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TRANSFER AND ADAPTATION OF COAL SLURRY COMBUSTION TECHNOLOGY TO DEVELOPING COUNTRIES

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1.0 SUMMARY

1.1 Background

The oil embargo imposed by the Organization of Petroleum Exporting Countries in 1973 and subsequent oil price increases, disrupted the economic development plans of developing countries. It most severely affected those countries without indigenous oil resources. U.S. foreign assistance programs include support of energy projects in these developing countries which will reduce their dependence on oil imports. Accordingly, policy the Agency for International Development seeks to ease constraints and pave the way for the difficult transition from a long-standing dependence on oil to alternative energy sources.

Oil was the preferred fuel for industrial use throughout the world following World War II, up to the 1970's. Oil is convenient to transport, handle and burn. Oil burning equipment requires less training and skill to operate, lower investment to own and is less polluting than coal-fired equipment. It cost less to control the pollution that oil generated and, overall, was no more costly than alternative fuels. During this period, many plants that burned coal were converted to fuel oil for this reason.

Oil prices have taken quantum jumps since 1973, resulting in coal becoming a more favored fuel for industrial and large commercial plants in developed nations. Conversion of existing plants from oil to coal, where practical, is an obvious choice for immediate implementation, particularly in those countries with coal supplies and coal experience. However, the industrial development and infrastructure that has meanwhile evolved, particularly in undeveloped countries without indigenous coal supplies has been based solely on oil. Conversion from oil to coal in these countries may take a decade or longer and will require major investments in plant and infrastructure to achieve significant reductions in industrial oil use. There are practical, economic and technical factors, such as process and equipment design, lack of plant space and lost production during conversion, which preclude conversion of existing facilities from oil to coal, even if a plant once burned coal.

To bypass many of these obstacles and constraints, substitute liquid fuels have been, and are, under development. Coal slurries, such as pulverized coal suspended in oil (COM) and pulverized coal suspended in water (CWM), are fuels which can be fired in equipment which has not previously burned coal.

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There are numerous advantages to converting to coal slurry fuel. A conversion to coal slurry fuel requires lower capital investment than conversion to coal, and takes less time to implement than a conversion to coal. To a large extent, an existing oil infrastructure can be used to store and deliver coal slurry fuel. Coal slurries have the flexibility and convenience of fuel oil and cost less than oil. They can be pumped, stored and fired like oil but the complexity of plant and equipment, space requirements and downtime for conversion are substantially less for coal slurries than for coal.

It is probable that conditions exist in developing countries which are suitable for the introduction and adaptation of the coal slurry fuel technology. The correct combination of financial, socio-economic, political and security incentives must exist to undertake conversion from oil to coal slurry fuel. In some cases, it may even be prudent to design new facilities to fire coal slurry fuel to achieve a reduction in oil requirements in the short term, while obtaining the longer term benefits of additional fuel options and gradual growth of a coal based industry.

Whether such situations do indeed exist needs to be established by a detailed study of the energy situation in each case country. Programs to transfer and adapt the coal slurry technology can then be formulated for each country.

1.2 Objectives and Scope

The objectives of the study described herein are:

- to identify the problems to be solved in order to transfer and adapt coal slurry fuel combustion technology to developing countries.
- to indicate the potential solutions to these problems.
- to assess the potential benefits to developing countries arising from successful transfer and adaptation.

To identify transfer and adaptation problems, the collaboration and cooperation of two non-OPEC oil importing countries, Portugal and Kenya, were obtained. Potential solutions are intended for use in planning and implementing technical assistance programs in countries interested in receiving and using coal slurry fuel technology. Technical assistance programs can be identified to help

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participating countries establish and implement projects to introduce coal slurry fuels to replace fuel oil. Technical assistance programs would be limited to those set by the defined mission of the AID program. Examples are surveys of potential conversion-candidate installations, studies to select the best method of coal slurry fuel supply, evaluation of environmental impacts, provisions for training and similar feasibility studies.

1.3 Procedure and Format

To achieve the objectives listed above, the following activities were undertaken:

- Preparation of a report describing the status of coal slurry fuel technology in the United States.
- Field assessments in two non-OPEC developing countries which would benefit from significant reductions in residual oil consumption through the use of coal slurry fuels.
- Determine whether it is practical to convert entirely to coal-based fuels, through modification and installation of coal handling, preparation and combustion equipment, all or some of the existing installations in each of the countries.
- Identify technology transfer and adaptation problems by comparing the relevant aspects of the situations in each of the developing countries studied with those in the United States.
- Indicate potential solutions to the transfer and adaptation problems by specifying the elements of prospective AID technical assistance programs that appear relevant to the AID objective.
- Estimate the benefits to be gained in each country, through a successful transfer and adaptation of coal slurry combustion technology.

The state-of-the-art of coal slurry fuels in the U.S. is reported in Annex I of this report.

A series of meetings were then held with AID Mission and State Department desk officers for Portugal and Kenya and the Washington embassies of these countries for advice and guidance prior to the start of field work. Documents and literature related to the area of interest were acquired and studied.

Approval for visits to the selected countries was obtained from the responsible ministry in the host government. One individual in the ministry was appointed by the government to plan and guide the program inside each country. About two weeks were spent in each country. Personal interviews were held with local U.S. Embassy and AID staffs and with government and industry representatives. Many large facilities, in which fuel oil is consumed, were visited. Information and data for each facility and the opinions and concerns of the personnel about coal slurry fuel substitution for fuel oil and potential cost savings were solicited.

A seminar was held in Nairobi to brief representatives of government and industry on the status and potential of coal slurry technology and, in turn, to learn about potential problems and impediments to their application in the particular industries in which they worked. A similar seminar was not held in Portugal because government and industry representatives had been following the development of coal slurry technology and were familiar with the development and potential applications of coal slurries.

Annex 2 includes summaries of the energy situations, interviews held, and information acquired in the countries visited.

1.4 Results, Conclusions and Recommendations

Coal-oil slurry fuel (COM) has been fully developed technically and demonstrated successfully on a large scale. However, it suffers an economic disadvantage because it contains a large amount of oil. Coal-water slurry fuel (CWM) does not suffer this disadvantage. But, CWM requires further technical development and testing before it is ready for application. Since it contains no oil, CWM has a large potential for reducing oil consumption once CWM technology is perfected.

Extreme dependency on petroleum is a typical condition in the countries visited, Portugal and Kenya. Oil accounts for over 80 percent of the commercial energy used in these countries. High oil prices have disrupted their economic development programs, balance-of-payments and exchange rates. Neither Portugal nor Kenya have found significant indigenous oil, gas or coal supplies. Portugal's oil imports provided 82 percent of its energy needs in 1973; Kenya's oil imports provided 84 percent of its energy needs in 1980.

It is difficult for these countries to reduce these imports because of the dependence on oil for industrial growth, needed to improve the quality of life for their populations which, in turn, engenders political stability. Scarce investment funds that were targeted for many worthwhile programs have been diverted to pay for oil imports. In addition, high energy costs increase the cost of exports making them less competitive on the world market. To try to gain control of the situation, often governments allocate oil supplies, regulate investment in energy infrastructure and control oil prices. As a result, any practical program that has the potential to reduce oil requirements is of interest to government and sectors of industry burning fuel oil.

The introduction of alternative energy supplies, such as coal slurry fuel, must be meshed with other economic development programs in a country. Many countries have organized central planning and energy bureaus which have the responsibility for developing and allocating energy supplies. Because coal slurry fuel is a direct substitute for oil in many applications and requires relatively modest capital investment, planning and energy bureaus have expressed interest in assessing the application of this fuel.

There are opportunities in developing countries for the transfer and application of coal slurry technology. In Portugal, studies for COM production and application are already underway. The cement industry is committed to converting from oil to coal. Petrogal, the government-controlled oil company, is planning to be the coal importer and distributor in Portugal. Petrogal has surveyed industry to ascertain the potential market for COM. The company sees itself as the COM producer and distributor, thus expanding its market for oil and coal in the form of COM sales.

Electricidade de Portugal (EDP), the government-owned electric company is committed to future construction of coal-fired generating plants. However, all operating units and several still under construction, are oil fired. EDP is in the process of an in-depth assessment of the technical and economic feasibility of converting its older units to COM. If the results are favorable, a 125 MW plant will be converted as a demonstration. If all the oil-fired units were eventually converted to COM, about 8,700,000 barrels of fuel oil per year would be displaced by COM.

In Kenya, only the Bamburi cement plant in Mombasa currently burns coal. The coal must be imported. Plans are underway to convert a second cement plant to coal. The sole

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oil-fired thermal electric generating plant in Kenya is in Mombasa. There is no opportunity for converting the units to either coal or coal slurries because of site conditions, in-plant equipment, and system designs. For Kenya, a probable scenario for introducing coal-based fuels is construction of additional harbor facilities to increase the coal handling capacity and construction of a coal slurry production plant at Mombasa. The coal-slurry would then be delivered to the Nairobi area and to the industrial plants in western Kenya by using the existing oil infrastructure. Eventually the system would evolve into a coal-based or mixed coal-oil-based economy.

There are nevertheless serious constraints in applying coal slurry technology in these countries. Both Portugal and Kenya will have to import coal if it is to displace oil as a fuel. The economic incentive for substituting coal for oil must consider the net cost differential of the fuels and the earnings of exported oil products.

In both countries, because refinery production is based on meeting the demand for light distillates, gasoline, diesel oil and kerosene, a high percentage of surplus heavier fractions are produced. The heavy fuel oil is burned in industrial boilers, but the heavy oil is still in excess and is exported at whatever price can be obtained. It is sold at the opportunity price on the world market; the profits fluctuate with the shortage or glut of the products in the market. Under present glut conditions, there is little or no net gain over the cost of crude.

The investigation findings lead to the conclusion that coal slurries can find a market in developing countries. The conclusion is based on general estimates that the economics for specific plant conversions will become favorable if the subsidies for oil are removed to allow oil prices to rise to world market levels. Governments will have to adopt policies and offer incentives which will aid industries that undertake the first necessary steps, risks and uncertainties, to import coal, market, produce and distribute the new fuels.

