evaluation, this was considered acceptable.

With regard to loan security the sponsors of the project were also required to give a personal guarantee for the term loan. While this is common practice among financial institutions in Thailand, in IFCT's case the main purpose is to ensure the commitment of the sponsors to the project rather than to be a recourse for loan repayment. This is particularly important when the enterprise is family owned and managed.

On the basis of the above-mentioned factors the sources of finance for the project can be summarised as follows:

	Bt. million
Shareholders equity	25.0
Directors' loan	10.4
Working capital loan	4.1
Term loan	21.0
Total	60.5

Based on the projected cash flow and a minimum debt service coverage ratio of 1.5, the term loan can be repaid in 5 years with a grace period of 1½ years. The working capital would be financed by an overdraft facility with a commercial bank. An overdraft has the advantage for this purpose of being used only in accordance with the seasonal variations in working capital requirements and thus saving interest expenses. The commercial bank was also interested in participating in the term loan in an amount of Bt. 6 million on the same terms as IFCT (with the exception of the interest rate which is on a floating basis while IFCT's is fixed). The remaining amount would be financed by a loan of Bt. 15 million from IFCT.

The financial analysis of the project based on the above financing plan showed that the project would have a net profit of Bt. 1.15 million in its first full year of operation rising to Bt. 6.33 million in the fifth year. The internal financial rate of return is 18 percent (15 percent without the promotional privileges). The debt service coverage ratio is 1.51 at the lowest and rises to 1.84 in the fifth year. The

capital structure of the company is sound throughout the five years. Regarding the project's economic benefits, TLM will employ 173 people at an investment cost of about Bt. 350,000 per job. The project would also result in net foreign exchange savings of about Bt. 261.1 million in the first five years of operations.

The TLM project was implemented on schedule but at a much lower investment cost than expected. Actual machinery and equipment cost was only Bt.24 million compared with Bt. 36.2 million in the project appraisal, and actual construction cost was only Bt. 4 million compared with Bt. 13.9 million mainly due to reduced lignite storage requirements. Only Bt. 9 million of IFCT's approved loan of Bt.15 million was drawn down. Actual production of lignite is at the rate of 300,000 tons per year compared with 210,000 tons per year projected in the appraisal. The pattern of demand for lignite is also considerably different from what was projected. The tobacco curing industry still prefers to use wood fuel rather than lignite so demand for this application has been very limited. However demand from the cement industry was much greater than expected. Furthermore the use of lignite for boilers was a new source of demand which TLM pioneered and developed by assisting factories in converting their boilers to lignite. As a result TLM was not able to meet its obligation under its agreement with NEA to sell 65 percent of its production to the tobacco industry and had to seek a waiver. With existing orders from the cement industry alone amounting to 250,000 tons a year and expected to increase following the raising of the tariff on imported coal from 10 percent to 25 percent, TLM is planning to expand its production capacity and has approached IFCT for additional financial assistance. In terms of profitability TLM made a net profit of Bt. 2.43 million and Bt. 4.28 million in its first two years of operations respectively, much higher than originally projected.

It is not often that a project exceeds the performance projections as much as the TLM project, but TLM's success gives an indication of the potential for the development of the lignite industry in Thailand. IFCT has financed several projects involving the conversion of energy systems to lignite and they all show the same potential for success, in terms of both financial returns and economic benefits for the country.

However, not all lignite related projects are a success. IFCT financed a project which was intended to produce artificial coal briquettes from lignite. The use of lignite to replace charcoal for domestic use has been a target for the further development of lignite and would have major benefits for the economy, as well as support the conservation of forests. When a German-educated Thai engineer demonstrated in a pilot plant a process for the conversion of lignite into artificial coal briquettes which could be used for both domestic and industrial use, IFCT was requested to provide long term financing for a commercial scale plant based on this process. IFCT was aware of the technical risks but decided to make a loan to this project as a "risky" project, which meant that the risks were worth taking as the potential benefits were enormous. The loan was, fortunately for IFCT, a small one as the plant was unable to make the transition from a pilot plant to a commercial scale plant and quickly went bankrupt.

In conclusion the financing of lignite projects requires some major adjustments from normal project financing methods. The main problem is the shortage of collateral within the project and the need to have recourse to external loan security. Project financing techniques should help to reduce the emphasis on collateral and place more importance on the feasibility of the project. The potential for the further development of lignite in Thailand is enormous, both for power generation and for industrial use, so it is important that sufficient financing on suitable terms continue to be available for this industry.

PRIVATE SECTOR FINANCING OF THE LAKHRA COAL PROJECT[1]

Niels de Terra
Lakhra Project Private Sector Advisor
Mathtech Inc.
London, England

INTRODUCTION

The Government of Pakistan's policy of encouraging the private sector to assist with the mammoth task of mobilizing more energy resources has received increasing emphasis since the publication of the Sixth Plan in June 1983. Very recently, this policy was further elaborated by the published notice of the Ministry of Water and Power inviting proposals from the private sector to build and operate power stations for the sale of bulk supplies of electric power to WAPDA and KESC.

If Pakistan's recent record of high economic growth is to be continued, adequate supplies of all forms of energy, particularly electric power, must be maintained. Manufacturing and processing industries as well as agriculture are highly dependent on electric power. While there is much room for improving the efficiency with which electricity is used today, there is no doubt that very major additions to the country's generating capacity will be needed until well into the next century. The demands on public sector resources are already very great, and it seems clear that unless significant private sector resources can be mobilized to increase energy supplies, Pakistan may fall short of its energy and economic targets.

The Private Sector's Role in the Coal Industry

The private sector has a larger role in the coal industry today than in any other energy supply sector in Pakistan. While precise figures are not available owing to the large percentage of coal production that goes unreported, it seems safe to say that at least 85% of production come from private sector mines, and the balance from PMDC and PUNJMIN mines. Total domestic coal production today is probably in the region of 3.0 million tons per year, with the Lakhra area accounting for not less than 800,000 tonnes.

Much has been said and written about the rudimentary state of coal mining in Pakistan, the lack of investment in mechanization and the poor attention to safety in all but a handful of mining companies. There are, however, valid reasons for the historical lack of investment. Since the arrival of cheap gas, the coal industry has been limited to its traditional brickmaking markets. There was no reason to invest in productivity improvements when existing mining methods were quite capable of meeting the moderate growth in demand from the brick kilns. In addition, all investments had to be self-generated. Until very recently, the mining regulations did not facilitate commercial bank lending to min-

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The opinions expressed in this paper are those of the author. They should not be taken as representing those of WAPDA, The Government of Pakistan, USAID of the World Bank.

ing companies nor were the banks geared up for this activity.

Today the coal industry faces its brightest future since independence discounting, as one must, the current fluctuations in the oil market. The cement industry is beginning an orderly process of converting its kilns to use Pakistani coals. Industrial users are beginning to take a new look at coal use for process heat and steam raising. And most important of all in terms of long term potential, power generation is about to become a very large user of domestic coal. As currently conceived, the Lakhra power plant would need at least as much and probably more coal than the entire country is producing today.

The Private Sector Role in Coal Supply for the Lakhra Power Plant

The Lakhra Project presents very new challenges for Pakistan's coal industry. The development of worldscale open pit lignite mines as well as one or more high productivity underground mines demands investment resources as well as managerial and operational skills that are not found today in Pakistan. Other speakers at this Conference have given you a full picture of the proposed mining operation that will produce coal for the power station. From that description it will be clear that the expertise to develop and operate these mines resides in foreign private sector mining companies, although local earth moving companies are most certainly expected to make a contribution in the open pit mines. Pakistani mining companies should also play an even larger role in developing the Project's new underground mines.

The situation in which an electric power utility, such as WAPDA, invites a private sector mining company to develop and operate dedicated mines to supply its power stations is common in a number of countries, including Australia, Germany and the United States. Even in the United Kingdom, the public sector National Coal Board uses private mining companies to carry out opencast mining operations.

The private sector can normally be expected to respond positively to any prospective business situations in which the potential returns on invested capital are as good or better than alternative projects available at the time. A company's assessment of potential returns will be heavily influenced by its perception of the risks involved. Such risks include economic, financial, political, and technological. My colleague from the Bank of America International, who are Financial Advisors to this Project, will be going into these questions of risk in considerably greater detail in a later session, but in discussing private sector financing it is essential to bear in mind at least four risks faced by investors.

In the case of the Lakhra Project the economic risks facing a private company woudl include risks that the price it expects to receive for the coal delivered to the power station would not cover its full costs. Such risks can be reduced both through a sound long-term contract covering coal price and escalation, as well as through a proper understanding of the underlying realities of the project. By this I mean the large unsatisfied demand for electric power in the economy of Pakistan which dictates that the power station will continue to be a customer for the coal throughout the lifetime of the plant.

Financial risks for the mine, for example, a worsening of credit terms once the project is under way or a foreign exchange crisis in Pakistan that would affect the ability of the mining company to make debt service and divident payments. The first event could be mitigated by pass-through provisions in the coal purchase

contract whereby interest rate fluctuations are reflected in the coal price charged to WAPDA. The only real protection an investor has against the second eventuality is the knowledge that Pakistan has to date never defaulted on a foreign exchange obligation, and is expected to continue to follow economic policies that will minimize the risks of a foreign exchange crisis in the future.

The private sector, both foreign and domestic, will make its own assessment of the political risks involved in commitment to a 30 year-plus mining project. The higher the perceived political risk, the higher will be the rate of return required from the investment. The perception of political risk will also place an overall limit on the total size of investment that foreign companies will be prepared to consider regardless of prospective return.

This mining project does not pose serious technological risks because the technologies to be employed are thoroughly proven and well understood. The only risks in this area might be those associated with proper operations and maintenance of the equipment, and these risks can be minimized with proper training, selection of personnel and skilled supervision.

Advantages and Disadvantages of Private Sector Financing

Advantages

Speed of Implementation. Because decision-taking in the private sector is normally faster than in public sector bureaucracies, a project usually can be implemented more expeditiously when managerial and procurement decisions are in private hands.

Experience. The private sector normally has more experience in project implementation than the public sector.

Optimal Procurement Mix. Private sector firms usually have more flexibility to negotiate an optimal procurement mix with equipment suppliers.

Additionality. To the extent that a privately financed project does not draw on funds that would otherwise be used by the public sector, additional capital is made available for productive use in the economy of Pakistan. Some of this capital may come from abroad, while some may be domestic capital that is transferred from less productive uses. Additionality is not achieved where a private sector project uses, say, World Bank loans that would otherwise have been used by the Government of Pakistan for other projects. However, IFC loans can only be made to the private sector.

Disadvantages

Commercial Financing Terms May Worsen Project Economics. The Lakhra Project coal mines, whether producing 3 or 4 million tonnes per year, will be a very capital intensive project.

Project financing terms will, therefore, have a significant impact on the cost of producing coal. Virtually all the capital equipment must be purchased during the initial years, and will be used for at least five years stripping overburden. During this time interest must be paid on the borrowed capital before any revenues are received.

To understand why commercial terms of lending have a very different impact on a private sector project than they do on a public sector project is is important to understand the difference between concessional and commercial terms of financing, as well as the different effects of commercial terms on public and private sector organizations. When Pakistan receives loans on concessional terms from bilateral or multilateral donors these typically have

a loan life, or tenor, of 20 to 40 years and carry interest rates of between 3% and 9%. Commercial loans in Pakistan currently are at rates of 13% to 14% with tenors of up to about 10 years. Generally, when the Government passes on a concessional loan to a public sector body, such as WAPDA, it does so on commercial terms; the financial impact on that institution is softened by the fact that the public sector body derives much of its income from the ADP - or annual government budget allocation. To state it another way, a public sector borrower paying commercial rates on its debt has regular recourse to government to finance its overall operations, whereas a private sector borrower must rely on its own cash flow to service its debt.

Any Lakhra private sector developer who uses commercial loans will face a debt service schedule that will be bunched in the first few years of the project. At the same time the mining company will not be selling coal until the sixth year of operations when the overburden has been removed and the power plant is starting in service. The developer will have to (i) borrow additional amounts to meet payments of interest during construction and (ii) realize virtually all of his debt servicing requirements from the coal price charged to WAPDA during the very first years of coal production. This will lead to high generation costs for WAPDA in the first few years of plant operation. Costs would drop once the mining company has met most of its debt service obligations. I will cover some ways of mitigating this in a moment.

Prospects for Private Sector Financing of the Coal Project

Financing may be expected to come from a number of sources:

The foreign and Pakistani mining companies who make up the group that is eventually successful in its bid to develop and operate the Project Area mines. These companies will be expected to contribute a substantial sum towards the equity needed by the project. It would not be appropriate to speculate on the amounts that local and foreign firms might be prepared to invest, but our discussions with potential investors are encouraging in that all have indicated their willingness to invest sums that demonstrate a serious commitment to the success of the project.

How do these expressions of interest compare with the amounts that the project will need? Bearing in mind that the final mining cost estimates are still being prepared by the mining feasibility consultants, if one includes provisions for cost escalation and interest during the five to six year mine development phase the mining project could cost somewhere between $500 and $700 million (excluding import duties).

Let us assume for the sake of argument that 75% of this could be financed by debt. This would still leave an equity requirement in the region of $125 to $175 million. Let us ask two questions. Is the private sector, either in the form of one company or a consortium of foreign and Pakistani firms, likely to be willing to invest on this scale in the Lakhra coal mining project? My own view is that this would be very difficult to achieve without the kind of Government of Pakistan guarantees that would undermine the private sector risk-taking nature of the project. The second question is - Does the private sector have to find the entire equity investment? The answer to this question is that it may not have to find the entire sum itself, and a possible role for WAPDA in solving this problem will be discussed shortly.