It appears necessary that both a market and production plant for coal slurries be developed in parallel. Once a market and supply source is established, additional industrial plants are more likely to accept the technology if it is shown that the economics for pioneer plants are favorable.

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Even if the economics for substitute fuels are marginal at present price levels, it may still be desirable to introduce the technology. The price of oil can balloon again at any time and the supply of oil cut off or reduced. With an alternate technology and infrastructure in place, fuel flexibility will help stabilize an economy and provide a means to adjust to the situation during oil supply disruptions or extreme price rises.

1.5 Country Programs

The follow-up programs in a developing country that would implement the findings of the investigation for the transfer and adaptation of coal slurry combustion technology include:

- Educate, train and re-train corps of middle management and operating personnel in government and industry in the coal slurry technology by holding seminars, discussions and workshops.

- Perform surveys of select groups of industrial plants burning oil to determine technical and economic feasibility of conversion. Train local engineers and technicians to perform the same services independently.

- Assist in evaluating the suitability of a coal supply for coal slurry applications and in exploiting it during the transition period.

- Assist in evaluation and selection of coal slurry sources, production facilities and preparation techniques.

- Assist in evaluation and selection of equipment and facilities for retrofitting plants. This is part of except selection

- Provide project management and commissioning assistance for conversions.

- Help identify coal slurry sites and local, regional and national facilities required to develop the technologies.

- Assist in consultations with U.S. institutions and industries experienced in conversions.

- Supply expertise to identify strategies for investments in production and industrial plants and infrastructure required for developing a coal slurry fuel option for industry. Identify alternate methods by which new energy source facilities have been financed in the U.S. and other parts of the world and participate in planning the facilities.

- Help prepare project proposals to enhance chances of being funded by international banking and financial institutions.

2.0 COAL SLURRY FUEL TECHNOLOGY

2.1 Composition and Properties

Coal slurry fuels are mixtures consisting of pulverized coal suspended in a liquid with or without chemical additives to enhance stability and fluid flow properties. The stability of the mixture, the tendency of the coal particles to remain suspended uniformly throughout a stagnant mixture, is a critical property. Stability depends upon the coal and oil properties, particle size, size distribution, presence of water or other additives, and preparation method. The viscosity and flow properties of a slurry determine its pumping, atomization and combustion characteristics. The apparent viscosity of coal slurry fuel is generally much greater than the viscosity of residual fuel oil it replaces. Coal slurry fuel is abrasive, which dictates that the fuel handling and storage systems be abrasion resistant. Coal slurry fuel flames are similar to fuel oil flames; however, flame stability and atomization require special attention, especially for the lower heating value coal-water slurries.

Pumpable coal slurry fuel has been prepared with water and tested in small installations with coal content of 70 to 80 percent by weight. Large scale demonstration tests have been performed using coal-oil mixtures with coal concentrations up to 50 percent by weight.

Most of the coal slurry fuel demonstration work has used pulverized coal of regular grind (70 to 80 percent passing through a 200 mesh sieve with average particle size of about 75 microns). This grind is obtained using commercially available pulverizers.

Ultrafine ground coal (typically particle sizes 15 microns and smaller) has been used successfully in some tests. Ultrafine pulverized coal is advantageous because it yields stable mixtures without additives, but it requires special pulverizers which consume much more energy than conventional pulverizers. For coal slurry fuel with a high percentage of coal, a bimodal coal distribution is generally used. It is obtained by mixing normal and ultrafine ground coals in a ratio to provide the desired flow properties. ARC

2.2 Production Facilities

Equipment for coal slurry fuel production, common to almost all such facilities, includes raw coal unloading,

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storage, handling and pulverizing equipment, liquid handling and storage equipment, coal slurry fuel storage, handling and loading equipment. Most equipment is commercially available, developed and tested in related process industries. Not available from commercial sources are large size ultrafine grinding units and reliable instrumentation and controls for monitoring final product properties and composition.

Several small and medium size production facilites have been built and successfully operated. ok for LDC's

2.3 Coal Beneficiation

Beneficiation, improving the quality of coal by reducing its ash and sulfur content, is almost always desirable for coal used to make slurry fuels. A lower ash content in the fuel reduces problems of slagging, fouling and erosion by fly ash, and diminishes ash disposal problems. Lowering the sulfur content in the fuel reduces sulfur emissions and reduces sulfur induced corrosion on heat transfer surfaces.

Several coal cleaning and beneficiation techniques have been developed and are in successful operation. Their primary purpose is to reduce the ash and sulfur content of coal. Benefication is most effective when small coal particles are treated. Most beneficiation techniques are wet processes. Thus, coal slurry fuel preparation blends well with coal beneficiation and cleaning because the smaller, wet coal particles from the beneficiation processes are desirable for making slurry fuels.

2.4 Location of Production Facilities

A coal slurry fuel production facility can be located near a coal mine or in the vicinity of fuel users. The availability of raw materials, market size, shipping costs, logistics, and required investments will dictate the most appropriate location for a production facility for each case being considered.

Location of a production facility at or near a coal mine appears attractive for coal-water mixtures when coal beneficiation is used. In this case, the product is shipped as a liquid, avoiding some of the high costs for solid coal shipping and handling facilities. For developing countries that import coal and have a surplus of residual fuel oil, location of a centralized production facility near a port where coal is imported or near existing oil storage facilities may be attractive alternatives. In these cases, facilities

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for receiving and handling coal are required only at a production plant. This is especially desirable in those instances in which the coal slurry fuel has to be delivered in relatively small quantities, a transportation network needs to be developed or where an existing network for fuel oil distribution can be used.

2.5 Shipping, Storage and Handling

The considerations for shipping, storing and handling coal slurry fuel are stability, pumping and erosion characteristics. In most cases, means for intermittent agitation, recirculation and flushing have to be provided. Additionally, if coal slurry fuel is prepared and used in countries with cold climates, freeze protection may be required during preparation, storage and shipment. Low flow velocities, streamlined piping arrangements and low-speed, positive displacement pumps are some of the most common requirements for a coal slurry handling system.

Transportation by truck, rail tank car and barge do not seem to present severe problems. Transportation by tanker needs further investigation, primarily because no experience JAPANESE exists with this mode of transport for coal slurry fuel. Generally, because coal slurry fuel is in liquid form, handling and transporting it is expected to cost less and require lower investment than handling and transporting for solid coal. Unloading, storage and handling facilities for coal slurry fuel at a user's plant will have to be added, but space and investment requirements are quite small compared to providing comparable facilities for coal.

2.6 Plant Modifications

Conversion of existing plants to coal slurry fuel firing will require modification or replacement of burners and windboxes, a particulate removal system, sootblowers, and ash handling system and a fuel forwarding system.

Many existing steam generators and industrial furnaces designed for oil firing will require either substantial alterations to achieve high thermal loading or have to be operated at reduced loads when firing coal slurry fuels. Using beneficiated coal in coal slurry fuel would reduce, or possibly eliminate, the need for operating at reduced loads and the need for substantial furnace alterations. Flame lengths, allowable heat release rates and flue gas velocities are factors which may limit furnace performance when firing coal slurry fuel.

Furnaces originally designed for coal firing can fire coal slurry fuel with minimal modifications.

3.0 TRANSFER AND ADAPTATION ISSUES

3.1 General

The transfer and adaptation of coal slurry fuel combustion technology to developing countries will require that difficult choices be made on a wide range of financial, institutional, political and social issues, in addition to the technical and economic assessments normally associated with a fuel conversion. Action by government, individual industries and assistance from international organizations will be required to develop and implement programs for coal slurry technology transfer and actual conversions.

Although many issues are complex, conditions do exist in developing countries which would make introduction and adaptation of coal slurry technology both desirable and practical. Conditions in non-OPEC developing countries offer incentives to switch from fuel oil to coal slurry fuel beyond those which arise solely from a comparison of low coal costs and high oil costs, which is usually the main incentive in the U.S.A. and other developed countries for switching fuels. The burden of financing with hard currency to pay for petroleum imports, balance of payment deficits, external debt, and the insecurity resulting from dependence on such imports are additional incentives.

The following describes typical issues which surfaced in the course of the investigation that must be considered for technology transfer and actual introduction of coal slurry fuel into developing countries.

3.2 Capital Investment Funds

Issue: Given that access to financing is limited, what priority should be given to the transfer and adaptation of coal slurry technology by any country? Because investment funds are limited, should the lower capital cost alternative of importing coal slurry fuel be adopted only to be offset by a higher cost for fuel? What should the magnitude of the initial investments be?

Petroleum has served as the main energy source for most developing countries for decades. Large investments have been made in the infrastructure and plant for an oil-based economy. Often a complex economic, social and political framework has been built up on a base of petroleum fuels.

In countries where coal has had, at most, a minor role in industrial development, a switch to coal as a major fuel would require new large investments for both plant and infrastructure. In most developing countries, the scarcity of capital funds is a major handicap for any project requiring sizable investments. Fuel conversion projects whose magnitude of required investment is large, must overcome this major hurdle, even though it can be demonstrated that oil use will be reduced, balance of payment problems alleviated, and other benefits realized.

There are many factors which have prevented the accumulation of funds for new plants and plant modernization. Both government policies and world economic conditions have combined to limit the opportunities for an accumulation of investment funds. Among these factors are government price controls of many commodities, recession in world markets resulting in low export prices, government restrictions limiting non-oil imports to finance large oil import costs and large investment requirements for infrastructure for all segments of the economy. Because of the competition for scarce funds, governments set priorities among competing and equally vital needs of the economy such as health, education, agriculture, housing, national security and political stability, leaving little available for alternative fuels.

If coal is to be imported and coal slurry fuel produced in a country, new investments in shipping, harbor facilities, transport facilities, slurry production plants and process plant modifications, will be required.