The perception of risk on the part of foreign investors normally leads them to be particularly cautious when approaching projects whose output or product is not exportable. Were this to be export quality steam coal or crude oil, one could be more

optimistic about attracting large sums of investment. But even in such cases the amounts needed might be difficult to attract in today's weak energy markets. And the fact is that Lakhra coal has no near-term value outside Pakistan. One day it may be possible to find regional markets for briquetted Lakhra coal, but this is not a current prospect.

However, the suggestion that private sector foreign and local mining companies may not be prepared or even able to come up with the total required amounts of equity should not be taken as a discouraging prospect for the project. Following the examples of similar projects in other countries, there are several ways in which the equity needs can be met.

However, before looking at these it is important to take a brief look at the other potential sources of financing for the private sector.

A number of Pakistani commercial Banks have indicated their interest in the project and their readiness to consider loans subject to their reviews of project viability. However, the discussions that the project's Financial Advisors have had with local banks indicate that one should not expect to be able to raise much more than the rupee equivalent of $25 to $50 million from all local project finance banks combined. These loans would be at the prevailing commercial rates.

The Karachi Stock Exchange could be a vehicle for raising a modest amount of financing, but a public stock offering prior to the start-up of operations of a commercial enterprise is unlikely to raise more than a nominal sum.

Foreign lenders that the private sector mining companies may be able to draw on include export credit agencies, the International Finance Corporation (part of the World Bank family), international commercial banks, and those development banks that have provisions to lend to the private sector in member countries. Once the mining company has determined its capital equipment procurement plan it is likely to find that the export credit agencies in the countries that manufacture the equipment will be prepared to finance a portion of the purchase. The terms of such financing should be slightly better than straight commercial loans. When development banks lend directly to private companies they typically do so through the national commercial banking system. Thus, for example, the Asian Development Bank has made available to Pakistan a credit which is on-lent through the National Development Finance Corporation and other lending institutions.

Opportunities for Risk-Sharing in the Financing of the Lakhra Coal Mine

We have already seen how the coal price to the power station would have to be raised during the early years of operation in order to cover the concentrated debt servicing requirements that would result from financing most of the coal mine on commercial terms. We have also seen that the large size of the mining project will make it very difficult to raise all the needed investment from private sector sources.

However, project success depends on one or more first rank private sector mining companies being given responsibility for executing the project and that they put enough of their own money in the project to create a strong incentive for efficiency and success. The next most important objective is for WAPDA to secure the lowest possible prices for the coal it buys.

It is not unusual in projects of this type in industrial countries for the electric power utility to share some of the costs of mine development with the mining company. Where very costly items of equipment have to be purchased arrangements are negotiated whereby the utility purchases the equipment and then leases it to the

mining company. Often the utility has far greater ability to raise financing than does a mining company. For example, in the United States most utilities can raise long-term financing on bond markets on attractive terms because of provisions in the tax code which make income from such bonds tax exempt.

The situation in Pakistan may be comparable in the sense that WAPDA is a regular borrower from institutions as the World Bank and Asian Development Bank. Thus, one could envisage arrangements being negotiated between WAPDA and the private sector mining companies under which WAPDA would make use of loans provided by donor agencies to purchase capital equipment items for the mine, such as draglines, dumper trucks, loaders, etc. The terms under which such equipment was then made available to the mining company would have to be negotiated. WAPDA would obviously require a lower coal price in return for the fact that it was taking on part of the financing burden for the mine.

An additional element could be a minority equity investment by WAPDA in the mining operations. This could take the form of a cash investment, or it could be achieved in-kind through equipment purchases.

Yet another accepted mechanism whereby the borrowing requirements fo the mining company during mine development could be reduced (and hence the coal price reduced) would be for WAPDA to make regular payments for overburden removal during this development phase.

Conclusions. Since we are not yet at the stage where the private sector is asked to come forward with firm bids on equity investment and coal price, much of what I have said has been speculative. The next major step in the project will be the issuance of the Private Sector Request for Proposal - probably in late Spring. That will be the acid test of the private sector's capabilities and intentions with respect to financing and implementing the mining project. My personal view is decidedly optimistic.

A good selection of first rank coal mining companies from around the world as well as from within Pakistan have already been prequalified. Others are still free to join the project if they meet basic tests of competence and if they team up with an already prequalified company. As Pakistan faces the world market as a buyer of power plants and as a customer for foreign coal mining expertise this project could not have come at a better time, because both these sectors are currently very competitive in seeking business. With the great need for electric power, with the strong interest in this project on the part of lending institutions as well as on the part of the Governments of Pakistan and Sind, and with the demonstrated interest in the part of the private sector, Pakistan's coal industry should now see the most important single forward step in its history.

THE ROLE OF THE OVERSEAS PRIVATE INVESTMENT CORPORATION IN PROMOTING U.S. BUSINESS PARTICIPATION IN PAKISTAN

John C. Moore III
Insurance Officer, Contractors Services
Overseas Private Investment Corporation
Washington, D.C. 20527

ABSTRACT

The Overseas Private Investment Corporation (OPIC) is a self-sustaining government agency whose purpose is to promote economic growth in developing countries by encouraging U.S. private investment in those nations. OPIC programs are designed to mobilize and facilitate the flow of U.S. capital, technology, skills and management into projects overseas.

OPIC assists U.S. investors through two principal programs: 1) the insurance of investments against certain non-commercial risks and 2) the financing of such enterprises through direct loans and/or loan guaranties. Also, OPIC has designed a variety of specialized insurance programs for U.S. companies involved in mining and other energy exploration and development projects, as well as for firms that provide goods and/or services on contract.

OPIC's insurance and finance programs have been available to American companies doing business in Pakistan since 1955. OPIC feels that Pakistan offers an attractive business environment for a wide variety of U.S. business sectors. In order to promote opportunities in Pakistan, in 1983 OPIC conducted an investment mission for U.S. companies interested in establishing or expanding joint ventures there. Over the past several years OPIC has experienced a significant increase in its activity in Pakistan and will continue to actively support a wide variety of projects in Pakistan.

INTRODUCTION

The Overseas Private Investment Corporation (OPIC) is a self-sustaining U.S. government agency, created by the U.S. Congress in 1969 to encourage U.S. private investment in developing nations. Although OPIC is an agency of the government, it is structured more like a private corporation and, in fact, it generates a profit every year.

OPIC has a variety of programs designed to assist U.S. businesses that are investing in projects and joint ventures overseas. In the forefront are two: an investment insurance program which protects the investor against certain non-commercial risks, and a project financing program.

INVESTMENT INSURANCE

OPIC's investment insurance program can insure eligible U.S. investors against losses caused by inconvertibility of currency, expropriation, and war, revolution, insurrection and, civil strife. Essentially, OPIC is insuring against the non-commercial risks that can inhibit U.S. companies from entering into long-term business relationships overseas. Although many U.S. companies see opportunities for their technology

and products overseas, they are hesitant to move into an unfamiliar locale due to uncertainty about the risks over which they can exercise little or no control. This is true even for a country such as Pakistan, which has a good record of equitable treatment of foreign investors and compliance with international law. The insurance that OPIC provides is long-term (the insurance contracts run for as long as twenty years) and the premium rates are relatively low. Thus, in many cases OPIC plays an important role in the investment decision and helps to make the project more attractive by providing the American investor with the security it requires before venturing into new business environments outside of the U.S.

In addition to the standard investment insurance, OPIC has designed a number of additional insurance programs to meet the needs of specific industry sectors. For example, OPIC has an insurance program for U.S. contractors and exporters which are providing goods and services under contracts in developing countries. This particular program has been used extensively by U.S. suppliers to major projects in Pakistan. U.S. suppliers to projects such as the power station at Guddu, the Tarbela Dam, and the Pakistan Telephone Network have used the contractors and exporters insurance from OPIC. OPIC insurance benefits the government buyer as well. If the U.S. company has OPIC insurance (available at a low cost), it can bid the contract at a lower price because it is not necessary to include an allowance for potential losses in the bid price.

OPIC also has specialized services and programs for U.S. investors involved in developing mining, oil and gas, oil shale, geothermal, solar and other energy projects on a commercial basis, as well as companies supplying support services or goods to such energy projects. The OPIC insurance program for mining projects is designed to provide coverage for the risks unique to a project in the mining sector. OPIC's insurance contract is available to cover both the construction period, as well as the commercial production phase of a mining project. The amount of insurance that OPIC can provide for any one project varies, but as a rule OPIC can insure up to $100 million per risk covered per project. The amount of U.S. investment in a mining project can often be considerably larger, however. In the case where OPIC cannot insure or finance the entire U.S. investment, the presence of the OPIC insurance in the project can serve as an inducement for other insurers or lending institutions to enter into the project and provide additional coverage or financing.

PROJECT FINANCING

One of the most significant problems faced by U.S. companies contemplating investments in Pakistan is the difficulty in obtaining the necessary capital from international financial sources. The problem is particularly acute for smaller firms and smaller projects. OPIC's finance program can provide medium and long term financing to U.S. businesses which are interested in establishing or expanding a business overseas. OPIC can finance projects through either a direct loan or a loan guaranty facility. Under the loan guaranty program, OPIC issues a government-backed guaranty to the private financial institution which makes the loan. OPIC's finance program can provide up to 50 percent of the costs of

establishing the venture. The terms and conditions of the loan are tailored to the specific needs of the project, but generally the term of the financing runs anywhere from five to ten years with a one to three year grace period. In short, OPIC's finance program provides an additional source of debt financing in countries where conventional U.S. financial institutions often are unable or unwilling to lend for long term projects.

OPIC also has local currency lending capability in Pakistan, through which U.S. companies involved in projects in Pakistan can borrow Pakistani rupees at favorable rates.

OPIC'S PROGRAMS IN PAKISTAN

Through OPIC and its predecessor agency, the insurance and finance programs have been available to American companies doing business in Pakistan since 1955. Currently, OPIC insures 25 projects in Pakistan in a variety of sectors (mining, energy exploration, pharmaceuticals, agriculture, and chemicals). Of the 25 projects insured, 19 involve equity investments and the remaining six involve insurance for U.S. contractors or exporters. OPIC insures approximately 33 percent of the total U.S. equity investment in Pakistan.

The total direct U.S. private investment in Pakistan is approximately $113 million. This figure has remained relatively constant over the past ten years. The largest investment of capital has been in the energy exploration sector, and this figure should continue to increase over the next several years as Pakistan continues to move towards greater energy self-sufficiency.

There has been a significant upswing in OPIC business in Pakistan in the last several years. In addition to the insurance contracts recently executed, OPIC has registrations for close to $90 million in additional investments and guaranties. OPIC has also extended local currency loans to projects in Pakistan totalling Rs. 278.8 million, or $25.2 million, since 1975. These loans have supported projects in agriculture, pharmaceuticals, and farm equipment manufacturing facilities. Several other projects are currently in the discussion phase for potential OPIC financing.

OPIC conducted an investment mission of U.S. companies to Pakistan in 1983. The mission identified many well-conceived investment proposals and focused attention on a dynamic local business community eager to join hands with appropriate American companies to undertake joint ventures. The mission was also effective in highlighting the positive developments in Pakistan's economic and investment climate. The number of visits by American companies to Pakistan to explore trade and investment opportunities have since been on the rise.

As a result of the mission, several joint venture agreements have been signed, implemented or are in various stages of negotiation. Progress on some projects has been somewhat disappointing, however, due in part to difficulties in obtaining quick Pakistani government decisions on the projects. While frustrating impediments to increased foreign investment are likely to exist for some time, the continuation of stable economic policies, increased energy discoveries, the development of major projects such as the Lakhra coal mine,

and the development of related downstream industries can assure steady economic growth in Pakistan over the next decade.

Furthermore, in order to attract foreign investment, Pakistan offers the foreign investor many significant inducements, including tax incentives and exemptions from customs duties for establishment of industry in certain provinces and sectors, export incentives and an export processing zone, as well as an excellent record for repatriation of profits and capital.

OPIC firmly believes that Pakistan offers a variety of promising opportunities for U.S. investors, contractors and exporters and that OPIC's programs can encourage U.S. companies to take a positive, long-term approach to Pakistan's business opportunities.

CONSIDERATIONS FOR FINANCING COAL SECTOR PROJECTS

A. Tsus...a, Director
Industry and Development Banks Department
Asian Development Bank (ADB)

I am very happy to participate in this Conference which marks the beginning of a major effort for accelerated development and utilization of coal in Pakistan. The coal resources of Pakistan, despite their relatively modest size and quality by international standards, have the potential to contribute to economic development, particularly at locations where transport costs of alternative fuels are high. We believe that careful planning for development, nurturing of potential markets, and harmonization with plans and policies pertaining to other energy subsectors will ensure that contribution of coal resources to the economy is optimized. The deliberations of the last four days have focused on the potential and needs of coal development. I am sure that these deliberations will help in the early formulation of necessary plans and programs of the coal sector.

Bank Assistance to the Coal Sector

Within the Region served by ADB, coal is the single largest energy resource available. While the share of coal in the energy resources in individual countries differ widely, on average it accounts for about 50 percent of recoverable energy resources in the Region. In recognition of the potential contribution of coal to the energy supplies in the Region, ADB gives particular attention to promoting and assisting coal projects. The ADB has provided loans* of about $340 million over the past years for various coal development projects, as well as for coal utilization projects. Loans to the Republic of Korea and the Philippines have assisted in the development or expansion of coal mining capacities. Loans to Thailand have increased coal utilization through creation of lignite-based power generating capacity of about 1125 MW.

* ADB Assistance to Coal Development

Country	Year	Project Title	Amount
Loans			(in $million)
Korea, Rep. of	1976	Coal Development	12.0
Korea, Rep. of	1979	Second Coal Development	25.0
Philippines	1979	Malangas Coal Development	14.0
Philippines	1984	PNOC Energy Project (coal component only)	24.0
Thailand	1972	Mae Moh Power	23.0
Thailand	1975	Mae Moh Power	37.7
Thailand	1979	Mae Moh Power	81.8
Thailand	1984	Mae Moh Power	122.0
			339.5
Technical Assistance			(in $)
Korea, Rep. of	1983	Third Coal Development	195,000
Philippines	1978	Malangas Coal Mine	114,000
Philippines	1982	Second Coal Development	330,000
Philippines	1984	Private Sector Coal Dev.	350,000
Regional	1982	ASEAN Coal Dev. Project	700,000
			1,689,000

Additionally, ADB has provided nearly $1.7 million by way of technical assistance to undertake techno-economic and policy studies required for promotion and preparation of coal development and utilization projects. The technical assistance provided to the Republic of Korea and the Philippines were useful in formulating projects that subsequently received Asian Development Bank support.

Under another technical assistance to ASEAN countries, an assessment was made of the likely levels of production, utilization and trade in coal within ASEAN member countries for the period up to the year 2000. The requirements of developing mining and coal handling capacities, logistical facilities, and associated investments were also identified. Simultaneously, institutional and policy arrangements needed to be evolved for the build-up of such a development effort were considered and outlined. The study has prepared an operational plan for development of projects, facilities and policy actions for the coal sector in ASEAN countries. The study has also indicated opportunities for increasing trade in coal and related investments within ASEAN member countries.

The latest technical assistance of the Bank to the Philippines in this field is designed to identify measures needed to increase private sector participation in coal development. It is recognized that development and distribution of coal offers numerous opportunities for participation by the private sector. Moreover, the development efforts required in the coal sector over the next decade in the Philippines, as in many other countries, are so large that mobilization of capital and entrepreneurship from all sources - public, private, local, foreign - would be necessary. ADB's technical assistance comprises two phases: Phase I, aimed at identification of factors that tend to discourage private sector participation in coal development; and Phase II, which will assist the private sector in conducting prefeasibility studies of promising sites for possible loan assistance from ADB. The findings of Phase I will be used by the Government to formulate appropriate policy and institutional changes that would encourage and promote private sector participation. Work under Phase II will enable private investors to mobilize resources from the Asian Development Bank and other financing institutions.

It is hoped that the completion of the ongoing technical assistance will pave the way to a rapid expansion of private sector participation in coal development in the Philippines. ADB looks forward to its continued involvement in this process through provision of loans and technical assistance for viable projects.

As for future ADB assistance to the coal sector, I would like to assure you that ADB continues to accord priority to projects for coal development and utilization, including those for coal handling, energy conservation and fuel substitution.

I would like to add that in addition to the provision of assistance in the form of sector and project loans and technical assistance as in the past, ADB's newly initiated program of direct assistance to the private sector will enable ADB to cater to the aid requirements of the coal sector more comprehensively. Under this program, ADB could extend loan assistance to the private sector without government guarantees and could also make equity participation in private sector ventures on a selective basis.

Issues in Coal Sector Development

Historically, in the years preceding the "energy crisis," growth in coal development and use slowed down because of competition from crude oil. With the changes in price and availability of energy since 1973, however, coal enjoyed a major cost advantage over oil. Even at the currently falling oil prices, coal could retain its cost advantage over the long haul; at this time, coal (with a calorific value of

10,000 BTU/lb) is available to many countries in the Region at about $40 a ton. Such coal is competitive in power generation at this price vis-a-vis fuel oil priced at $16/bbl.

Notwithstanding generally favorable economics of coal vis-a-vis competing fuels and particularly oil, coal development in the region has been somewhat slow. Coal production and use in the last decade increased only at an average rate of 6 to 7 percent in most countries in the Region. As a result, the share of coal in energy use in the Region still remains at about 8 percent.

One of the main factors that seems responsible for inhibiting rapid growth of the coal sector in the Region is the lack of institutional and physical infrastructure needed. Any significant growth in production and utilization of coal requires coordinated development of a network of related activities such as resource assessment and evaluation, mine planning and development, beneficiation, storage, transport, handling, blending, retrofitting of existing and development of new user facilities. Planning of these activities and creation of capacities require substantial investments and implementation efforts. In addition, formulation and adoption of appropriate policies and establishment of suitable institutions will be required.

Matters of policy need to cover a wide range of issues such as foreign and local investments; incentives, taxes and royalties on coal development, interfuel price differentials; arrangements for guaranteeing supply to new users; assistance for conversion of existing facilities to coal use; and manpower training and skill development In addition, appropriate institutions need to be established to formulate and implement such policies and to plan and monitor development projects for the growth of required facilities and activities. Need to safeguard the quality of environment assumes special significance in the context of increasing use of coal.

Absence of such a network is a constraint particularly in situations where accumulated experience in coal use is modest. Likewise, it can become a critical gap in situations where physical and/or institutional links between coal producer and consumer are weak. For instance, mine-mouth power plants would obviate the need to develop transport facilities; similarly, when coal is mined by a final user such as a power or cement company, marketing problems are minimized, and better coordination on coal quality is assured between mine and user plant. In contrast, when coal produced is to be sold to a number of users who may also be physically separated from the place of production, a whole range of interrelated activities concerning production, transport, marketing, user facilities, and coal quality needs to be coordinated. In the absence of an adequate institutional mechanism that would bring about such coordinated development, sustainable growth of coal sector is difficult.

In recognition of a network of such activities needed to sustain coal sector development, ADB assistance includes not only projects designed for directly increasing coal production and utilization but also projects for developing associated facilities and capabilities. Future ADB assistance available to coal sector projects, therefore, could take the form of provision of loans for coal production/-utilization ventures, as well as for the creation of associated capacities in transport infrastructure, washeries, retrofitting of existing and development of new user facilities. The ADB's assistance could also include provision of expert services, inter alia, for analysis and evaluation of policies pertaining to fuel choice, interfuel prices, and private sector involvement; it would also include services for exploration and evaluation of reserves, project engineering, and manpower training.

The criteria used in considering coal sector projects for ADB assistance are similar to those used for all its projects and required that the project (a) is viable, (b) represents least cost solution for meeting forecast demand, and (c) is consistent with the broader sector and economic development programs. The minimum expected standards of financial and economic viability are usually expressed in terms of internal rates of return of about 12 per cent; requirements of sound financial structure are generally expressed in terms of acceptable debt-service and debt/equity ratios. Normally, ADB expects a debt-service ratio of about 1.2 and a debt/equity ratio of about 70:30. It is regarded that for projects such as those in the coal subsector, a reasonably sound equity base is essential to provide flexibility and to ensure that the promoters have a sufficient stake in the success of the project.

As indicated earlier, coal is expected to retain its cost advantage vis-a-vis competing fuels over a wide range of price variations. In the case of indigenous coal, it may often enjoy advantage in transport costs vis-a-vis competing fuels at certain demand centers. It is expected, therefore, that development of indigenous coal particularly in situations of reasonable production costs would turn out to be the least cost option. However, given the major uncertainties now prevalent regarding oil prices, it is also necessary to establish that any project proposed for coal development would be capable of maintaining its viability against possible major reductions in oil prices. Moreover, as the international oil prices influence international coal prices, projects for indigenous production of coal will have to counter competition from imported coal. In considering coal projects, ADB would, therefore, ascertain the sensitivity of such projects to a range of varying oil and coal prices.

It would, however, be an oversimplification to conclude that considerations in assisting projects are largely confined to economic and financial aspects alone. A number of other considerations also prevail. Since coal production and utilization are essential complements of one complete transaction, ADB seeks an assurance that developments regarding the two are sufficiently coordinated. For instance, acceptance of a project for coal production would be contingent upon evidence of a strong and assured market for the coal to be produced. Inasmuch as there are often competing fuels available to the target consumer, it becomes necessary to ascertain and fully consider the plans of user sectors as well as those for supply of competing fuels such as natural gas and oil. In parallel, ADB also requires that arrangements should be in place to bring about coordinated growth of various supporting activities (such as coal handling and logistics) so that project implementation and operations are not adversely affected later. Further, ADB would expect to be satisfied that adequate environmental safeguards are built into the coal mining and utilization projects.

Every individual project is seen as an integral component in the longer term development of the coal sector and that of the energy sector as a whole. For this reason, the ADB ascertains that the project is viable and desirable not only in the short term but would also be consistent with the longer term development of the coal and energy sector, besides being in tune with the needs and policies for sustained development of the national economy. While examining issues specific to the project, ADB, therefore, examines programs relevant to the longer term development of the coal sector such as policies on mine planning and modernization, safety and environmental protection, manpower training, and choice of technology.

Before concluding, let me commend the efforts of the Government of Pakistan for their promotion of the coal sector. Viable and rapid development of the coal sector

will continue to require Government support and willingness to consider appropriate changes in policy and institutional framework that will facilitate rapid increase in coal production and use. The nature and size of coal sector developments being proposed, including those for Lakhra coal, will require significant participation of the private sector. I hope this Conference would have helped raise the awareness of the private sector to such opportunities. On its part, ADB is interested in assisting the development of the coal sector in Pakistan. We have followed with keen interest the comprehensive preparatory work for Lakhra coal carried out with the assistance of USAID, and we look forward to considering possible assistance in the future for coal development projects in Pakistan within the framework of considerations outlined by me earlier.

FINANCING THE LAKHRA PROJECT

Tim Hartshorn
The Bank Of America

Introduction

I am very pleased to be appearing before such a large and distinguished group whose mutual interest is the development of Pakistan's coal reserves.

As has been mentioned earlier in the Conference, Pakistan benefits from large reserves of average to poor quality coal. Currently this energy resource is only marginally used, but it is the aim of the Government that such an indigenous source of fuel should be included within the country's energy plans provided that such use fits into a least cost energy model for Pakistan.

The Lakhra Coal and Power Project (which has been described in detail by earlier speakers) is by far the most advanced of the proposed major uses of Pakistan's coal and has been actively supported by the U.S. Agency for International Development (USAID) since 1983.

Bank of America's Role

In November 1985 Bank of America was appointed, under a USAID funding arrangement, to assist the Water and Power Development Authority (WAPDA) by providing financial and packaging advice with respect to the Lakhra Coal and Power Project (the "Project"). Our initial role covers the following general areas (which of necessity require us to understand and then define the objectives of all the parties concerned to ensure that their interaction is feasible and amicable):

- Relating the Project's finances to the legal, contractual and regulatory relationships between the Federal and Provincial Governments, governmental agencies and private investors;
- Developing a feasible plan for risk allocation and performance guarantees for both the coal and power aspects of the Project;
- Structuring potential joint venture relationships in the mining component among donors, and private and public sector entities;
- Establishing that the coal mining portion of the Project (the Lakhra Coal Project) is feasible and financable as a business venture;
- Preparing provisional financing and the financial planning aspects of procurement for all elements of the Lakhra Coal Project;
- Assisting with the drafting of the formal request for proposals (RFP) for private sector participation in the coal mining portion of the Project; structuring the RFP to include as many private sector participation options as are feasible (reviewing and contributing to the development of a model coal supply contract as an attachment to the RFP).

Risk Analysis

There are many separate, distinct risks to each project. Project financing is the business of identifying and evaluating these risks and allocating or sharing them between the project sponsors, project beneficiaries such as customers and suppliers, other parties such as governments and insurers, and lenders. The project risks for this Project (the coal and power sections have distinct but interrelated risks) mainly fall into the following general categories:

Resource Risk - covering the [illegible] that

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insufficient coal reserves are available or that insufficient reserves are technically or economically recoverable. Lenders will normally lend only on proven reserves immediately capable of extraction. They will require an independent technical audit to be performed, together with an extensive engineering feasibility study. The feasibility study currently being prepared by the mining consultant should provide the required comfort, provided the coal mines actually developed are based on reserves that have been fully proven and described in that study.

Raw Material Risk - the risk that raw material inputs to the Project may not be economically available. This risk category is usually covered by arranging for throughput agreements or supply contracts, along with a thorough analysis of the markets for the raw materials. Lenders to the power plant portion of the Project will especially perceive the existence of the raw material risk and will look for long-term coal supply contracts. For the Lakhra Coal and Power Project this risk is linked directly with the coal resource risk.

Completion Risk - a key issue in most financings of projects. This risk is defined as the risk that the project will not achieve required levels of actual or demonstrated capacity sufficient to generate the necessary cashflows to cover operating expenses and debt service. Normally lenders will require a Completion Agreement between themselves and the project sponsors, where completion is defined to cover the period of construction, volumes and quality of production by a certain date, cost overruns and projected future cashflow levels. Until completion, the project sponsors would be obliged to guarantee the project debt, or agree to either guarantee the debt or perhaps to purchase the assets of the project, contingent on completion not taking place by a specific date. As an alternative to project sponsors providing this support, lenders may agree to accept either a soundly structured fixed price turnkey construction or development contract from a strong contractor or the provision of a pool of funds to ensure completion.

Operating Performance Risk - the risk that the project will fail to perform satisfactorily after completion. The prime areas for concern are labor relations, together with technological, environmental and regulatory risks. Evaluation and mitigation of operating risks will often be subjective and lenders will normally assume such risks within the margins of financial safety. Quite often, the completion tests embodied in the Completion Agreement can be designed to significantly reduce post-completion operating risks.