The capital investment requirements could be reduced if pre-prepared coal slurry fuel was imported rather than constructing facilities for handling coal. Existing fuel oil facilities could readily be adapted to receive, store, deliver and burn the slurry while eliminating the need for shipping, port unloading, transporting, storing, preparing solid fuel and constructing slurry production plants. Whether these savings would compensate for the higher costs of the imported coal slurry fuel would have to be determined for each country considering this option.

Investment requirements for coal slurry technology transfer and applications are considerably less than would be required for conversion to coal technology for similar applications. Coal slurry fuels can, to a large extent, utilize the infrastructure that now exists to handle fuel oil, thus avoiding major investments. The introduction of

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these substitute fuels can be initiated on a small scale so that the facilities to handle coal slurry fuel production will require relatively modest investment. The markets served by a small production plant need not be large to make the plant viable, and as demand increases, production capacity can be increased to serve the demand. Investments at this low level may not be disruptive of an existing economic situation and would not necessarily be made at the sacrifice of other needs of a country. Disruption can be further reduced by importing finished coal slurry fuel, to keep required investment to a minimum. After a period of testing with imported coal slurry fuel, a country can then make a decision about further investment in coal slurry fuel technology, based on the results of the test period.

Such a step-by-step program will ameliorate the problems associated with projects requiring large investments when funds are scarce.

3.3 Prices and Security of Fuel Supply

Issues: What are the price and security risks of converting to coal slurry fuel? If coal has to be imported, will the risks be less with coal slurry fuel than with coal? Should economic incentives be provided to reduce the fuel oil yield in existing refineries and thereby the pressure to continue to use oil? Should domestic fuel oil prices be permitted to reflect its true market value?

Coal is an obvious substitute for oil where coal supplies exist, but not when it must be imported. Government and industry in developing countries have expressed concerns that the price and security of coal supplies are subject to the same uncertainties as imported crude oil. They are wary about making large investments in infrastructure when the degree of risk remains high. If much of its industry were converted to coal, there are fears that a country would be irrevocably committed to coal and would not be able to turn back even should the cost advantages of coal be reduced or even disappear.

Some developing countries have large oil refineries with excess refining capacity. Because throughput of crude oil is based on meeting the demand for light distillates, the resulting heavy fraction produced is in excess of domestic needs. This excess must be exported. The market and price conditions for this excess are unfavorable at this time. There are therefore pressures for fuel oil consumers

to continue to use oil. These consumers, such as thermal power plants which burn residual fuel oil, are not considering reducing consumption by substituting coal or coal-based fuels for oil. There are no pressures to convert to coal-based fuels because it would only increase the excess of the heavy fractions and aggravate present problems.

In many countries, the government controls the price of domestic residual oil but does not control imported coal prices. The price differential between coal and residual fuel oil does not reflect the true market value of these fuels and does not provide sufficient incentive for conversion to coal.

Coal slurry fuel alleviates some of the concerns about the risk of large price rises and supply insecurity for imported coal. The commitment to coal slurry fuel is not an absolute commitment to coal. A return to oil or a mixed fuel economy is still possible, with coal slurries. The mix can be adjusted to maximize that component which will result in lowest cost or stretch a low supply. Fuel flexibility can also provide leverage in negotiating fuel contracts. Security of supply is enhanced if industry has a choice of fuels; it reduces the risks of uncontrollable price rises and supply cutoffs.

Even if the cost differential favoring coal slurry fuel over oil is marginal, it may still be desirable to introduce coal slurry technology. The price of oil may balloon again at any time, and the supply of oil cut off or reduced. If alternative fuels are available, the difficulties that will be experienced will be lessened.

3.4 Institutional Issues

Issues: What kinds of decisions do government planners and policymakers need to make in order to encourage the introduction of alternative fuel sources - such as coal slurry fuel?

Because of the pervasive effects of oil costs throughout many economies export costs increased as oil prices increased. In addition, the price of these exports, on which most developing countries depend to pay for the oil imports, have been depressed, making income insufficient to pay for oil imports. Recent oil price increases for imported oil have outpaced any rise in export earnings. Because of foreig trade deficits, imports essential to further development are limited to those which meet immediate needs, with no provision for emergencies. High tariffs are placed on imported equipment to limit these imports in order to make funds for crude oil available.

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The circumstances that have forced all oil importing countries to seek ways to reduce imports have been most damaging to less developed countries. The strain on their foreign exchange, produced by the increases in imported oil prices, has slowed the rate of growth of their economies and jeopardized further improvements in their standards of living.

Curtailment of energy use through mandatory reductions or rationing as a matter of government policy is generally politically unacceptable in developing countries. Developing countries have below average standards of living and per capita energy use, so that any government imposed reduction of oil use which results in reducing economic growth will be unpopular.

Because oil is vital to the economic well-being of the developing countries, their governments often allocate supplies and fix prices of oil and other scarce fuels. The prices of fuel oil, electricity and gasoline are subsidized to stimulate industrial development and permit lower economic levels of the population to gain access to energy supplies which they could not otherwise afford. On the other hand, prices that do not respond to market forces encourage inefficient consumption of fuels and reduce incentives to conserve or use substitute fuels. The funds used for subsidies might otherwise be available for capital accumulation and investment in improved and modernized plants and new technologies, if the subsidies are eliminated. But, if subsidies are suddenly removed, plants that are viable with subsidized energy may no longer find markets as their prices escalate. Therefore, removing subsidies is a difficult decision to make under present circumstances.

To overcome many of the institutional and economic barriers to the introduction of coal slurry fuels, it will be necessary for the government to make commitments to tolerate a transition phase in which oil use is reduced or, at least, not increased, while substitute energy sources are introduced into the economy. Removal of the subsidies for oil and allowing oil to increase to its true market price will allow alternative fuels to compete and economic forces to govern. Another step would be to reduce the tariff on coal or coal slurry mixtures and on equipment and infrastructure required for the changeover from oil to coal slurry fuels. It may also be necessary to allow prices to be adjusted so that investments in new facilities can be amortized in a short time and a reasonable rate of return realized.

National energy planning is an essential element in guiding countries in their economic and social development. A national energy plan needs to stress use of fuel oil substitutes, such as coal and coal slurry fuels. Also, any decision to transfer to a new technology would have so wide-ranging an effect on the country and interact with so many institutions and segments of industry, that a conscious decision to do so must be made at the highest level of government.

3.5 Alternative Energy Sources

Issues: What are the alternative energy sources in countries without indigenous coal sources? Is it more important to invest in indigenous energy sources than in lower cost imported coal supplies for reasons of security, socio-political or other reasons?

In countries surveyed, alternative energy sources would be in competition with coal slurries for development funds. These alternatives are hydropower, geothermal, alcohol from sugar and molasses, wind, wood and agricultural wastes. Such supplies, available within a country's boundaries, offer significant advantages where balance of payments problems exist. Investments in such supplies may be considered more desirable than investments in imported supplies even if the economic assessments do not always favor the domestic energy source.

Strategies must be developed for investment of government and industry funds in energy supplies. Personnel who have the background to develop such strategies will be required to assure that the optimum choice is made among alternative energy options. The economic benefits and technical risks must be clearly defined and assessed so that government or industry has the information it needs to decide what is best for a country's short and long term interests.

3.6 Technical Issues

Issues: What facilities are required and what are the technical problems associated with the introduction of coal slurry fuel into a country? What technical and professional training programs are required to assure that coal slurry technology transfer and its applications are made correctly and efficiently and that its special problems are understood?

Coal slurry fuel can be burned in oil-fired equipment which has not been designed to burn coal. Having the properties of liquid fuels, they have the flexibility and convenience of fuel oil at lower cost. Slurries can be pumped, stored and fired like oil. The complexity of plant and equipment, space requirements and downtime for conversion from oil to coal slurries are substantially less than for conversion from oil to coal.

To introduce coal slurry technology into the economies of developing countries requires a reliable source of coal which can be used to produce coal slurry fuel. If coal is indigenous, the logistics of transporting, handling and processing it, are less formidable than in a country which has to import coal. The problem is very great if the infrastructure for handling coal does not now exist in a country considering a switch to coal or coal slurry fuel.

Where only small quantities of poor quality coal exist and it is considered unsuitable for use in most industrial applications, it is possible that such coal might be used more efficiently in coal slurries. Upgrading such poor quality coal by beneficiation may further enhance its suitability for coal slurry fuels.

The determination of the technical and economic feasibility of converting a specific plant from fuel oil to coal slurry fuel must be based on plant and site specific conditions. Availability of space for the required additional equipment and facilities may preclude consideration of a coal plant. Incompatibility of system and equipment designs with new fuels could result in loss of equipment life, reliability, availability, and cause high maintenance costs precluding use of a substitute fuel. Such assessments require detailed surveys of a plant for each fuel considered.

Another technical problem is the potential loss of production because of downtime required to modify equipment during a conversion. In most industries surveyed, boilers and furnaces are operated at high capacity factors and have little or no spare capacity. This loss of production and the usual requirements that the payback period be short (not more than 2 to 3 years) are major deterrents for many smaller industries to convert. In some countries, larger plants have instituted conservation measures or taken other energy cost cutting steps that can be implemented with low capital expenditures. Smaller companies are aware of the high cost of energy but have not generally investigated methods of improving efficiency, conserving energy or

evaluating energy alternatives. Most managers and engineers are occupied with immediate concerns and have not considered energy strategies for their plants. In large plants, long term planning is normally performed by a group outside of the day-to-day plant operations.

Conversion from oil to COM fuel could be the initial stage of development in the transfer of the coal slurry technology. It offers an interim solution, while coal, CWM or other alternative energy sources are developed and an infrastructure for using the new fuels is developed. The amount of the oil that has to be imported can be reduced in a short period without having to wait a decade or longer for other fuels by switching to COM fuel.

A serious concern associated with converting boilers and furnaces to coal slurry fuel is the degree of derating required to assure a reasonable life after conversion and good availability. The use of beneficiated coal removes much of the ash and sulfur, reducing the amount of derating required, which makes a conversion more attractive.

Well designed and executed surveys and feasibility studies will be required to assess the economic benefits and technical risks associated with any plant conversion.

should be "green - universal" approach

3.7 Manpower Capabilities

Issue: How much of the country's resources should be devoted to educating and training skilled technicians and professionals to acquire and utilize this technology?

The transfer and application of coal slurry technology will require the development of special expertise and skills. relative Professional and technical expertise must be made available to install, operate and maintain new coal slurry storage, handling and firing equipment. A pool of managers, engineers and skilled labor is required if the transfer is to be made successfully. If such a pool does not exist, skills must be obtained from outside a country or an adequate training program undertaken. It is expected that it will be easier to train people to operate a plant burning coal slurries than one that burns coal, especially if they have had experience with fuel oil. The extent and depth of education, training and experience in coal technology and the awareness of the potential applications and benefits of coal slurry fuel varies widely amongst developing countries. The amount and type of education and training needed by industry and government to implement a program to introduce coal slurry technology will vary from country to country.

Skills required for the transfer and application of coal slurry fuel will require training and re-training of planners, designers, technicians, managers and mechanics at all levels of skill. The success of programs to introduce new fuels will depend largely on the people who implement them. Identifying the areas and skills required for development of the new technology can be the first step. Engineers and technicians will be required to perform in-depth surveys of plants to assess the feasibility of conversions and to ascertain the potential market for coal slurry fuel. The potential for further energy conservation can also be ascertained at the time of these surveys.

3.8 Market Development

Issue: Which path of development in adapting coal slurry fuel is best to follow for the near and long term interests of a country?

Development of an infrastructure for preparation and distribution of coal slurry fuel is dependent on the existence of a potential market for the product. Development of the market requires familiarization of the industry managers with the technology, as well as economic incentives to convert existing facilities to coal slurry fuel. Coal slurry fuel can, to some extent, utilize the infrastructure that now exists to handle fuel oil.

It is expected that coal slurries would find a market in developing countries if subsidies for oil were removed to allow oil prices to rise to world levels. Should a government establish a national policy to reduce oil imports, incentives could be offered which would aid those industries which take the first necessary steps to import, market, produce and distribute a new fuel.

Both a market and a reliable supply to serve it must be deveoped in parallel. Once a market and supply source are established, it is expected that many additional plants will be willing to consider converting, causing the market to expand and the coal slurry fuel industry serving it to grow correspondingly.

3.9 Benefits

The successful transfer and application of coal slurry technology to developing nations could have many beneficial effects. Switching to coal slurries in those situations in which switchover entirely to coal is not feasible, could contribute significantly to stopping, or at least slowing, the growth of demand for fuel oil. The beneficial effects

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of reduced oil consumption would be widespread. The problems of trade deficits and foreign exchange would be ameliorated, and if oil and electricity prices continue to rise steadily over the coming decades, the benefits would continue to accumulate. Even at present day prices, reduction of oil use is economically attractive.

The funds saved by reducing energy costs could be made available for investment in other segments of the economy, such as importation of equipment and machinery, necessary for the continued growth of the economy. Also, reduced energy costs would allow energy intensive industries to increase plant productivity or manufacture products which have high export value.

A country with a domestic coal supply would receive benefits from coal slurry technology applications that one without coal resources would not receive. Where coal is indigenous, new industrial growth can be generated in an expansion of a domestic coal industry which, in turn, generates benefits in addition to those obtained solely from fuel switching. Also, if coal is not an imported commodity the reduction of oil imports does not have to be offset by the cost of coal imports, thereby improving a country's balance of payments situation.

Beneficiation of a poor quality coal, which may be unsatisfactory for other uses, may permit use of such a coal in slurry fuel. This will permit a country with only poor quality coal to use its own coal in coal slurry fuels and thereby create a domestic coal industry. Cost of beneficiation

The benefits of reduced oil imports are diminished when coal has to be imported. Without coal resources, a country may be subject to price increases in imported coal. Also, depending on its geographic location, the location of oil supplies may be much closer than the location of the coal supplies, making the coal more expensive due to increased transportation costs.

The introduction of a new energy source strengthens the foundation on which industrial expansion can take place. The growth of an infrastructure, with its associated facilities and need for professional and technical skills will provide opportunities for jobs, which can in turn, accelerate expansion and growth. The introduction of coal slurry production plants in a country could serve as the nucleus of an expanded coal slurry industry for the future.

The introduction of a new energy source to provide industry with a choice of fuels is a major benefit to both government and industry. Planning can be based on use of more than one fuel or on the one that is expected to be lower in cost, more secure or more compatible with the process in which it is to be used. Coal slurry mixtures, in which the oil, water or methanol content can vary, provide additional fuel flexibility because the composition can be varied to suit existing market conditions. Should coal prices take a sudden jump, the oil content can be increased; similarly, if oil prices increase, the mixture can be adjusted to use the maximum practical amount of coal.

Fuel flexibility also provides greater security of the supply. Should imports or production of one fuel be curtailed or cut off because of strikes, conflicts or natural events, it would be feasible to shift fuels in situations in which the process and equipment were designed to utilize both fuels. Loss of production and impairment of reliability are less likely where this flexibility exists. The dependence on oil of all sectors of an economy would be reduced and, in many cases, eliminated by a switch to coal slurry fuel. Fuel flexibility also provides leverage in negotiating fuel contracts.

Coal slurries have the flexibility of oil at a lower cost. The number and complexity of alterations to equipment required to convert an oil-designed plant to coal slurry fuels may be significantly less than a conversion to coal firing. However, for many plants the benefits of lower fuel costs must be weighed against the reduction of capacity often associated with the substitution of coal and coal slurries in existing furnaces and boilers. In most cases, it is possible to modify a boiler or furnace to retain oil firing capability so that the rated capacity can be obtained on short notice.

Capacity reduction can be minimized by extensive modifications to combustion equipment. Also, beneficiation to reduce coal ash content can significantly reduce the amount of derating required. To ascertain which combination of fuel type, treatment and modifications will result in achieving optimum results requires a detailed technical and economic assessment. Such an assessment should cover site and plant conditions, fuel costs, investment requirements, operating costs, maintenance costs, lost capability, environmental impacts, materials logistics, process downtime, lost production, reliability changes and availability changes.

4.0 COUNTRY PROGRAMS

4.1 General Programs

The follow-up opportunities that exist, based on the findings of the surveys, to help participating countries to establish and implement projects to introduce coal slurry fuel to replace oil are many.

- Skills required for preparing, transporting, distributing, handling and combusting coal slurries will require training or re-training all levels of skills, from planners, designers, technicians and mechanics. The success of the technology transfer program will depend on the people who implement it. Educating and training a corps of government and industry personnel in coal slurry technologies will improve the chances of success of any plan to substitute coal slurries for oil. Identifying the areas and skills required for development of the technologies would be the first step of such a program. In developing countries, a sizable body of industrial personnel are familiar with fuel oil; the transition to coal slurries should be much less difficult than a transition to coal. Programs can include formal regional seminars, in-plant discussions and workshops, as well as visits to existing production facilities and operating plants.

- The costs and benefits as well as technical and economic feasibility of conversions are site and plant specific. It is therefore beneficial to perform in-depth surveys of a select group of plants to assess the feasibility of such conversions and to simultaneously ascertain the potential market for coal slurry fuels. The surveys would be made with the assistance of local engineers and technicians to train them to perform such surveys, cost-benefit evaluation techniques and reporting, so that they can continue to perform such services independently. Included in these surveys would be assessments of boiler and furnace efficiency so that an energy conservation program can be performed simultaneously with the conversions. U.S. AID programs could provide specialists in plant conversions, project management and commissioning assistance to further technology transfer.

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- Expertise in specialized areas would be of particular value where such expertise is in short supply, particularly in countries which have no coal use experience. In cooperation with government and industry, AID can help plan the framework for the introduction of the new technology. Such a framework would include developing programs for evaluating and acquiring a suitable, reliable supply of coal, facilities to receive, store, handle coal, facilities to produce and distribute the coal slurry fuels and to assess coal beneficiation processes for coal slurry production.

- Strategies for investments by both government and industry must be developed. An AID program to identify methods by which such facilities have been financed in other parts of the world and the requirements for furding such projects by established institutions would be the first step in developing such a strategy. AID can also help prepare well-developed project proposals to enhance the chances of them being funded by lending institutions. By ensuring that the requirements are met, that the applications indicate sound planning and that they contain other information that investors and finanacial institutions look for, the chances for obtaining capital for coal slurry fuel projects will be enhanced.

- Programs, to help countries identify and select practical coal and coal slurry sites are required. Establishing environmental criteria would serve as a guide to locate such sites and to assess the potential impacts of conversions.

- AID can offer consulting services to institutions involved in all phases of conversion. These include project management and commissioning assistance; expertise to identify strategies for investments in production plants, industrial plants, as well as the infrastructure required for developing a coal slurry fuel option for industry.

4.2 Specific Programs

Follow-up programs that would facilitate adaptation of coal slurry technology to developing countries include:

- Educate middle management and operating personnel in coal slurry technology by conducting seminars, discussions and workshops.

- Assess the potential market for coal slurry fuel by surveying oil-burning industrial plants to determine the feasibility of conversion and train personnel to perform the same services independent

- Assist in evaluation and selection of coal supplie for making coal slurries.

- Assist in development of coal beneficiation techniques.

- Assist in evaluation and selection of coal slurry sources, production facilities, and preparation techniques.

- Assist in evaluation and selection of equipment and facilities for modifying and retrofitting plants.

- Provide project management and commissioning assistance for conversions.

- Assist in evaluation and selection of coal slurry distribution techniques.

- Assist in consultations with U.S. personnel experienced in conversions.

- Explore strategies for financing conversions to coal slurry technology.

- Assist in preparation of proposals for funding by international banking and financial institutions.