Marketing Risk - that the project output cannot be sold at the forecast prices. This risk is usually covered by the arrangement of long-term contracts for the sale of project output with as strong terms and conditions as possible. "Take or pay" or "take and pay" contracts are often arranged where the purchaser agrees to pay a defined price (perhaps including a floor price) with the aim that the revenues will at least cover operating costs and debt service. A "take or pay" contract is one where the purchaser agrees to pay for the output, even if it is not produced. A "take and pay" contract is one where the purchaser agrees to pay for the output if it is produced and offered to the purchaser. Lenders to the coal mines will want to be sure that the coal sales contracts to the power plant (i.e. WAPDA) are sufficiently strong to ensure that finance can be arranged. The marketing risk for the power plant will be viewed as a regulatory one (if prices are controlled by the Government or some Government Agency) or a consumer acceptance one, and will have to be reviewed when considering the strength of the sales contracts. However, to ensure that the coal mine operation is efficiently run, we believe that it is essential that a fixed price plus escalation coal pricing formula is agreed. A "cost plus" mechanism

does not normally provide sufficient incentive for the mining company to improve the economics of its operation.

Management Risk - the ability of the project to attract and retain an effective management team. This risk may be covered by one of the project sponsors having the required experience, or alternatively an operating/management/training contract should be entered into with an experienced third party. As the coal mine developers may vary considerably in their financial strengths and technical expertise, the solution for each coal mine development may be different.

Foreign Exchange Risk - the risk that project cash flows during the construction and operating periods may be adversely affected by movements in foreign exchange rates. This risk can sometimes be reduced or eliminated by arranging, as far as possible, for the matching of the currencies of the project receivables with those of the project expenditures. However, in this particular instance, the end product is sold in the local market while over one third of the Project's cost will be incurred in foreign currency. Governmental and Central Bank approval to remit foreign currency offshore will be needed. In fact, foreign currency will have to be dedicated by the Government and included within its national plan to ensure its availability when required. Quantifiable foreign exchange risks may be coverable by hedging in forward foreign exchange markets, although the market for hedging between foreign currency and local currency is likely to be limited.

Political and Regulatory Risk - government intervention or regulation may jeopardize a project's ability to service debt. Dealing with this risk can be difficult as the methods used to mitigate it can also be subject to the same risk. Political risk insurance cover can be obtained from government agencies such as the U.S. Overseas Private Investment Company or from commercial sources such as Lloyds of London. Additionally, the risk may be reduced by creating appropriate incentives and disincentives for the government concerned, and by diversifying both project sponsors and lenders, with the inclusion of the host government in the former and foreign government agencies in the latter. The involvement of one or more of the multilateral agencies can also be of benefit.

Casualty Risk - the risk of damage or destruction of the capacity of the project to bring output to market. Insurance against loss of project assets before and after completion, and cashflows after completion, must be entered into.

Force Majeure Risk - the risk of events occurring outside the control of the project sponsors, which could delay the project, stop construction or production, or reduce cash flow through lower revenues or higher costs. This risk, which includes natural disasters and strikes, can be insured against or lenders may seek guarantees from the project sponsors or other involved parties.

The ten risk categories, as set out above, are certainly not exclusive, nor are they independent. Each project has its own particular risks and novel solutions may have to be created to satisfy lenders, project sponsors and other involved parties.

Once the Lakhra Coal and Power Project's risks have been analyzed in depth, a risk allocation plan will be structured by Bank of America in such a way that those parties who are prepared to take the risks are adequately compensated for so doing.

Economic Acceptability and Viability

Based on the economic feasibility study being prepared by the economic consultant (which in turn will be supported by the technical and other feasibility studies), we will review in depth the feasibility and the ability to finance each major constituent part of the Project together with the effect of each part of the

Project on the total feasibility of the project and the ability to finance the total project. It may be that a particular aspect of the Project has a disproportionately adverse effect on the total Project's economics. In such a case, we would work with the other consultants in an endeavor to solve the problem. Alternatively, the economics of say, a particular coal mine, will depend on the terms of the sales contract entered into with WAPDA. If the coal mines are, as is possible, funded separately, then we will have to ensure that the appropriate terms are contained in the coal supply contracts to provide acceptable security the lenders. In fact, Bank of America would utilize its past experience in reviewing coal supply contracts to ensure that a standard, broadly acceptable contract is drafted and presented to the coal mining companies. Variations in these contracts, negotiated by particular coal mine sponsors, will be reviewed on a continuing basis, so that the basic strengths of the contracts are not impaired.

Procurement and Financing Plans

Procurement and Export Credits

- Procurement and export credit financing are interlinked so we shall consider them together.

Part of our role is to assist in preparing a preliminary procurement matrix in conjunction with the technical consultants. This matrix will list the various sourcing alternatives available for all major items of equipment, goods and services. The potential suppliers would all be technically capable of fulfillng the specific contract requirements. The procurement matrix will be formulated under the initial assumption that maximum procurement from each country is obtained. Using this matrix we intend to produce a compatible matrix for the financing options which will detail the terms and conditions under which the identified Export Credit Agencies would, in principle, provide finance.

Export Credit Agencies are major sources of funds for international capital projects. They are generally government or quasi-government agencies and although they operate in different styles, they are very similar in purpose. Many provide fixed-rate subsidized finance. Some, most notably Japan, West Germany and Switzerland, do not provide subsidized finance, but provide funds primarily in their local currency at market rates; whereas the majority of Agencies are willing to consider lending in hard currencies, particularly the U.S. Dollar.

The lending policies of most Export Credit Agencies are governed by the Organization for Economic Co-Operation and Development (OECD) Consensus, which sets guidelines under which maximum and minimum terms and conditions are stated. The Consensus separates the guidelines into three categories, based upon the GNP per capita of the country of the borrower. Pakistan is a category III country, and the standard terms for this category in U.S. Dollars is 8.80% p.a. fixed, with a repayment period of up to ten years from commissioning of the project. The rates are reviewed every 6 months with the next review as at 15th July, 1986. In addition to setting levels for U.S. Dollar finance and other higher interest rate currencies, the Consensus also defines certain currencies as Low Interest Rate Currencies (LIRCs) and allows officially supported export credits to be granted in these currencies at market rates below the above quoted U.S. Dollar interest rate. For example, the Japanese Yen, the Swiss Franc and the Deutschemark are defined as LIRCs.

The willingness of Export Credit Agencies to accept certain project risks varies greatly between the Agencies, and it is, therefore, important to develop a security structure which will be acceptable to a number of Agencies. To do this effectively it is important to know the mode of opera-

tion and references of the individual Agencies, and to develop a strategy where the most receptive Agencies are approached first, followed by the next flexible Agencies. If Export Credit Agencies are unwilling to accept project risk, it may be possible to arrange an alternative security structure.

Standard export credit terms permit finance to cover 85% of the value of goods and services exported; however, it is often possible to obtain cover for local costs associated with the project to the value of 15% of the exported goods and services. Also, supplies from third countries, to the value of 10%-30% of the exported goods and services, may be covered, particularly if both countries are within the EEC.

Export Credit Agencies do not usually require principal payments to be made during the construction period of a project; interest only is paid prior to completion. However, some Agencies may agree to capitalize interest during construction. This benefit should be sought wherever possible. In addition, there are normally no prepayment penalties associated with export credits, therefore attractive possibilities for refinance may become available upon completion or at a later date.

As we stated earlier, the lending terms and conditions of most of the Export Credit Agencies are initially controlled by the OECD Consensus, so theoretically all terms should be similar; however, in practice, terms vary as most Agencies are at least willing to match superior terms and conditions offered by competing Agencies. This willingness to match, together with the desire of countries to participate in a project as prestigious as Lakhra to the maximum extent possible, may allow for an improvement in standard terms to be made. It is one of our main objectives to achieve this incremental benefit.

Once the parameters of the procurement and relating finance have been defined and our strategy agreed, we will make our initial, carefully planned approach to the Export Credit Agencies, either solely or jointly with the project sponsors as agreed. The first step will be to write a specific Information Memorandum for the Agencies which will fully describe the Project, its financial requirements and the risks to be absorbed. From this approach we expect to receive an "in principle" agreement to provide finance. Where possible this will be on a project line of credit basis, so that bidders from that particular country will not each individually have to negotiate export credit terms. The approach will be structured in such a way that those Agencies most likely to be flexible and to offer the more advantageous terms will be approached first. Once acceptable terms and conditions are obtained, then approaches will be made to the less flexible Agencies on the principle of obtaining, as a minimum, matching terms and conditions.

The outcome of this initial approach to the Export Credit Agencies will, of course, have to be considered in conjunction with the prices, technology, delivery arrangements, etc. that are likely to be offered by the suppliers of the equipment and services from that particular country.

The finance offered by the various Export Credit Agencies will most likely include a variety of currencies, tenors, interest rates and other fees, and therefore immediate comparison will not be possible. To facilitate this comparison, we will analyze the cash flow implications of each offer, including the effect of currency movement. The actual evaluation will include expressing the cash flows resulting from each option in a single currency with a single annual cost. This will enable each offer to be expressed as a Net Present Value (NPV), thus allowing direct comparisons of each option to be made.

Additional to this NPV analysis, a detailed sensitivity analysis will be completed; this will concentrate on the main risk areas associated with each alternative. Sensitivities examined will include

the effect of potential exchange rate movements. One aspect of this will compare the annual change in exchange rate needed to equalize competing offers (breakeven analysis).

Preliminary Financing Plan - At the same time, and in addition to the Export Credit Agencies, Bank of America will prepare a preliminary financing plan for attracting the most competitive sources of funds to the Project. This plan will endeavor to link the economic benefits of the Project to the potential lenders and aid donors who might benefit directly or indirectly from the Project's successful implementation. It is expected that the World Bank, the Asian Development Bank (ADB) and USAID will play major roles in the funding of the Lakhra Coal and Power Project, as will the Government of Pakistan in the local currency area. Other regional development banks or specialized funds, including Arab Institutions, will also be considered. Subsidized export credits will be maximized, suppliers will be encouraged to offer "mixed credits" from countries where aid support, in addition to export credits, is available. Commercial debt (local and off-shore) will be minimized, as it is generally the most expensive source of fund with a relatively short tenor. Possibilities of co-financing under the new rules of the World Bank and the ADB will also be considered.

We will base the financial plan on the economics of the Lakhra Coal and Power Project (as presented by the various consultants) which will have been analyzed for their financial implications. Sensitivities will be performed where the major variables of the Project are modified to observe their effects on the Project's vaiability. Particular concern will be placed on foreign exchange variations, mining costs, delays in production, electricity prices, and the level of equity, aid and subsidized funding raised. Each participant in the Project (be they the Government of Pakistan and its Agencies, multilateral agencies, area development agencies, aid donors, Export Credit Agencies, specialized funds, foreign and local sponsors, local equity sources or foreign and local commercial loans) will have their own objectives and requirements. After negotiating to see how far these objectives and requirements can be modified into a standard form, Bank of America will ensure that the financing plan fully meets the requirements of the various funding sources. It should be noted, however, that the Project's constituent parts may attract differing funding sources with varying security and other requirements.

Request for Proposal to Participate in the Investment Development and Management of the Mines

Press announcements have been issued which notified interested parties of the opportunity to prequalify to participate in the investment, development and management of the coal mines. We have reviewed all the prequalified proposals as classified under the five options included in the third press announcement (which have been described by earlier speakers).

Based on the above review of the prequalified proposals, and on the work we have performed previously, we are working with USAID's other consultants in structuring a formal request for proposal (RFP) for private sector participation in the coal mining component of the Project.

While structuring this formal RFP we are bearing in mind the requirement that the private participants in the coal mining sector may have to work effectively with pubic sector entities in the same industry, and the related power sector, and will the aid donors involved in that particular portion of the Project. This relationship may have to be covered by a joint venture agreement which will describe the activities and responsibilities of each party, and how the joint venture entity will deal with outside companies and Government

Agencies and Departments. The content and structure of this joint venture arrangement will be considered prior to the issuing of the RFP; however, its final form will depend on the proposals received.

Choice of Participants in the Investment, Development and Management of the Mines

Following the receipt of the offers in response to the RFP, the offers will be reviewed in detail to ensure that they conform with the terms set down therein. Those conforming offers will then be analyzed in detail, but with specific attention being given to:

- The cash equity being offered;
- Private sector involvement;
- Other funds being offered;
- The ability to raise additional equity, aid and debt based on the structure implied in the offer;
- The risks that the bidder is willing to accept;
- The resulting price of the coal and power;
- The economics of the coal mine development and the effect on the overall Lakhra Coal and Power Project economics;
- The bidders' experience;
- The technical soundness of the bids;
- The Pakistani involvement;
- The foreign exchange requirements;
- The amount of coal supply contained in the bid.

The aim of the RFP process is to maximize the private sector involvement in the coal portion of the Project as it is perceived that the benefits to Pakistan of pursuing this privatization endeavor will be many and material. The main benefits may be summarized:

- Surface coal mining is new to Pakistan; therefore an experienced foreign partner is required. Pakistan should benefit from the transfer of technology resulting from such an involvement.
- Modern underground mining technology.
- A real equity interest (running into millions of dollars) should ensure that the most dedicated and economically sound support is obtained from the non-Pakistani mining partner.
- The private sector (particularly the major non-Pakistani companies) are experienced in obtaining excellent prices for equipment and services on a world wide procurement basis.
- The profit incentive (via a fixed price plus escalation formula for the sale of the coal to WAPDA under a 30 year contract) will ensure that the capital and operating costs will be minimized and that sound management techniques are employed.
- The private sector may be able to tap sources of funds that are not available to the public sector (i.e., the International Finance Corporation).
- The successful implementation of such a major coal mine development by the private sector should set a precedent for future private sector capital intensive projects in Pakistan by providing the legal framework of such developments and by demonstrating that both the financial and political environment is conducive to such activities.