- Assist in planning constructing, commissioning and operating new coal slurry facilities.

Transfer and Adaptation of Coal Slurry Combustion Technology to Developing Countries

Volume II

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Prepared for the

United States Agency for International Development

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Annex I

Status of Coal Slurry Fuels Technology in the United States

November 1982

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A. INTRODUCTION

The accomplishments in research, development and demonstration have advanced the state-of-the-art of coal-oil mixture (COM) combustion technology to the point that full scale commercial applications are now possible. Conversion, at the present time, from oil to COM is considered to be the initial stage of development in the transfer of coal slurry technology, with the intent to switch to coal-water mixture (CWM) fuels should the associated technology reach the commercialization phase and the economics favor a second conversion.

As part of this study, a survey of the state-of-the-art of coal-slurry fuels in the USA was performed and is presented in this Annex I to the study report. It covers coal-oil mixture (COM) and coal-water mixture (CWM) fuels technologies, with a brief section on other alternative coal slurry fuels. The COM and CWM sections each include history, discussion of fuel characteristics, preparation methods, production equipment, combustion applications, an overview of representative demonstration projects and an economic discussion. Coal slurry fuels are of great interest as replacement for fuel oil in existing industrial and utility installations.

B. COAL-OIL MIXTURE FUELS

1. GENERAL

Coal-oil mixture (COM) fuel is a slurry of pulverized coal and residual fuel oil. Small quantities of additives may be used to inhibit coal particles from settling. Mixtures containing up to 50% coal by weight have pumping and burning characteristics similar to those of heavy fuel oil and have been successfully tested.

The post-World War II era saw an increasing use of residual fuel oil and a decline in coal use. Oil was cheap and clean while coal was dirty, an advantage that became more important as concern over the environment increased. However, the 1973 oil embargo caused oil prices to increase dramatically, triggering a vigorous search for oil substitutes. COM fuel is an especially attractive substitute because handling and burning characteristics are very similar to those of residual fuel oil. The oil price increase and the extensive dependence of the United States on foreign oil brought a congressional mandate, (currently embodied in the Fuel Use Act of 1978) to reduce oil consumption by replacing it with domestic coal.

During the cheap oil era, many utility and industrial boilers were built capable of burning only oil or gas, and many coal-designed boilers were converted to oil or gas firing. Converting such boilers to burn pulverized coal can be expensive because of the boiler modifications and coal handling equipment necessary. Thus COM fuel which is cheaper than oil is a possibly attractive option because it requires less extensive modifications than does a conversion to pulverized coal. Also, the Environmental Protection Administration (EPA) will usually consider a COM conversion to be a minor modification subject to less stringent emission standards than a pulverized coal conversion under the New Source Performance Standards (NSPS).

In spite of its apparent advantages of lower cost relative to oil and fewer equipment modifications than a pulverized coal conversion, COM fuel is not in commercial use. Government and privately sponsored COM demonstration projects since 1973, have demonstrated COM fuel use is technically feasible for both utility and industrial uses, but the few COM producers supply most of their fuel for demonstration projects. COM conversion economics have not been sufficiently attractive for a large number of COM conversions to occur. Equipment modification costs often outweigh fuel savings. Although COM fuel is cheaper than oil, often it is not cheap enough. Currently there are no COM fuel plants in the U.S., large enough to supply electric utilities, because COM fuel economics are not now sufficiently attractive to induce large scale utility COM conversions.

2. HISTORY

COM fuel was first proposed and demonstrated in Britain in 1879. In the same year a U.S. patent was granted for COM technology. Thereafter, interest in COM has been sporadic, reflecting fluctuations in oil prices and availability.

World War I caused the first major interest in COM, because it threatened to interrupt oil supplies. In a U.S. Navy test, a COM fuel of 33% pulverized coal by weight with 1% lime-resin soap as a stabilizer showed no adverse effects on the ship's water tube boilers. However, COM was never used as a regular fuel.

Oil demand and supplies expanded between the two World Wars causing coal use to decline. From 1932 to 1935, the Cunard Line, ran land and sea trials with COM fuel to test the possibility of reducing the amount of oil imported and finding an expanded use for British coal. Use of COM fuel with up to 40% coal showed no adverse effects on the boilers by weight other than the need for more frequent cleaning than before.

World War II again revived interest in COM fuel. The U.S. Bureau of Mines and Kansas State College tested COM fuel with up to 40% coal by weight in a 151 hp straight watertube boiler with no difficulties during the 388 hour test. The end of World War II again brought a decline in interest in COM fuel.

During 1963 and 1964, Combustion Engineering, Inc. conducted tests in an oil-designed boiler using COM fuel with up to 50% coal by weight. The tests indicated no decrease in boiler efficiency at full or part load, but they were not long enough to determine wear or ash deposition. The 1973 oil embargo and subsequent oil price rise revived interest in COM fuel mainly in countries heavily dependent on imported oil. The Department of Energy (DOE) (earlier ERDA) in the United States, the Electric Power Development Company in Japan, and the Canadian Combustion Research Laboratory in Canada were the major researchers. These agencies have sponsored large scale tests in cooperation with private industry.

International Symposia on COM Combustion held in 1978, 1979, 1981 and 1982 reflect the worldwide interest in the subject. Participants represent many countries including the United States, Japan, Canada, France, Italy, Sweden, Australia, the United Kingdom, the Federal Republic of Germany, and the People's Republic of China.

3. COM PROPERTIES

COM fuel is a slurry of pulverized coal and residual fuel oil (most often No. 6 fuel oil) with characteristics similar but not identical to those of fuel oil. COM characteristics are dependent on the coal and oil from which it is made as well as its production method. Handling and combustion characteristics are most important for any fuel. COM fuel handling is most affected by its rheological, stability, reagitation, and erosion potential properties. COM fuel combustion is most affected by its heating value, atomization ease, ash slagging, fouling and emissions properties.

The four properties which affect COM handling are equally important. The two most important rheological factors are viscosity and non-Newtonian fluid behavior. Viscosity is dependent on temperature and coal concentration. As Figure 1 shows, COM viscosity increases with percent coal content by weight. Since high power is required to pump very viscous fluids, the practical upper range for coal concentration in COM fuel is about 50% by weight. COM fuel is a non-Newtonian fluid, and its viscosity depends on its shear history. This factor must also be considered in pump selection and piping design.

A very important property of any slurry is its stability, the speed with which particles settle out of a fluid in which they are suspended. Stability affects the ease with which COM fuel can be stored and transported. Coal particles should not settle out during storage or in stagnant areas of a COM piping system. In general, the higher the coal concentration (30% to 50% by weight) and the smaller the coal particle size, the more stable is the COM. Figure 2 shows the effect of coal concentration on COM stability, the higher the coal concentration, the longer it takes for the coal particles to settle out of suspension. Mixing and surface acting additives are used to keep COM fuel homogeneous and stable. Coal and oil characteristics also affect stability, especially the coal surface characteristics, wetting, etc.

Reagitation ease must be considered along with COM stability. In some situations coal particles settle loosely so that only gentle agitation is required to re-homogenize the COM, and in others coal particles settle into a dense paste that is nearly impossible to re-mix. This thick paste can plug pipes, valves, and storage tanks.

The final major COM handling property is erosion potential, which is of greatest concern for its effect on piping system or any place where the abrasive COM is in motion. Coal mineral ash content and particle size determine how abrasive the COM will be. Since the former is most important, coal with low mineral ash content (natural or cleaned) should be used to make COM fuel.

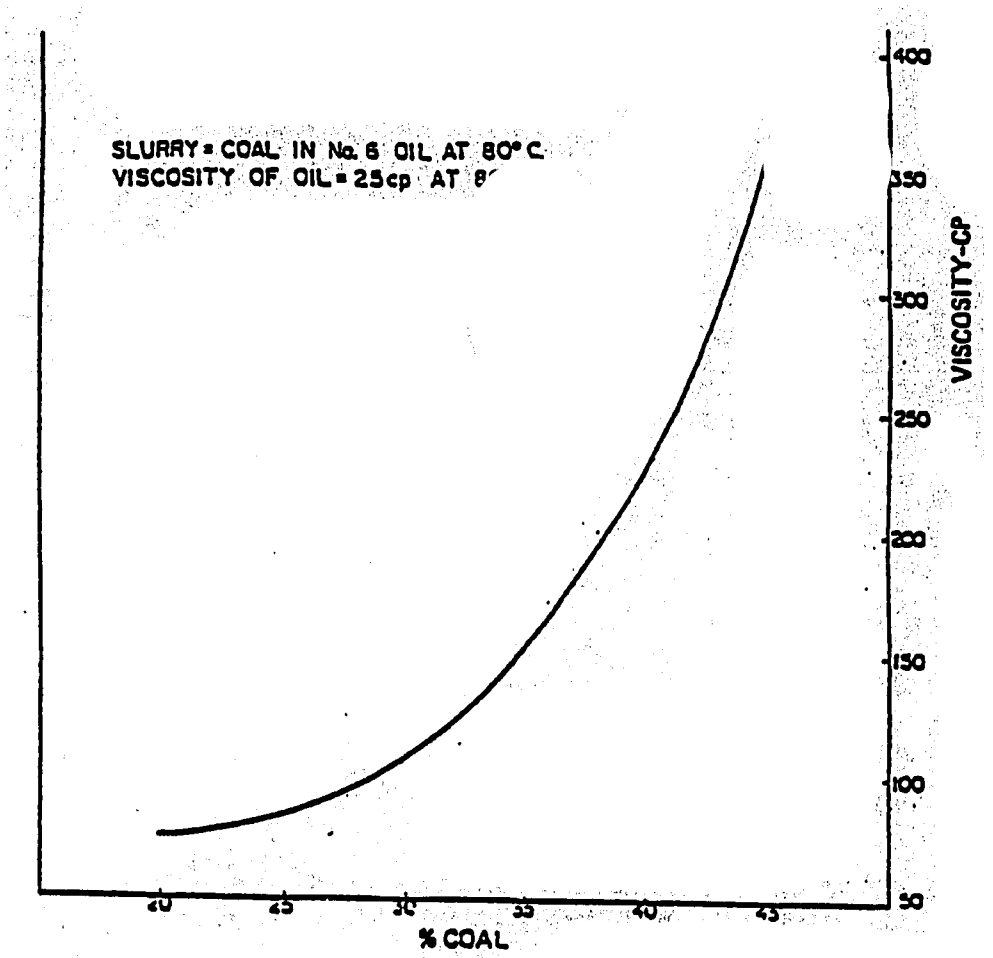

Figure 1. Viscosity of Coal-Oil Mixture

Source: Reference 30

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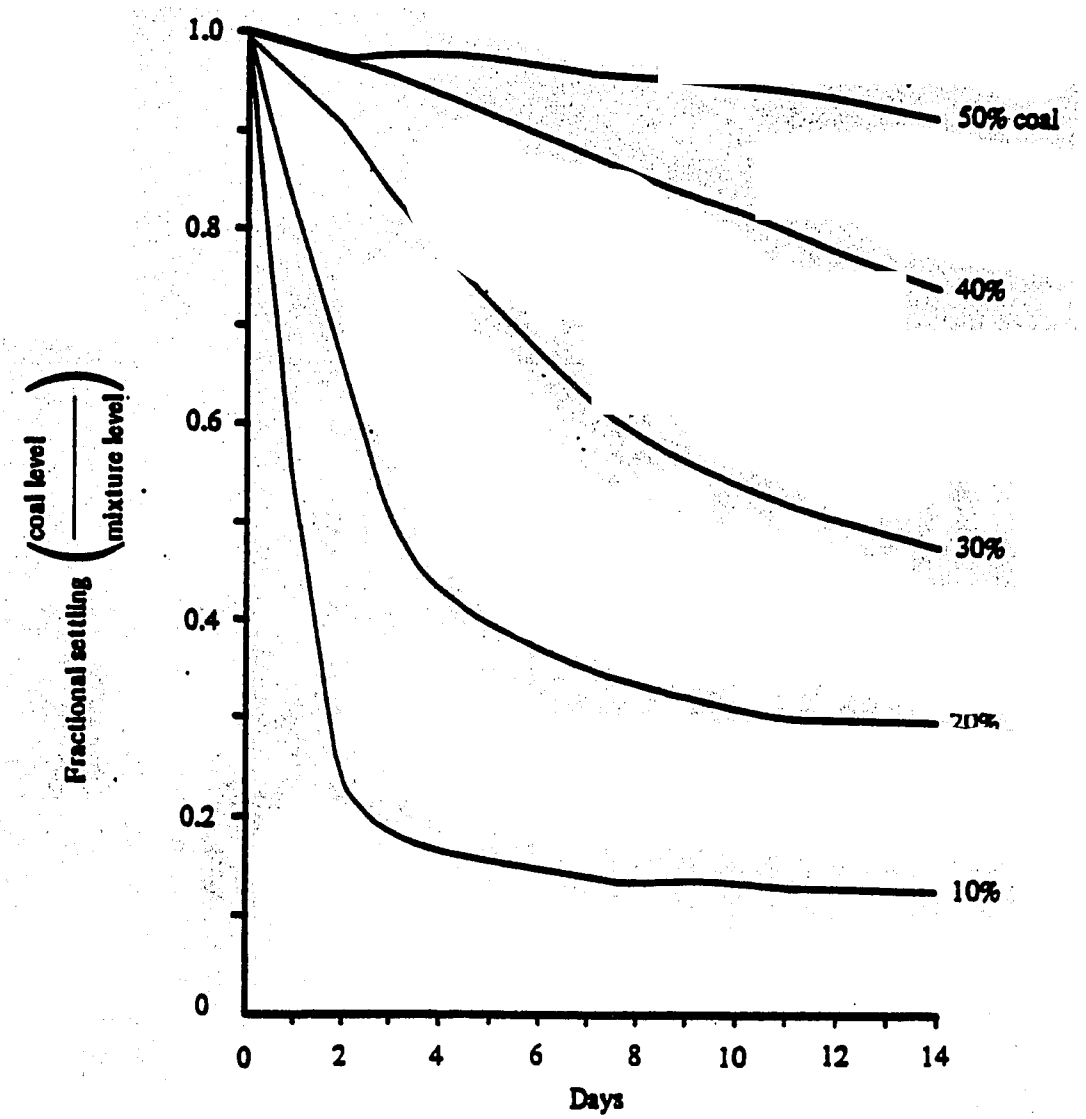

Figure 2. Effect of Coal Concentration on Sedimentation Rate

Source: Reference 12

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Coal mineral ash content and mineral composition also affect ash slagging and fouling characteristics during COM combustion. Ash slagging and fouling, which reduce combustion equipment efficiency, can be minimized by using low ash coal and controlling combustion temperatures.

The three remaining properties affecting COM combustion characteristics are heating value, atomization ease, and emissions. A given weight of COM fuel has a lower heating value than the same weight of fuel oil and a higher heating value than the same weight of coal. This is because a given weight of oil has a higher heating value than the same given weight of coal. Atomization ease depends on the original oil atomization characteristics, coal particle size, and coal volatility.

COM emissions, with the exception of fly ash, result from the combination of coal and oil composition. Fly ash and most particulates come from the coal in COM, making precipitators necessary to control particulate emissions. Low ash or cleaned coal can help reduce COM particulate emissions. Cleaned coal also has a reduced sulfur content, which presents an opportunity for COM fuel to help reduce sulfur emissions if it is made from a low sulfur coal and high sulfur oil or vice versa. If the oil and coal are carefully selected for sulfur content, sulfur emissions may be met in some areas without using scrubbers. However, both low sulfur oil and coal are expensive. Nitrogen oxides and unburned hydrocarbon emissions are controlled through the combustion process. In general, cleaned coal presents many advantages in helping to reduce particulate and sulfur emissions from COM combustion, as well as reducing ash slagging.

4. COM PRODUCTION METHODS

An important factor determining COM stability is the production method. Among numerous methods for COM fuel production, the most developed are:

- Simple coal-oil mixing
- Ultrafine grinding
- Wet or dry grinding with surfactant
- Ultrasonic emulsification

Simple coal-oil mixing consists of pulverizing coal so that 70% to 80% is less than 75 microns and mixing it with fuel oil. This method is most suited to on-site COM preparation and immediate use because the coal particles tend to settle quickly. Since this COM is unstable it must be continually agitated during transport and storage.

COM fuel produced by ultrafine grinding, so that 50% of the coal particles are less than 15 microns, is fairly stable as long as the coal concentration is greater than 40% by weight, though gentle recirculation or agitation is recommended to prevent settling. Settling can occur because of oversize coal particles, but not because of pumping or high temperatures. In general stability for COM fuel prepared by ultrafine grinding is less sensitive to coal type than COM fuel prepared by other methods. However, it is more expensive because energy requirements for ultrafine coal grinding are high. Figure 3 shows an increase in grinding power as coal particle size is reduced. Florida Power Corp. successfully prepared and used COM fuel made from ultrafine coal at its Crystal River Unit 1 COM demonstration project. Florida Power Corp., in collaboration with Dravo Corp., used a fluid energy mill to produce ultrafine coal which was mixed with oil without a chemical additive for stability.

Most COM fuel produced to date has been made from either wet or dry ground coal mixed with oil and a surfactant to stabilize the mixture. The surfactant effects a microscopic interaction between coal particle surfaces, oil and any water present (moisture in raw coal). New England Power Services Corp. has tested over 50 different commercially available products that can be used to stabilize COM fuel. Fuel prepared by this method is more stable than ultrasonically prepared COM during pumping and high temperature exposure because the surfactant retards water evaporation. In 1978, General Motors started operating a 600 bbl/day surfactant-stabilized COM plant using coal pulverized to 80% less than 75 microns. In 1980, New England Power Service Co. started operating a 2278 bbl/day surfactant-stabilized COM plant using similar coal. COM-Energy, Inc., an Occidental Petroleum subsidiary, constructed a one million bbl/year surfactant-stabilized COM plant in Jacksonville, FL. It has been in operation since September 1981, though not at full capacity.

The final type of COM fuel to be considered is made from coal pulverized to 80% less than 75 microns, fuel oil, and water, emulsified using ultrasonic processing. The typical composition is 45% coal, 45% oil, and 10% water. Stability is sensitive to coal type because the stabilizing mechanism depends on the ability of oil and water to wet the coal particle surfaces. Some ultrasonically emulsified COM fuel is stable in storage but becomes unstable during pumping or heating because of evaporative water loss. In 1979, Coaliquid, Inc. started operating an 1190 bbl/day ultrasonic emulsion COM plant in Shelbyville, KY. Their licencee, Banklick, Inc. is constructing a 6000 bbl/day plant.