Conclusion

Much work has been done over the last few years by all the parties involved with the Lakhra Coal and Power Project and the Project has not been brought to the stage where all the related feasibility studies are about to be completed and the issuance of the RFP for the coal mine development is imminent. However, there is still some way to go, i.e., the evaluation of the bids resulting from this RFP, the appointment of the A/E (Architect and Engineer) for the power portion of the Project, the negotiation of the coal sales contracts and the orchestration of the funding arrangements for the Project.

ROLE OF DEVELOPMENT FINANCE INSTITUTIONS IN COAL DEVELOPMENT

Muzaffar Mahmood Qurashi
Managing Director and Chief Executive
Regional Development Finance Corporation
Islamabad

INTRODUCTION

Coal mining in the subcontinent started in the last 19th century to feed the Railways and after independence was continued, perhaps more as an occupation than an industry, in the traditional coal producing areas. Since the mid-1950's utilization of coal was gradually replaced by oil and later by gas, but after the oil crises of the 1970's industry is shifting back to coal. Our low production of oil and limited gas reserves have led to renewed emphasis on coal. PMDC and PUNJMIN in the public sector, together with a large number of private mineowners (operating 232 leases and 501 prospecting licenses) produce 1.8 million tons of coal. About 85% of the production is contributed by the private sector.

The quality of our coal varies from lignite to bituminous. The main coal mining activity is in Baluchistan province. The estimated coal reserves of 1,178 million tons are located in 13 major coal fields: of these 8 are in Baluchistan, 2 in the Punjab and 3 in Sind. There are also minor coal reserves scattered throughout the country, including NWFP and Azad Kashmir.

Although the energy demand has increased at a rate of 9.3% per annum during the last five years, only 5% is supplied by coal. NWFP and the Punjab are the major markets for coal, together consuming about 85% of the output, whereas Baluchistan consumes only 6%, mostly for electricity generation by the Quetta Power Plant. The major use of coal is in brick kilns, estimated at 90% of total consumption. The remaining 10% is used for power generaton and domestic heating. The consumption of coal as a source of energy is growing at a compound rate of 5.6%.

The role of financial institutions in assisting the private as well as public sector agencies to expand output has been limited, but it is necessary for it to grow if expectations about future availability of coal are to be realized. Coal mining involves huge investment long before production becomes available. The initial investments on exploration are all borne by the mineowners themselves. By the time production starts, the financial resources of the mineowners are exhausted. To keep on producing, mineowners require short term financing. The coal marketing channels involve middlemen between consumers and mineowners. These middlemen, the dealers, then become the source of short term financing, but their services are costly. Huge advances are paid by middlemen to book future quantities of coal. On the one hand, advances paid by the dealer to the mineowners include mark-up on the capital invested; and on the other, the dealers demand advances from the consumers. The main burden of this financing rests on brick kiln owners being the major users. Institutional finance would help reduce the excessive burden of mark-up charged by dealers. This will make the product cheaper and use of coal competitive to other fuels.

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This paper attempts to describe the coal mine situation, estimate the requirement of credit if mining is to be expanded to meet the target of producing an additional 3.4 million tons, focuses on the difficulties involved in evaluating private sector coal mining projects and the role that development finance institutions can play. Brief mention is made of the problem of security and some critical policy decisions that need to be taken at the national level. The financial needs of the public sector agencies, while substantial, are easier to meet; the decision rests squarely with the Government. The paper concentrates instead on expectations of the private sector and seeks to provoke discussion on how these can be met.

EXPERIENCE OF DEVELOPMENT FINANCE INSTITUTIONS (DFIs)

Before looking at the framework for providing financial assistance to the mining sector, we have to consider the legal, administrative and operational structures which prevail and through which mining activities are implemented. Prospecting licenses and mining leases granted by Provincial Governments prescribe a rigorous discipline for reporting, scientific management and progressive improvement in mining. The actual reality is a far cry from this expectation. Prospecting licenses and mining leases are more often than not managed as "one man business" or tenancy, often as a part-time occupation, and in many cases even follow the example of absentee landlords. It is by no means uncommon for lessees to sublet the concession, especially if the mine is profitable. When the lessee himself is not working on the mine, it is managed through a "Munshi" (a rustic farm manager) who in technical matters has to be guided by knowledgeable veterans of the locality. For the rest, it is a simple question of employing experienced laborers, keeping a daily (but informal) account of materials excavated and dealing with the buyers. There are many profitable coal mines which men cannot enter except by crawling or bending to waist height and donkeys are used to transport coal from inside tunnels to dumps outside. The only capital investment is usually in wooden supports for tunnels and animal power. Employment of mining engineers and geologists is rare.

Little wonder, then, that institutional finance for mining has been practically non-existent. It is a new initiative. The NDFC financial assistance during 1982 amounted to Rs. 20.9 million, of which Rs. 7.2 million was capital for exploration and feasibility studies. A working capital of Rs. 1 million was also disbursed during 1984. Three projects were sanctioned by PICIC for Rs. 33.168 million in foreign exchange while the Industrial Development Bank of Pakistan sanctioned 3 mining projects in 1981-82 (Rs. 1.92 million in local currency and Rs. 11.16 million in foreign currency). It disbursed Rs. 2.35 million in 1983-84 to one project and Rs. 15.43 million to four mining and quarrying projects during 1984-85.

IDBP is preeminent in having taken the lead to finance private mining projects. However, it is a measure of the difficulties involved that all those loans were processed more on the basis of adequate security rather than a project loans. Mineowners did not establish financial viability of their proposals, nor did they provide geological data.

The recently established Regional Development Finance Corporation (RDFC) has been given special responsibility for the mining sector. It made a small beginning to identify mining projects by writing 120 letters to different mineowners, out of whom only 15 responded. This measure of response can be considered systematic of the mining ecology. These fifteen parties were followed up, but most of them dropped out and eventually five projects were developed. Subsequently, however, interest in mining projects seemed to have in-

creased. Since its establishment in 1985, RDFC received 51 applications against which seven projects (Rs. 2.375 million in foreign currency and Rs. 9.912 million in local currency) have been sanctioned. Another 23 projects (requiring foreign currency Rs. 28.575 million and local currency Rs. 48.579 million) are at advanced stages of appraisal. Seven coal projects under active consideration require Rs. 10.926 million in local currency and Rs. 19.984 million in foreign exchange. The numbers are small and the amounts are modest. But this is not for lack of effort.

Commercial banks, on the other hand, have long been providing short-term credit for coal mining. This is regulated by securities and is based on the business relations that mineowners maintain with banks in their multifarious dealings, often touching upon sectors other than mining. Railway receipts (R/R) are also purchased by banks against a margin, securing the advance against coal loaded in railway wagons. The effort to provide institutional credit for development of mining is of recent origin. It needs time to grow, and support to overcome the many hazards in this new, hitherto unchartered course. The demand for long term finance has to be backed with ability to prepare viable projects. Financial institutions have set up mining cells which are only the nucleus. Their expertise has to develop and widen with exposure to the new demands. There is also great need to develop proper yardsticks on the basis of which projects could be appraised, so that many conclusions which at present are derived from painstaking study and analysis of difficult to obtain data can be reached more quickly and confidently.

ESTIMATING FINANCIAL REQUIREMENTS

Two fundamental questions to be faced are: estimating the credit requirements for coal mining in the private sector, and establishing satisfactory mechanisms to prepare and evaluate projects to be financed by financial institutions. The two are inter-related.

Private sector mines which give about 85% of coal production are small in size but large in number. There are only a few large mineowners (about 10% of total lease holders) mostly in Baluchistan Province, and they produce in the range of 30,000 and 100,000 tons per annum. Most mineowners have more than one lease; therefore the management of leases vests with groups of mineowners. In the Punjab, although the coal reserves are smaller than those in Baluchistan, there are a large number of leases but giving low production. The number of lease holders by size of the area granted is as follows:

Size of Lease Acres	Lease Holders (Nos.)	Total Area Acres	% of Total
a) 0-500	130	33,967	18.32
b) 501-1000	63	45,778	24.69
c) 1001-1500	22	27,735	14.96
d) 1500-2000	11	18,818	10.15
e) 2001-3000	12	30,898	16.66
f) 3001-5000	3	13,254	7.15
g) Over 5,000	1	14,981	8.08
Total:	242	185,431	100.00

Thus, 43% of the area is held by 193 small mineowners. Even if we go up to 1500 acres, 58% of the area is held by 215 lease holders, i.e., 89% of the total. We have only 27 lessees whose holdings are sizeable. Ten leases, mostly large, are in the public sector.

This pattern has serious implications for provision of capital and new technology. Even the task of estimating their financial requirements is made complex and difficult.

Coal mining in Baluchistan, which provides 60% of the production, is the oldest in Pakistan. The mines now require further investments to meet the production targets set in the sixth plan. Except for a few large mineowners who have maintained their mines well, the coal mines of small mineowners are heavily fox-holed and it

would be unrealistic to expect increased production from the existing assets. The tunnels are capable of handling limited transportation and cannot cope with increased production.

Most private mines are small in capital structure and deploy machinery which is five to fifteen years old. The existing machinery has to be replaced in order to increase production and make the operations safe. This requires long term financing. In the past equipment such as compressors, haulage system, water extraction equipment and safety equipment was imported. But such items are now locally manufactured. Purchase of locally manufactured machinery would not only save foreign exchange but also reduce time lag between the financial decision and its implementation. Above all, credit for its purchase is cheaper. Finances are also required to replace existing locally manufactured machinery such as transportation equipment for use inside the mines, parts of safety equipment, charging racks, equipment to improve mining methods and tunnel support systems. Improvement in existing tunnels and excavation of new tunnels is necessary to upgrade internal transportation facilities. Estimating capital requirements for this kind of a massive transformation and modernization is difficult, especially in the absence of any set standards.

In short term financing, the major demand of mineowners is working capital. During the peak season, the mineowners receive advance orders from coal dealers. During such seasons, labor becomes scarce in mining areas and since it is traditionally drawn from far flung areas of NWFP, this can become a major constraint. Regular supplies of mining timber are also required. Advances have to be paid by mineowners in order to retain labor and keep the supplies of timber flowing according to requirement. These advances are sometimes in six or seven digits, which mineowners cannot easily mobilize; they require institutional help. It is estimated that approximately one third of the total production cost of coal is required as short term financing to meet working capital requirements.

The private sector has been given a production target of 3.43 million tons at the end of the current five year plan. Present production from private sector mines is 1.53 milllion tons, leaving a balance of 1.9 milllion tons of additional production required. In a study commissioned by the Government of Pakistan by a leading consultant, the capital expenditure per ton of coal production has been estimated at Rs. 300 per ton. But the existing mines are also in a poor state of repair and would therefore need extensive balancing and modernization to sustain present levels of production. The capital investment on BMR of the existing mines is estimated at Rs. 150 per ton. Based upon these, the capital investment for coal mining in the private sector is estimated as follows:

Existing mines:	
1.53 m. tons @ Rs. 150/ton =	Rs. 250 m.
New mines:	
1.90 m. tons @ Rs. 300/ton =	Rs. 570 m.
Total:	
3.43 m. tons	Rs. 800 m.

Another estimate of the investment required by private sector mines to meet the same target production is made by one of the leading coal mine owners at Rs. 1110 million (Financing and Marketing For Coal Mining Industry, Saifullah Khan Peracha. Paper read at 2nd. National Seminar on Dev. of Mineral Resources, Peshawar, May 21-24, 1983). Taking the two figures together, it can be said that a capital outlay of Rs. 1000 million for the private sector mining industry would be a fair estimate to begin with.

If finances are provided to private sector mine owners in the debt equity ratio of 70:30, then local currency requirements would be 50% of the total credit require-

ments, the foreign exchange component being about 20%. Therefore, approximately Rs. 500 million in local currency would have to be financed by DFI's to meet production targets set in the Sixth Five Year Plan. In addition, when the mines so developed go into production, approximately one third of the capital cost (i.e., Rs. 300 million) will be required as working capital. These amounts do not seem unmanageable and could be provided by financial institutions in the next three years.

These estimates may need to be modified. They may even prove all wrong. They, nevertheless, do give us a basis to begin work in a direction that we all consider important. If credit allocations can be made for these projects and DFIs encouraged to make disbursements, a more reliable estimate of the requirements would in any case soon emerge.

OUR FIRST COAL PROJECT

The applications received by RDFC from mineowners are on very simple format, two pages only, prepared with a view to record basic information like the type of company, mineral, location, machinery in use, etc. The sponsor of project "E" took the simplification a step further; he only signed the form and then requested the RDFC officer to fill it out for him. He stated that he is not in a position to provide any information, and invited RDFC to visit the site for compiling the required data. After some insistence, the sponsor provided copies of development schemes submitted to Director of Mineral Development in the 1970's. The maps originally produced in the 70's were provided with updating; they were not signed by any Surveyor or Mining Engineer. However, on request the sponsor updated the maps, showing a very rosy picture, with well-drawn adits, inclines, levels and galleries. But actually the adits, inclines, levels and galleries were small in size, haphazard in dimension, and zigzag in shape.

On inspection, it was found that the mine had a central incline in which a man of average height cannot walk straight. At the farther end a side track was found, which was merely a fox hole. A kerosene lamp was burning at the end of the main incline. A laborer appeared with a coal bag on his back, crawling on hands and knees. The old method of poisonous gas detection with the help of birds is still being used. The deeper you travel, the more suffocating it becomes.

The RDFC officer visited a number of mines to obtain estimates of operating expenses. A working paper was then prepared on the basis of information received, setting out the assumptions of project cost and earnings forecast. Each detail of raw material and manpower was reviewed at the head office. The production cost so calculated was then discussed with a number of mineowners for confirmation. To firm up the project cost, machinery was selected with the help of the sponsors, and after discussion with PMDC engineers who have vast experience in coal mining. Quotations were then called for by RDFC from local suppliers of foreign machinery.

The main problem arose in preparing financial statements of the project. The sale price of coal, the quantity sold by the sponsor, and the cost of production were confirmed for the last three years. On that basis the project showed tremendous profits and there was no apparent reason for it to be short of finance. Further analysis showed that all the profits, which were high, had been drained away. None of it had been reinvested. Nor were any deposits retained in the bank. The instantaneous depreciation of the mine's machinery aggravated the problem in firming up its true value. It took about seven months to finalize the project proposal, and it underwent another analytical study for a month before being put up for sanction.

RDFC suggested in the sanction letter that the partnership be converted to a private limited company. The sponsor had

already agreed to this, but after issue of the sanction letter, he discussed it with his income tax advisors and refused to convert the form of management. It was only after lengthy discussions and arguments over a period of six months that the sponsor agreed to form the private limited company. The process of finalizing the Memorandum and Articles of Association took another two months; the company was formed eleven months after sanction. By this time the project had to be revised yet again in accordance with the decision to adopt non-interest bearing modes of financing.

The finances still could not be disbursed because of legal objections on the security offered. Since the balance sheet provided was not authentic, not having been signed by qualified chartered accountants, the mine machinery and the lease itself could not be considered as adequate security. The sponsor then had to be requested for additional collateral to cover the local currency component of financing.

During all this time, the RDFC was under constant pressure as the sponsor did not realize the importance of the issues involved. In his view, the mine was saleable and had substantial value. He felt that reserves were proven. But this had not been done scientifically. RDFC therefore took a different view altogether. For RDFC the value was mainly its good will, not a tangible asset which could be encashed on default. Most of these difficulties arise from the fact that the mineowners have not realized the importance of maintaining proper books of account and other records.

HAZARDS IN APPRAISAL OF COAL MINING PROJECTS

Appraisal of mining projects is quite different and more exacting as compared to the appraisal of industrial projects. Here we deal with a hidden product; it would surface only if the assumptions made are justified fully and the planned methodology is implemented. These are all open questions. They can be answered to some extent with adequate technical support as was done by PMDC when they sought financing from NDFC. Their proposal gave details of each aspect of project cost, production, sales, reserves, etc. Their sales were already committed because the collieries were being developed for Pakistan Steel Mills and WAPDA power generating units. The mines were operative, the reserves were authentic and properly verified; therefore there could be no difficulty in accepting the mining assets including lease as security. The accounting records were well kept, and reserve estimtes scientifically undertaken. The equity investment was made from the Corporation's own sources. Repayment of the loan was not doubtful; therefore no problem arose during appraisal of the loan for sanction.

But mining in the private sector does not follow established accounting and technical methods. The mineowners follow a sort of hit and trial procedure; their emphasis is on easy production; they seldom undertake any planning before hand. The first bottleneck is the availability of reliable and accurate accounting and technical data. Like most small businessmen, the mineowners tend to keep two types of record, i.e., for tax purposes, and for personal use.

Most coal mineowners are registered firms, partnerships or sole proprietorships. Often the lease owners directly supervise the mining activities and do not feel the need to keep any record of quantity or quality of coal mined out. This helps avoid payment of taxes and royalty, but it severely hinders project appraisal.

The accounts prepared for personal use are recorded on personal diaries which can only be understood by the author of the accounts or sometimes his close family members. These accounts are not available to DFIs, and could not be deciphered if they were. It is difficult to appraise mining projects on the basis of records

prepared for tax purposes because that record shows losses in coal mining. The rates of profit in coal mining vary from mine to mine depending upon the quality of coal, and can be a mere 10% or as high as 300%. But in the absence of accounting data it is difficult to justify either hypothesis. At the same time, the mineowners claim that they earn meager profits and therefore mining with modern equipment purchased through self financing is not possible. All this makes institutional financing so difficult.

Appraisal of the project requires information regarding previous working to link it with future prospects. The labor costs, raw material costs, development costs, operating cost, administrative costs, selling costs, etc. are basically inputs for preparation of a feasibility study to ascertain project profitability. The mineowners undoubtedly spend huge amounts during exploration, before production is available, but these costs are not recorded. This results in difficulties while calculating depreciation schedules of mine development, the extent to which the mineral assets have been depleted and finally the net worth of assets. The net worth of the project is a basic requirement in financial analysis as well as to ascertain net value of the mine for security purposes.

A bigger problem is estimation of reserves. The total reserve of leased areas, the reserves exhausted and remaining potential of the mines on the basis of which the project could be evaluated are not available because few mineowners estimate reserves with modern drilling methods. The provincial mineral departments do not insist on core drilling, since this is not mandatory. The mineowners prefer to excavate small tunnels (at small outlay) to touch the coal seam. The seam is then followed for excavating coal. The excavation method followed is also not scientific. The mined out area (Goaf Area) is not properly filled. This practice not only makes the adjoining area dangerous for future working and results in wastage of reserves; in the absence of proper drilling and planned excavation, it is also difficult to estimate the exact quantity of coal reserves on the basis of which future potential of the mines could be estimated.

The financial institutions can provide assistance ony after making sure that the project is commercially viable and that payments from the borrowers are likely to be timely. For this purpose, it requires proper mining plans which can only be prepared by expert surveyors and engineers. Most mineowners, being small, do not employ such technical staff. They rely mostly on mining "sardars" who are not in a position to prepare written mining plans. The internal survey of the mines requires sophisticated equipment which is usually not available to mineowners.

Drilling equipment is only available with public sector organizations and some private drilling companies. Its use costs Rs. 500 to Rs. 800 per ft., while the expenditure inclurred on excavating tunnels and levels manually is Rs. 200 to Rs. 300 per ft. The latter method, though certainly cheaper, only gives a rough indication of the reserves available between two levels/tunnels; it is time consuming and does not give accurate potential of the mine for its remaining life. On the other hand, we have very few consulting houses capable of making accurate and authentic estimates of reserves, on whose recommendations the DFIs can rely for project analysis. The capability of these consulting firms is by no means proven. Further, their services are expensive and therefore beyond the reach of most mineowners.

Mining, especially underground, is a risky and difficult industry anywhere. In Pakistan, the mining areas are particularly inaccessible and their environment inhospitable, which makes mining even more risky. This makes it all the more necessary for financial institutions to evaluate the projects with care and ensure that their financing is secured properly.

PROFILE OF A MINING ENTREPRENEUR

RDFC received an application which was so deficient in supporting data that it could (and should) have been rejected out of hand. This RDFC did not do. The verbal description provided by the mineowner and the preliminary study conducted by RDFC officers encouraged us to look further into the possibility of developing the mines. This made the exercise an interesting - and vastly instructive - endeavor.

In this district the coal belt extends for many miles. The occurrences were known as early as 1876, having been first reported by the Geological Survey of Pakistan, WPIDC, and two well-reputed Consultants. The reports of the Geological Survey of Pakistan and one of the Consultants classified the coal as of "superior" quality, being of bituminous to anthracite grade, with high fixed carbon as compared to other coals. However, the reports showed limited reserves. The coal seam ranges from 1 ft. to 4 ft. in thickness and reserves of all categories have been estimated at 126,400 tons. This estimate, based upon surface geological data, proved to be much too low in light of the claims of these mineowners and reports fo their practical working.

Crude aditing was done by six parties on different locations at a depth of 100 to 300 ft. This proved that the reserves are much more than what was reported earlier. The mines had ceased operation on account of water logging, non-availability of road links to mine heads, market constraint (the coal being suitable for brick kilns which required transportation over long distances), primitive mining method and limited investment. While the project did not appear viable for major commercial development, possibilities of operating it at a modest level did exist.

The sponsors approached RDFC for financial assistance for mechaniztion of their mines, construction of approach road, and working capital to restart mining. Though the coal reserves were limited, it was felt that small scale mining would be feasible. Further, the coal appeared suitable for the cement industry, and if the project became viable it could provide a good breakthrough. The sponsors were asked to restart mining and move in further depth by utilizing their own capital so that the reserves could be proved by studying subsurface geology. In the meantime RDFC wanted to study the market of this coal. One of the sponsors tried to open new adits but could not overcome the underground water problem with his scarce resources.

The mineowners insisted that the area is not short of coal but had never been explored for detailed study. They were asked to provide a feasibility report; they responded with a geological report prepared at one of the Universities which merely mentioned the quality of coal and concluded that reserves of the area are satisfactory where the strike length of coal is 4000 yards. This report was again prepared on the basis of surface geology.

The sponsors refused to invest any money in preparation of a feasibility study. The coal mines, therefore, had to be studied twice and each time in great detail by RDFC to verify the report. Eventually a proposal was prepared to provide working capital on the assumption that the project be undertaken in two stages. Stage one would bring the mines in working condition, market the coal and prove the reserves for the second stage. It was proposed to them that mining activity be gradually built up, starting from two parallel adits, but they insisted upon opening up all four adits from the very beginning.

The mineowners were reluctant to provide security other than the lease itself. They claimed to have exhausted their own finance. That is why, they said, they requested RDFC financing to restart the operation. During these discussions it was suggested to them that they should either let another party with financial resources undertake the operation, or enter into partnership with someone interested in co-

financing. Some parties were interested in development of this mine and were willing to finance it. But the present sponsors were willing to forego no more than a 5% share in the mines against the offer of a substantial financing package. This obviously did not provide a practical basis to secure agreement.

RDFC arranged with a drilling company to undertake drilling work in order to quantify the deposits and, in an effort to set the ball rolling, the drilling company was persuaded to undertake one free drilling. It was further agreed by the drilling company that they would expect payments for the remaining holes only in case the first hole proved successful. In drilling the first hole, no investment by the present mineowners was involved. Unbelievably attractive, one would have thought! But the mineowners were not willing to undertake any payments at all, not even in future, not even if the first hole drilled free of cost proved successful. This is a sample, and by no means unrepresentative, example of the kind of attitudes encountered in appraisal of mining projects.

LEASE AS SECURITY FOR MINING LOANS

Institutional financing for mines is a new initiative in Pakistan. According to the prevalent financing practices, the only mineowners who qualify for loans are those who have proved mineral reserves and who have developed some mining facilities on their own or who can provide personal securities and collateral to secure the loans. The mineowners are hesitant in pledging their personal properties as collateral and urge that only leases should be taken as security.

The mineral bearing areas tend to be located in mountains, or at far flung areas away from urban centers. In case of default, the exercise to assume possession of mines becomes very difficult. The physical conditions of mining projects differ from the condition of industrial projects. Most industrial projects are located in areas where marketability of the project itself is not difficult. On the other hand, marketability of mining projects is highly uncertain, to say the least.

The past experience of the DFIs is not encouraging. For example, the RDFC received six loan requests from medium and large mineowners. Two of these had already availed financial assistance from other institutions, granted five to eight years ago. In both cases the security was a mortgage of the mine assets. One party was a complete defaulter, while the other had been only paying the interest. The adequacy of the mine assets as security has yet to be established.

One practical problem in taking the lease as security would be the difficulty in assessing it in monetary terms. In case the reserves have been properly evaluated and coal excavation is carried on in a systematic manner, it would be quite easy to assign monetary value to the undepleted mineral stock. But the absence of authentic data on reserves and unsystematic excavation of minerals make it very difficult to ascertain the quantity of undepleted reserves. It is difficult to assess the actual resale value of the assets at which the mine could be sold in case of default. Considering leases as security is only feasible in case of good and developed mines, for which only big mineowners qualify. But mines which are not properly developed are risky.

There are also legal problems in taking leases as security. The mining concession rules of the Punjab and Sind do not allow transfer of lease to any third party, while the laws of Baluchistan and the NWFP have been amended to allow assignments of lease in favor of financial institutions. Even in Baluchistan and the NWFP assignment of the lease does not seem a practical alternative because of location of mines in difficult areas. Mines that have been controlled and operated by the lease holders for a number of years tend to

be regarded as their particular domain; their authority and control is well established, and it is not easy for any outsider, even if backed by law, to take over in safely operating the mine. Furthermore, even when the lease is assigned, the first charge is always that of the government dues. DFIs will have to be content with the second charge.

The tax rules permit charging depreciation at 100% in the first year of deployment of mining machinery. After the first year the book value of such machinery and fixture becomes zero. Mineowners do not keep records of the market value of the machinery for its remaining life. There is no practice of charging yearly depreciation and calculating book value of the assets. In many cases the machinery is 10 to 15 years old, fully depreciated but still used, with heavy maintenance costs. Can it still be considered as good collateral?

The first step, therefore, is that mining concession rules of other provinces should also be amended on the lines of the amendment made in the Baluchistan and NWFP rules. This change would at least provide a basis for financial institutions to look upon the mining lease itself as possible security. The next step will be to ensure proper implementation of those rules under which accounting and record keeping is mandatory. This is likely to be far more difficult, but it is essential and must be initiated. Gradually, as leases come to be traded in the industry, their acceptability as collateral should improve.