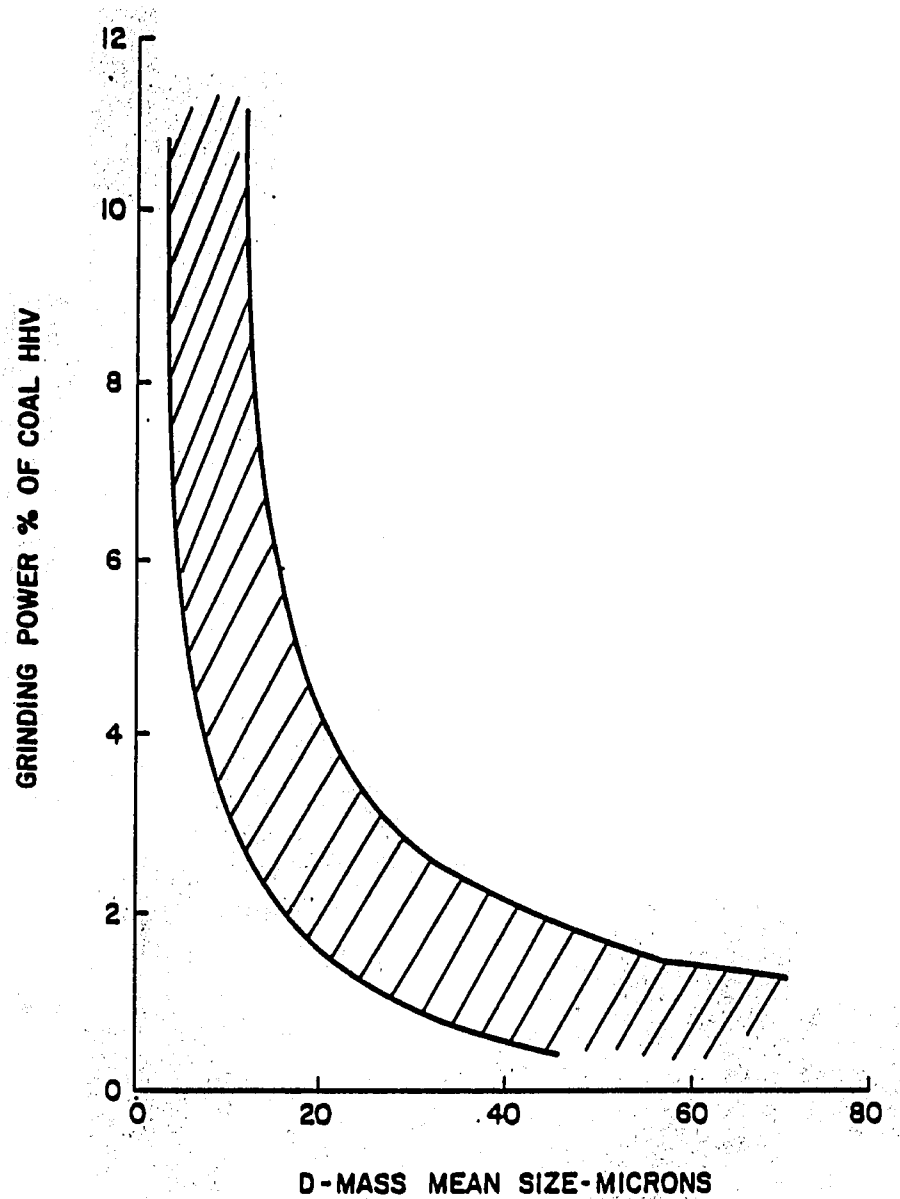

Figure 3. Coal Grinding Power Requirements

Source: Reference 12

5. COM PRODUCTION EQUIPMENT

Much of the equipment in a COM production facility is common to all of the production methods, including unloading, handling, and storage systems for both raw fuel and finished COM fuel. Pulverizing and mixing equipment types may vary from method to method but are generally commercially available. Only the ultrasonic emulsifiers and the ultrafine grinding units are not currently available in very large sizes and further scale-up of these two items would be required to make these two production methods economical. The following paragraphs describe facilities necessary for a typical COM production plant, whether or not it is adjacent to where the COM is consumed.

5.1 Coal-Oil Receiving, Storage and Reclaim

Washed coal, in large pieces, is delivered by ship, barge, rail, or truck, unloaded by conveyor, sampled, and weighed. A stackout system distributes the coal to live and dead storage areas. Space for 60 to 90 days supply of coal is necessary as protection against coal supply interruption. Coal is reclaimed from the live storage pile and conveyed to the grinding system.

Fuel oil is also delivered by ship, barge, rail, or truck and pumped to storage tanks. Typical oil storage capacity is 10 to 15 days supply. The fuel oil is pumped to the mixing area for COM preparation.

5.2 Coal Grinding and Mixing

Coal reclaimed from the live storage pile is placed in a bunker or silo for feeding to the grinding mills. The type and size of mill depends on the COM production method and the capacity of the plant. Spare mills should be provided to insure availability. Coal moisture content can be reduced, if necessary, by heating the gases which contact the coal before, during and after grinding. The coal is separated by passing it through a cyclone and/or a fabric filter. The fine coal is conveyed to a surge storage bin where it is held prior to mixing with oil. Coal is transported through the grinding system by means of fans.

If a chemical additive is used, it is metered precisely into a tank for premixing with fuel oil at an elevated temperature (typically 145°F) to insure uniform mixing. The oil, with additive, is pumped to a series of mixing tanks equipped with internal baffles and agitators. The pulverized coal is fed into a mixing tank filled with warmed oil (typically 200°F). The mixture is stirred for a specified

length of time (usually about 45 minutes) and pumped to surge storage tanks. The COM is sampled prior to discharge from the surge tanks into the main storage tanks, and any which does not meet specifications is sent back to the mixing tanks.

5.3 COM Storage and Loading

COM storage tanks must be insulated and equipped with mixers and recirculation loops to keep the coal in suspension. Suction heaters and heating coils are usually required to maintain storage temperature (typically 130°F). Main storage tank capacity for about 10 days COM production is usually considered adequate.

Positive displacement progressive cavity pumps have been found most suitable for COM service. Due to its abrasive nature, special alloys are required for moving parts that contact the COM. The piping system also requires insulation and heating to control COM viscosity; should it become too viscous, COM fuel is impossible to pump.

6. SELECTED COM PROGRAMS

This section describes some important recent COM fuel programs for both utility and industrial COM applications, as well as for commercial COM fuel production.

6.1 General Motors Corporation COM Program

In 1974, General Motors first tested a 30% coal, 70% No. 2 oil mixture in a 30,000 lb/hr packaged oil fired boiler. The mixture burned well at full boiler load with a flame similar to No. 6 oil. The fuel was unstable during handling and storage.

General Motors then formed a consortium of government agencies, petroleum and coal concerns, boiler and equipment manufacturers, and utilities to solve the fuel stability problem and determine the practicability and economics of burning COM in industrial boilers. The program demonstrated that a stable mixture of pulverized coal (50% by weight) and No. 6 fuel oil could be prepared and burned under changing load conditions. The test was performed in a 120,000 lb/hr gas fired boiler with intermittent oil fired capability. The COM was made from bituminous coal, No. 6 oil, water and stabilizing additive. The investigations showed that:

- COMs burn in a manner very similar to No. 6 fuel oil.

- Stable COM may be prepared with coal weight content up to 50%. COM stability decreases at temperatures greater than 150°F. COM should be stored below 150°F and heated to 160°F to 180°F for pumping to burners.

- Erosion due to COM is minimal in straight pipe with velocities of 10 ft/sec or less. Appreciable erosion occurs in fittings which cause sudden flow changes.

- A variable speed, low shear, constant displacement pump is recommended.

- Pumps, piping, and process equipment should be oversized to minimize pressure losses and erosion.

- COM storage tanks should be agitated and provided with a heat source distributed evenly over a maximum area.

The tests demonstrated that a stable COM containing up to 50 percent coal can be continuously prepared and successfully fired in an industrial sized boiler up to 75 percent of its maximum rating with no major reduction of boiler efficiency. The boiler operated with minimal ash deposition and no tube erosion. Particulate emissions were similar to those from pulverized coal boilers. In phase I, the boiler burned 60,000 gallons of 35% coal for 250 hours. In phase II, 250,000 gallons of 50% coal, 43.3% No. 6 oil, 6.5% water, and 0.2% additive burned successfully over 494 hours of testing. The program concluded that modifying industrial boilers to use COM fuel was marginally economical at the time of the test. However, COM economics are very sensitive to changes in oil and coal prices, so that any economic advantage of COM could be eliminated in an oil or coal price change.

6.2 Pittsburgh Energy Technology Center (PETC) COM Tests

In 1976, PETC tested a 20% coal, 80% oil slurry without an additive, in a 100 hp fire-tube boiler modified with a new burner designed for No. 6 fuel oil and a coal-oil slurry mixing and feed system. The test objectives were to determine: erosion in components such as valves, pumps, piping and burners; fouling of pumps, gages, etc.; deposits in the combustion chamber; boiler tube fouling; boiler tube erosion; particulate and gaseous emissions; and slurry stability.

The results of a 1000-hour test firing showed that the flame stability when burning COM was equal to that of No. 6 oil, and boiler efficiency for COM and No. 6 oil were nearly the same. Gaseous and particulate emissions were within the expected range. Slag deposit on tubes and ash deposit were light. Boiler tube erosion was low, but brass burner nozzle parts were heavily eroded.

The data obtained during this test program were used to design and construct a 700 hp watertube boiler COM test facility with sophisticated instrumentation, data acquisition and control facilities. This boiler was a packaged industrial boiler designed originally for firing No. 6 fuel. Tests were run with a series of COMs with 30, 40 and 50% coal by weight to determine burner and boiler performance, pollutant emissions and ash deposition. The purpose of this program was to determine if COM was adaptable to industrial size packaged boilers. The test facility was self-contained with fuel storage, COM preparation, fuel transfer, flue gas cleanup system and instrumentation and data acquisition.

The tests found that fuel temperature, atomizer nozzle size and injection gun position adjustments were necessary to achieve a proper flame pattern and avoid flame impingement on the furnace wall. A poor flame pattern causes ash slagging on watertube surfaces and clinkers on the burners. Wear in the atomizer holes and other parts of the injector gun made tungsten carbide tips necessary. A sootblower effectively removed ash deposition from the convection bank. A bottom ash removal system was needed to remove bottom ash accumulation during extended furnace operation. No boiler derating was required using COMs up to 50% coal concentration. Boiler efficiency was nearly the same as when firing No. 6 fuel oil, with carbon burn-up efficiency on the order of 98%.

PETC concluded its COM fuel tests in the spring of 1981 and then converted the facility to CWM fuel testing.

6.3 Florida Power and Light Demonstration Testing of COM Firing

Florida Power and Light conducted a 120-day demonstration test of on-site preparation and firing COM (up to 50% coal) in the 400 MW Sanford Unit 4 boiler which was originally designed for oil firing. The plant achieved nearly full capacity while firing COM fuel.