TWO ESSENTIAL STEPS

The credit system in Pakistan is regulated at the national level. The requirements for various sectors and sub-sectors are estimated for the financial year. The requirements and availability of credit are then matched by the National Credit Consultive Council which lays down the ceiling for each sub-sector. The ceilings are then assigned to financial institutions for financing over the year. Thus, the requirements for agriculture, working capital needs of industry, exports, small loans, food procurement, etc. are all estimated, programmed and monitored. There is no such allocation for the mining sector. Mining has to take its share from the credit provided for industry. In the industrial sector, however, various sub-classifications have been made. First, the public and private sector; second, between fixed investment and working capital requirements; and third, special allocations are made for small industry. Certain sectors are assigned mandatory targets which the financing institutions are required to disburse. The first step, therefore, seems to be that specific annual estimation be made for the mining sector and suitable allocation provided. The financial institutions as well as the mining industry would thus become aware of the needs and availability. This would stimulate formulation of projects to be financed. The six monthly and annual review of disbursement would exercise effective pressure on financial institutions to seek avenues for disbursing credit for mining. Their expertise in credit management and their influence in the marketing system would be used to the advantage of mining.

This, of course, will only be a beginning. The next step is to see what support is needed to assess the mining sector. The sixth plan states:

> "It is proposed to provide judicious set of incentives to the private sector for the quick development of mines to meet the targets of coal production."

Traditionally, concessional terms of financing have been used to assist such priority sectors as exports and agriculture. It cannot be disputed that the mining industry faces many a traditional disadvantage. Further, it also occupies a strategic place in the national economy. Its need for support, therefore, is no less urgent than that of the agriculture sector.

Consequently, concessional terms of financing already given to many sectors need to be given for mining as well. The Government of Pakistan, with the collaboration of International Development Agency, has instituted a concessionary credit (popularly known as the IDA credit) to provide incentives for small industry. This credit is available up to Rs. 1.5 million per project and carries an 11% intrest rate. The mining industry, however, is not eligible to receive this credit. This should be rectified. Again, the State Bank of Pakistan provides a soft line of credit to encourage use of locally manufactured machinery in preference to imported machinery. This credit carries an interest of 7.5%. Similarly, as a measure to increase exports, the Government of Pakistan has allowed an export credit at a concessional rate of 3%. Since the increased use of coal will aid in reducing Pakistan's import bill, its mining and development should also be entitled to a similar incentive. It is now the declared policy of Government to encourage use of coal in preference to other forms of energy.

Can we not say, then, that coal mining qualifies for at least a comparable incentive?

RISK EQUALIZATION FUND

While there is uncertainty in agriculture on account of weather, the net output from a farm can still be forecast with a reasonable degree of accuracy, but such a forecast cannot be made for mining. The risk element in mining is much greater. This implies that while softer terms of financing would enable the mining sector to overcome some of the financial handicaps, separate arrangements will still be necessary to provide cover against risks which are substantial. There have been several proposals under consideration of the Government which, one understands, have received sympathetic consideration. Their logic requires a bold decision to create a pool of capital, a Risk Equalization Fund, out of which investment that goes bad can be replenished.

MACHINERY POOL

It has been suggested that RDFC should finance the establishment of machinery pools in the mining districts, at locations to be fixed in consultation with associations of mineowners and the provincial governments. These machinery pools would include items in common use like pneumatic drills, compressors, pumps, generating sets and some heavy equipment like bulldozers and cranes. This equipment would be provided to mine operators on a rental basis. The availability of equipment on rent or lease, particularly in the case of heavy equipment where individual purchases are not justified by small mineowners, would expedite development, reduce costs, and minimize the need for risk capital. The critical constraint, however, is professional management of the machinery pool. So far RDFC has not been able to identify a party that can provide efficient management. The proposal has been discussed with mineowners more than once, who all expressed interest but have not yet come forward with a specific project. The difficulty in getting this worthwhile proposal implemented underlines once again the nature of handicaps confronting the industry.

REPORTS OF THE RAPPORTEURS

OVERVIEW

Ashfaq Mahmood, Chief, Energy Section, Ministry of Planning & Development

The session began with the paper on overview of the Energy Policy of Pakistan, followed by papers on coal utilization policies, factors influencing coal supply and demand and exploration strategy for assessment of coal resources of Pakistan. The key points and recommendations emerged as follows:

Location of Lakhra Plant

The site selection should give proper consideration to human factors including the educational needs of workers' children and other social facilities. It was noted that such facilities could be built at new sites as was done at PASMIC.

National Coal Authority

One viewpoint held that a National Coal Authority would only duplicate efforts by PMDC, Provincial Coal Agencies, WAPDA, ENERPLAN and the Mineral Coordination Board. The other view suggested that a central organizing body was needed to provide overall policy direction and to set goals.

Alternatives For Energy Supply

Alternate energy sources other than coal were considered, such as advancements in nuclear power. Since Pakistan's energy requirement is about 550 MW/yr, it was concluded that coal and other resources must be developed to supplement, not supplant, each other.

Too Many Studies

Numerous studies have been done on Lakhra Coal for more than 20 years. The opinion of those present was that it was time to start a project which would yield tangible results.

Market Constraints

The Conference noted that the coal mining industry in Pakistan has faced a severe crisis for the last two years. This has lead to an accumulation of coal stocks at mine sites, low sales, falling prices and heavy losses. A constrained market is the cause of the problem. Nearly 85% of the national production is consumed by the brick kiln industry. Overproduction during the past two years, particularly from Lakhra fields, has also contributed to the glut situation.

Market diversification of coal was recommended especially in the areas of cement, sugar production and power generation. If necessary, laws should be enacted to immediately require use of coal in other industries. Coal use for gasification, fertilizer production, town gas and coal-oil mixtures should also be considered since it will take at least 5 years to fully utilize coal for power generation. Action is needed immediately to alleviate the current coal glut and this can be achieved quickly by reducing market constraints.

Integrated Planning For Coal

Planning for coal development and use should be part of the national energy plan.

- R&D facilities at PCSIR should be upgraded.
- The Mining Industry in Pakistan must be modernized. Joint ventures should be encouraged to bring modern technology and foreign equity into the country.
- Mining laws need to be made more liberal. Import restrictions for machinery should be liberalized and concessional funds be made available.
- Studies should be done to evaluate the potential of geothermal energy resources, especially in the Lakhra and Bugti regions.

International Coal Resources Development and Utilization: Policies and Procedures

Charles Bliss, United States Agency for International Development

Five papers were presented during the session. One dealt with the world trade in coal. The other four presented coal development experiences in the Peoples' Republic of China by Zeng Qinghe, Greece by Andrea Vakalis, the Phillipines by P.P. Gallego, Jr. and Thailand by Tammaschart Sirivadhanakul.

In the paper on the world trade in coal, conditions governing the export of coal from the major coal exporting countries (Australia, Canada, Poland, South Africa and the United States) were described. The paper explained the resource and production conditions in these countries which determine the export price of coal. The quantities of metallurgical and steam coal in world trade were analyzed over the past 15 years. The changing conditions of trade and pricing were analyzed in three separate categories. The first category prevailed about 1970-1978 and was characterized by a balance between supply and demand and stable prices. The second category, occurring in the late 1970's and early 80's, was characterized by excessive demand resulting in rising prices. The period coincided with a steep rise in world oil prices. The final and present category is one of excessive supply and falling prices. There is concern over the conditions which will prevail in 1990-91 when the Lakhra Power Project could begin operation.

The paper on experiences in China covered the development of low-rank coal from the Jiangxi Province. Special attention was given to the development of specially designed steam generating equipment that could handle this coal effectively.

The next paper covered the development of low-rank lignite from northwestern Greece. The quality of this coal is poorer than coal in Lakhra. Large power plants have been built in Greece to utilize this low-rank lignite and have successfully operated for many years.

The Philippine paper showed how it has been developing its coal resources for many years and has already built a large (300 MW) power plant to use coal. Unfortunately, lack of attention to the design of the steam generating equipment has forced the plant to import coal to blend with local coat to permit reliable operation.

The final paper showed Thailand's development of its lignite resources and how the country is advancing to serve other than the power generating industry. Noteworthy is the official government policy to encourage private sector involvement in coal mine development and the protection given to indigenous coal through tariffs on imported coal.

EXPLORATION AND MINING

Mohammad Ali Mirza, Geological Survey of Pakistan.

Five papers were presented in this session. The first paper on "Coal Exploration Techniques", by E. R. Landis described a series of stages in an exploration programme. It emphasized the development of effective information, standardization of coal resource assessment, increased use of rotary type drilling and extensive use of geophysical logging and surveys. He explained inductive and deductive approaches to coal exploration and their application to extend the knowledge of an area and narrow down choices through conclusive data. In reply to various questions, the speaker provided following elaborations on his paper:

- Extending the information of a geologically known area to an unknown area is inductive, while narrowing down to a specific area based on exploration is called deductive. The speaker suggested that the inductive approach be used for Baluchistan and the deductive approach be used for Sind.
- With intensive geophysical logging, 70-80% core recovery is as good as 100% core recovery.
- In an area with adequate geological control, one hole every 1 sq. mile is sufficient. If control is inadequate, it may require 4 holes every sq. mile.

The second paper on the "Sonda-Thatta Coal Field" was given by Farhat Hussain. He gave a detailed description of the work done by GSP in identifying and evaluating the field, which according to his judgment has vast potentials. The results of 23 exploratory holes were presented, which lead to an estimated 140 million tons of coal reserves in this field. He proposed a long term program of 190, 125 and 125 additional holes in the Feasible High, Medium and Low areas respectively to determine the field's true potential. The speaker and the Director General Geological Survey of Pakistan emphasized the need to drill 4 holes per square kilometer in a "Feasible High" area where a fifth centrally located hole is normally drilled to further improve the grid. DG, GSP observed that spending Rs. 60 million to explore Sonda is worthwhile since it will prove reserves worth Rs. 60 billion.

The third paper entitled "Contract Drilling" was presented by Mohammad Istifa. The development of core drilling in Pakistan and the efforts of GSP to promote drilling and train competent drilling engineers was summarized. He also discussed the role of private drilling in Pakistan and highlighted some of the difficulties that private companies are facing, including the deployment of public agencies drilling units which restricts private sector growth. He provided guidelines for private drilling companies and proposed that the government provide incentives to promote private drilling.

The next paper was presented by Ashgar Malik, entitled "Coal Mining Policies and Practices". He provided a summary of coal exploration, production and use in Pakistan and showed how coal is being "overproduced" and under utilized. He pointed to policy constraints as the source of the problem and offered solutions to cure the ailing coal industry. He emphasized the need for jont ventures between the public and private sectors and with foreign firms. He also proposed financial and other incentives to promote private sector participation in the exploration and utilization of Pakistani coal. The speaker agreed with suggestions from the floor that coal industry could be better managed through the concept of public companies. He suggested that the government should offer commercially viable projects for joint venture between the public and private sectors, including foreign participation if necessary.

The final paper entitled "Private Operations" was presented by Abdul Khaliq who summarized the ailing status of the coal industry in Pakistan. He asserted that existing government mining policies and practices prevent private industry from entering and remaining in the industry. He proposed radical changes in existing laws to attract private

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investors. In reply to various questions, the speaker provided following elaborations on his paper:

- Banks loan available to the private sector are currently at a 14% interest rate and require solid guarantees. Developed infrastructure and mineral reserves are not counted as assets. Further, private mine owners must create infrastructure for their own mines, adding to the cost of their investment.

- The private sector was capable of restructing the industry towards low cost production. In new areas this can be done without compensating the public sector for preinvestment. The speaker also focussed on the need of developing indigenous capabilities in planning and designing mines, power plants and combustions technologies.

Sessions Recommendations

To effectively explore for coal in Pakistan a sound basis of information is needed. Procedures should be standardized, increased use of rotary drilling is needed and extensive geophysical logging and surveys are required.

- The preliminary results of the Sonda-Thatta coal field are extremely encouraging. The field potentially holds more than 500 million tons of good quality coal suitable for power generation. A thorough and systematic evaluation should be done to determine its true potential.

- To become competitive and profitable, private drilling companies should develop teams of highly trained operators, apply new techniques of core drilling and maximize core recovery through proper use of mud chemicals.

- Future large scale drilling programs must be done efficiently by using diamond drilling techniques. The private sector in Pakistan has this expertise and the government should encourage private drilling through financial incentives such as concessions on import duties, taxes and credit.

- The mining code should be investment oriented and joint ventures of economic viability between the public and private sectors and with foreign consultants, should be encouraged for future development and utilization of coal.

- Participation of the private sector will help increase the percent of coal used in the energy mix, currently at about 6%. In addition to financial incentives, infrastructure facilities should be developed by the government for the private sector.

- Exploration licenses should be awarded freely on a first come first serve basis. The refusal right of the public sector, while sanctioning a new area, should be reconsidered.

- The mining code should be modified to be more investment oriented, based on recommendations made by the four committees appointed by the government during the last 20 years.

- The Lakhra coal study for power generation should provide experience and skills to help develop future coal fields and power facilities, especially with regard to

  - Formulation of an Energy Policy,
  - Developing a national team of experts to evaluate minerals,
  - Developing Pakistani consultants to design mines and power plants in Pakistan,
  - Transfer of coal combustion technology.

ICATION AND TRANSPORTATION

Khalid Pervaiz, Inspector of Mines, Punjab.

The session covered six papers.

The conclusions drawn from the John T. Boyd Company paper are:

- An annual production of 4.3 metric tonnes of Lakhra coal will be required to fuel a 700 MW power plant;

- The cost of surface mining although twice as much as underground mining is recommended because the coal resources will be conserved.

The PCSIR paper discussed the need to chemically and physically characterize coal in order to evaluate the economic and environmental boundaries.

The Burns & Roe paper discussed the use of truck, rail and conveyors for transporting coal. Mr. Philipp suggested that the exact combination of transporting modes is very site specific. Lakhra has to be studies especially since the stacking and transporting of coal that spontaneously ignites is a difficult problem. Special handling such as water spraying is required.

The Stone & Webster paper indicated that conventional coal washing of Lakhra coal will not produce sufficient benefits to offset the carbon loss that will result from the washing. As a result, Mr. Moore suggested that the sulfur and the ash could be reduced by blending with a low sulfur bituminous coal. Based on the analysis of this lignite, 3.88 tonne of low ash, low sulfur bituminous coal will have to be blended with 1 tonne of Lakhra coal. Tests have shown, however, that electrostatic cleaning may be a promising approach which needs further study. It appears that Lakhra coal would have to be beneficiated to a higher heating value if it is to be used in fluidized bed boilers.

The Geologic Associates' paper suggested that disposal of waste from the mine and power plant must be carefully studied and subsequently planned if it is to be done in a cost-effective and environmentally safe manner. If it is done properly, land can be reclaimed and, in certain cases, it has been shown that coal waste will help vegetation grow.

The British Mining Consultants' paper demonstrated that when underground coal mines are mechanized, production is increased and the mines become safer.

INDUSTRIAL APPLICATIONS

Mohammad Nawaz Khan, Secretary, Mineral Coordination Board,
Ministry of Petroleum and Natural Resources

The session on Industrial Applications was chaired by the Secretary Ministry of Industries. The session covered the use of coal in industries and the applicable technologies.

The Pakistani papers brought out that prior to the introduction of natural gas, local coal had extensive use in the transportation, sugar and fertilizer industries. The switch over to gas, and later to fuel oil, was because of low prices and not due to any technological advantages or policy decisions to regulate the use of fuels in industry.

The speakers discussed how local coals could be efficiently used in wet process cement plants and large sized heating units through appropriate retrofitting. Extensive retrofitting experience in other countries and the coal operating experiences in Pakistan in the '60s provide the confidence to introduce large scale conversions based on local coal. If it becomes necessary to blend fuels to lower sulphur output, very low sulphur furnace oil, produced from Dhurnal crude at the Attock Refinery, could be used.

All speakers suggested that local high sulphur coal could be used in dry process cement plants as well by providing flue bypass techniques successfully used in other countries.

A Chinese paper discussed the extensive application of fluidized bed technology in China and suggested the enormous potential it holds in Pakistan for using low grade high sulphur coals.

The technology of using coal-water mixtures was presented. Although this technology is still under development, demonstrations using coals similar to that in Pakistan have been successful.

Another economical use of local coals could be as household fuels in rural areas through briquetting. Experiences in Haiti and Pakistan were described.

Through the session, the following recommendations emerged:

- Policy decisions are needed to introduce local coals in existing cement plants along with arrangements to sustain a steady supply of coal at stablized prices and to provide financing to cover retrofitting costs;
- Policy decisions are needed to require new cement plants to use local coal;
- The Government should sponsor Pakistan scientists and entrepreneurs to learn the use of China's fluidized bed technology and the use of low grade coals for cement manufacture and power generation in the USA;
- Negotiations should begin with foreign firms engaged in research on coal-water mixture technology with the purpose of studying and setting up of demonstration units in Pakistan.
- Manufacturing smokeless coal briquettes in Pakistan should be undertaken on a priority basis;
- The Government should institute all necessary incentives and regulatory support to encourage the use of local coal.

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MANPOWER DEVELOPMENT AND TRAINING

Abbas Ali Shah, Chief Inspector of Mines, Baluchistan

The paper titled "Environmental Considerations in Coal Development and Utilization" highlighted the need to consider the effects of coal utilization on all aspects of the environment including land, air, water, biological and cultural resources. Major impacts in each of these areas were discussed relative to coal mining, preparation, transportation and use.

The remaining papers of this session addressed manpower development and emphasized the need for training and to assign the right man to the right job to increase efficiency. Manpower training should be planned for and implemented prior to the start of the project. The application of modern training technology was shown to produce remarkable results. When undertaking new enterprises, the transfer of technology training should be an integral part.

The Conventional Energy Training Project (CETP), which is conducted by the Institute of Internal Education, Washington, D.C. under a contract with USAID, has designed a 16 weeks training course for utilization of low rank coals in industries and utilities. The Institute can design special courses for a particular coal utilization facility. Areas where U.S. Coal technology practices and research could be transferred were also discussed.

Session Recommendations

- Policy and guidelines for environmental considerations in coal development and utilization should be established,
- A system of environmental training should be created;
- Training mine supervisors, technicians and workers at Lakhra should begin by starting a pilot project there;
- Pakistan should insist that training technology be included along with other technology that is transferred into Pakistan;
- USAID should arrange to train engineers and geologists in the Conventional Energy Training Project in coal mining and utilization techniques as applicable to Lakhra.

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MOBILIZING FINANCIAL RESOURCES

Bashir Ansari, Chief Inspector of Mines, Government of Sind

The first paper entitled "Private Sector Coal Mining Industry in Pakistan" was presented by Mian Saifullah Khan Paracha, Minister for Planning and Development Government of Baluchistan. He gave a brief history of coal mining in Pakistan and then elaborated on,

- Utilization of coal in Pakistan,
- Evaluation of mining methods and mechanization of coal mines;
- Technical problems in coal mines,
- The future of coal mining in Pakistan,
- Work to be done by the private sector,
- Incentive to be considered by the Government.

Mr. Paracha assessed the present coal mining situation in each province and specifically discussed the problems related to the present coal glut. If the mines are forced to stockpile coal, as they have been for the past 2 years, he believed that many mines will close within a few years especially in the Punjab and Baluchistan regions. To prevent such a situation he suggested that the cement industry immediately switch over to coal and that the private sector build small thermal power plants.

In summary, the speaker concluded that:

- The policy adopted by the Government will decide the fate of the private sector in the coal mining industry. If the private sector is not allowed to establish a number of small thermal power plants many coal mines in Baluchistan will close down during next few years.
- The Government should encourage the private and public cement industry to switch from fuel oil to indigenous coal, thereby increasing coal demand
- Public sector coal mining should be able to co-exist with the private sector, especially with the advantages of Government financing, foreign aid, and soft loans. Healthy competition from the private sector will promote better efficiency in public sector organizations.
- The private sector is capable of producing most of the coal needed by the proposed thermal power plants provided the Government grants them necessary incentives.
- 1000 holes be drilled in the Lakhra coal field for proper evaluation.
- 25-30 MW power plants be established in joint ventures between the private, public and provincial governments.
- WAPDA should offer a realistic price for electricity produced by the private sector through a guaranteed and long term contract.

The second paper by Mr. Aswin Kongsiri, Industrial Financial Corporation of Thailand, covered financing private sector lignite projects. He presented the status of a thermal power plant based on lignite and of a utility in Thailand to use lignite to replace wood as a domestic fuel.

The last paper of this session was on the private sector financing of the Lakhra Coal Project by Mr. Neils de Terra of Machtech. He highlighted the risks associated with the involvement of private sector in this project. The risks cover economic, financial, political and technological issues. Outweighing these risks are the following advantages:

- Expeditious implementation of the Project,
- Greater experience,
- More flexibility of procurement;
- Availability of financial sources.

He said that the Lakhra Mining Project may cost $500-700 million excluding taxes and suggested that lending agencies channel financing through WAPDA because of its established credibility.

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Session Recommendations

A separate Department of Mines and Minerals be established in the Provinces to pursue all energy related matters particularly the exploration and development of coal resources and the safety of mines.

WAPDA should examine the feasibility of converting existing thermal power stations to coal.

WAPDA should assure a fair price to private sector firms establishing small thermal power stations based on local coal.

Coal demand must be increased to remedy the present glut in the coal market.

Immediate steps should be taken to encourage coal use by the cement industry and for the private sector to establish small thermal power plants.

THE VIEWS OF LENDING AGENCIES

Tajamal Hussain, Deputy Chief(Minerals), Ministry of Planning and Development

This session was chaired by Mr. D. M. Qureshi. The following recommendations emerged from the presentations and discussions:

- The World Bank agreed that the reports prepared by consultants on the Lakhra project are satisfactory: However, the issues raised at the January 1986 meeting in Washington still required further work. The Bank would submit detailed comments by March 1986.

- The Asian Development Bank assured that it accords high priority to coal development and utilization projects and has initiated a program of direct assistance to the private sector without requiring Government guarantees. It would make equity investments in the private sector, on a selective basis, provided the rate of return is about 12%, the debt-service ratio is about 1.3 and the debt/equity ratio is 70-30. The ADB indicated a strong interest in the Lakhra Project and expressed its continued support for the project.

- The Bank of America discussed the complexities and risks attached to the coal mining industry and said that once the risks of the Lakhra Coal and Power Plant Project have been analyzed in depth, a risk allocation plan will be developed by the Bank. The plan will call for compensation commensurate with the risks involved.

- The Bank of America will also prepare and develop a security structure to Export Credit Agencies and preliminary financing Plan for attracting the most competitive sources of funds for the Lakhra Project.

- The Regional Development Finance Corporation of Pakistan suggested that:

  - local financial institutions should make specific annual estimates for the mining sector and provide suitable allocations.

  - credit at a concessional rate of 3% be provided to the mineral sector.

  - due to the risky nature of the mineral sector, a Risk Equilization Fund be created from which bad investments can be insured.

  - mining machinery pools be created in the mine districts through cooperation of mine owners and Provincial Governments.

The United States Agency for International Development expressed its continued commitment to cooperate with Pakistan in its coal development and utilization activities. These include the Lakhra power project, coal resource assessment, coal briquette market assessment, coal technology transfer (such as possible fluidized bed combustion), coal equipment financing, and support for coal-related technical and policy seminars such as this coal conference. USAID is particularly committed to assisting Pakistan pursue the important agenda of coal related regulatory, pricing and policy reforms raised during this conference, with emphasis on expanding the role of the private sector in Pakistan's future coal development and utilization.

CLOSING ADDRESS

Haji Mohammad Hanif Tayyab
Federal Minister for Petroleum & Natural Resources

Excellencies, distinguished delegates to the First Pakistan National Coal Conference. Assalamoalaikum.

I feel privileged to chair the Closing Session of this Coal Conference which has been addressed by eminent experts in various disciplines related to economic use of low grade coals. I congratulate the agencies of the Pakistan and U.S. Governments who sponsored and ably arranged this Conference. I also like to extend my sincere thanks to the speakers, particularly expatriates, who have generously shared their knowledge with Pakistani scientists.

The Summaries presented by the Session Rapporteurs indicate that the presentations have covered all issues related to indigenous coal. This must nave helped the local and foreign audience in having a clear perception of the importance and potential that local coal carries in meeting ever increasing energy demand and employment generation requirements of Pakistan.

The present Government attaches very high importance to socio-economic uplift of the masses through goal oriented economic development. The audience of this Conference shall be pleased to know that the Prime Minister or Pakistan has declared the greater utilization of local coal as one of the action programs for realizing his publicly announced Five Point Economic Program. Pakistan needs to expand and diversify its energy base to cater to the energy demands of a fast expanding economy. This requires large financial and technological inputs and above all national determination to come up to the challenge. In the current Five Year Plan, highest priority has been given to the energy sector by earmarking 38% of the total size compared to 23% during the previous Plan. The levels of annual development allocations have been closer to the Plan figures. We have been able to make significant progress in the oil sub-sector, where 41 exploration wells have been drilled during the first half of the current Sixth Plan compared to 26 wells during the last Plan period. In the matter of oil production also, our efforts have been blessed with success and we are now producing over 42,000 barrels per day compared to an average daily production of 10,781 barrels per day during the last Plan period.

I hope that multinationals will come forward to make satisfactory contributions in the development of the coal sector in Pakistan.

To help early materialization of such foreign inputs in coal, we need to spell out clearly our national priorities and to well delineate the investment opportunities. This Conference has done well in quantification of the energy gaps which can be filled in by indigenous coal and the issues which need to be addressed and resolved. I am sure it would result in serious dialogue between local and foreign entrepreneurs over concrete proposals concerning coal production as well as utilization.

The papers contributed by the guest speakers from other countries have given the Conference participants an opportunity for insight in the economic and efficient utilization of low grade coals, as of Pakistan. We are thankful for this contribution which has instilled a still greater confidence in us to achieve self-reliance

in energy. The Government would further help in strengthening this conviction through exposure of industrialists and experts to such facilities abroad, utilizing low grade coa ; for multifareous purposes.

Apart from paramount socio-political consideration of energy autarky and employment generation, there are other economic factors also requiring decreased dependence on imported energy. The position of balance of trade and of payments does not allow large scale energy imports on a regular basis. Under such conditions, it would be most appropriate to develop and utilize indigenous coal for pressing economic reasons alone.

Expansion in coal production and increased industrial utilization, in addition to many other inputs require a strong institutional set up. The weakness of the present set up can be seen from the past events affecting the coal market in Pakistan. This set up did not help in the much needed expansion in the local coal market when the international oil prices jumped manifold and it also failed in reacting methodically to a position of oversupply caused by coal having lower production cost. These institutional weaknesses need to be removed if coal is to be relied upon as a reliable sub-sector of the fuel sector. The Federal Government, in consultation with the provincial governments, shall give guidelines for restructuring, which we hope shall be welcomed by all parties in a spirit of broad national interest and outlook.

On behalf of the Government of Pakistan, I extend felicitations and thanks to the distinguished delegates from friendly countries who joined us here in deliberations over use of our low grade coal. I hope they had an enjoyable stay in Pakistan and wish them a safe journey back home.

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