The project was engineered, constructed, and operated in less than a year. The COM preparation facility constructed on-site consisted of coal unloading and storage, coal

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silos, pulverizer, cyclone separators, bag filters, coal bin, COM mix tank, nitrogen inerting system, stability additive system, and COM storage and transfer system. Boiler modifications included replacing the mechanically atomized burner guns with steam atomized guns, modifying combustion controls and burner management, adding a temporary bottom ash system, and changing the fly ash system.

The steam generator is a Foster Wheeler, natural circulation, single reheat unit designed to fire No. 6 fuel oil in a balanced draft furnace. Rated steam capacity is 2,560,000 lb/hr at 2,590 psi and 1,005°F. Fuel is fired through 18 burners in a common windbox on the front wall. The furnace has a steep sloped hopper bottom. Flue gas exits to a mechanical dust collector for fly ash removal. Two centrifugal forced draft fans provide the combustion air to the unit. Furnace wall blowers keep ash from building up on the furnace walls.

The project demonstrated the following:

- COM mixtures can be prepared with additives and stored with continuous agitation to prevent settling.
- Commercial valves and pumps suitable for abrasive service are adequate.
- Thermal combustion efficiency is equal to oil; however, carbon burnout is less efficient than oil.
- On-line switching from oil to COM or COM to oil is practical.
- Hardened materials for burner tips reduce erosion.
- Both low pressure air-atomized and steam-atomized burners can be used.

The amount of derating and long-term erosion effects are yet to be determined.

A number of important operating problems were encountered, including the following: If the COM gets too cool, it becomes too viscous and difficult to pump, if it gets too hot, the coal tends to settle out of the oil. Tungsten carbide on pumps, atomizer tips and trim on valves worked well and reduced erosion due to COM. Solid hard-packed coal deposits formed inside the burner gun pipes; means for controlling this deposition has yet to be devised. Deposits building up in plant fuel oil heaters were controlled by

flushing with No. 6 oil. The COM storage tank accumulated coal sediment deposits up to 5 feet deep, and attempts to re-entrain the deposits have been unsuccessful. Combustion material losses in the flue gas were approximately two times greater than expected. This was attributed to the difficulty of properly atomizing the total mixture introduced at the burner.

The high capital and operating cost of COM preparation facilities and cost of the plant modifications offset much of the advantage of the COM since a 50% COM only displaced 40% of the oil used.

6.4 Florida Power Corporation COM Demonstration

In mid-1977, Florida Power Corporation and Dravo Corporation started a joint program to produce and burn a COM fuel with up to 50% ultra-fine coal by weight. It was thought that COM prepared from finely ground coal would be more economical, burn better, and require less costly retrofitting than COM using normal grinding methods. Experiments were made with 30/70 and a 48/52 ratio COMs in small industrial boilers before development of a pilot batch plant and full scale test burn at the Crystal River Unit 1, 383 MW plant.

The pilot plant produced 1000 bbl/day of 50% COM. The fuel was transported and stored on a barge with 10,000 bbl capacity to test the feasibility of transporting and storing a COM. The COM was pumped from the barge to the boiler for combustion. The tangentially fired Combustion Engineering boiler was rated at 2,500,000 lb/hr with 1,005°F superheat. None of the major components (such as tanks, pumps, strainers and boilers) were modified because the intent was to demonstrate minimum unit modifications for COM firing.

The test produced much valuable information. Boiler efficiency changes were not measurable. The boiler flames were stable with good conical shape and envelope. Ash deposits could be cleaned up by soot blowing; water cleanup would probably be needed. A precipitator would be needed to properly control particulate emission.

High COM temperature accelerates the coal settling rate. Once coal and oil are mixed, recirculation is all that is necessary to maintain stability. COM storage temperature should be 120°F to 180°F. COM transportation at ambient temperatures considerably decreases settling rates. COM can be transported at high coal concentration and diluted to the concentration required for use. The tests showed that the COM can be burned without any major burner modifications.

The major problems with mixture preparation were high steam consumption and wear on the hardened surfaces in the grinder. The short test duration (33 hours on COM) was not conclusive with respect to wear, fouling, or heat transfer surface slagging.

6.5 New England Power Service Company Demonstration

New England Power Service Company (NEPSCO) demonstrated the feasibility of on-site preparation, storage and combustion of 30% coal and 70% oil mixture in the 80 MW Salem Harbor Unit 1, Babcock & Wilcox coal designed boiler converted to oil firing. The program was sponsored by ERDA and then DOE and EPRI.

NEPSCO initiated COM research programs at three universities that performed tests for COM stability, viscosity, and blending techniques. The research concluded that a stable COM could be produced from a nominal 86% through 200 mesh coal with a suitable additive added during blending.

COM was produced from coal pulverized in a conventional ball mill. The pulverized coal was stored in a bin and sent through a coal feeder to the COM blending tank. Continuous in-line blending was used, with coal flow and oil flow regulated to produce the desired concentration. A 200,000 gallon oil storage tank was modified to store COM.

The boiler was a balanced draft front wall type with a rated steam flow of 625,000 lb/hr. As a result of combustion experience in the General Motors COM program and a concern that accelerated burner erosion would occur, the existing high pressure (1000 psi) mechanical oil burners were replaced by Forney Verloop burners which rely on 40" H_2O primary air pressure for fuel atomization. Variable speed burner pumps controlled fuel flow to the burners, eliminating the need for control valves.

Initial oil and COM firing with the new burners resulted in unsatisfactory combustion conditions, requiring burner throat modifications and other adjustments to improve air distribution. Atomizer nozzles had to be replaced with tungsten carbide alloys to reduce erosion. Stack opacity was exceeded when 30% COM was fired. Load had to be reduced to 68 MW to reduce opacity. During the remainder of the test period, COM concentrations were reduced from 30 to 20% to permit compliance with air quality regulation. A maximum coal concentration of 42% had been blended without evidence of coal particle settling or plugging in storage tanks and process piping. There was no excessive equipment wear observed. Also there was no evidence of furnace slagging due to depressed fusion temperature of the combined coal and oil ash.

NEPSCO experience indicates that although COM with up to 30% coal was successfully burned, there was insufficient economic justification for burning COM. They would have to add expensive electrostatic precipitators in order to burn COM, negating any fuel cost savings.

6.6 Inland Steel Company Testing

Inland Steel Company has conducted an experimental program of COM injection in blast furnaces in an effort to reduce oil consumption in steel production. COM use in place of oil also reduces coke consumption because of the higher carbon content of the coal. The experimental program consisted of laboratory investigations, pilot plant tests and experiments on an operating blast furnace.

The laboratory investigations determined the effects of oil temperature, coal particle size and coal fines content on COM fluidity and viscosity. They also determined the feasibility of using various percentages of coal over various slurry holding periods. Several types of coal were tested.

An experimental pumping system was constructed for the pilot plant investigations. It was to gather information on slurry density and viscosity as functions of temperature, coal particle size and coal percentage. Pressure loss data were obtained to determine the relationship between flow rate and pressure drop for various size pipes. Operating procedures, such as start-up methods and line purging techniques, were determined. Also, equipment was evaluated in terms of pump durability, pipe layouts, lance size and valve type.

At the completion of the pilot plant tests, a program was conducted on the 20 ft hearth diameter No. 2 blast furnace at Inland's Indiana Harbor Works. A coal-oil slurry (up to 50% coal by weight in bunker C oil) was injected through two tuyeres. The COM was prepared on site. The injection rate was 4 gpm corresponding to a consumption of 1200 lb of coal per hour of operation utilizing a 50-50 slurry.

The test results determined that a COM slurry injection system is technically feasible for iron blast furnaces. However, successful operation of a COM system is highly dependent upon the exclusion of oversize solid particles. Some difficulties were experienced with one of the pumps, indicating the need for highly durable pumps.

Although savings can be realized by displacing bunker C oil with COM, even greater savings can be realized by converting to 100% coal injection. Since conversion to complete coal injection is technically feasible, as well as more economically attractive than COM injection, Inland Steel Company decided to discontinue the COM project. Instead it is continuing to develop solid fuel injection systems which would totally displace oil.

6.7 Tennessee Valley Authority (TVA) Testing

TVA has conducted an investigation of the fluid properties of unstabilized and stabilized coal-oil-water mixtures and the economics of converting the light-off system of a large 2,600 MW coal-fired utility station to COM firing. TVA has determined viscosity values for various concentrations of COM for both No. 2 and No. 6 fuel oil. Mixing tests on different blades to maintain suspension as well as reduce power show that a three-bladed, axial-type propeller is most effective. As expected, the least power was required at higher temperatures. Settling occurred immediately after the mixer stopped. To ensure adequate mixture distribution, continuous mixing is required. Additives are necessary if continuous mixing is not desired and to prevent settling around bends and elbows in pipelines.

The light-off sequence in a coal-fired electric generating station requires that a stable oil flame be established prior to introducing a stream of pulverized coal. This investigation showed that COM was an attractive alternative to No. 2 oil as a utility boiler light-off fuel, particularly in large stations where up to 100,000 gallons of oil are used in a single startup procedure.

6.8 Coaliquid, Inc.

Coaliquid, Inc. is a commercial COM fuel producer located in Shelbyville, Kentucky. Its main plant started operating in September 1979 producing COM fuel using a modified Cottell process (U.S. Patent No. 3,941,552). In an effort to raise more money and get increased technical support, Coaliquid sold a majority in itself to McDonnell Douglas Corp. in January 1981.

Coaliquid sells a fuel which consists of 50% coal, 40% No. 6 fuel oil and 10% water by weight. After initial mixing, the COM is subjected to ultrasonic processing, which produces a stable emulsion ready for use or storage. Coaliquid's main customers have purchased supplies of COM fuel for testing, such as St. Regis Paper, McDonnell Douglas, and K-U-B Corp. The company has big plans, but the market for COM fuel does not warrant expansion.

6.9 COM Energy, Inc.

COM Energy, Inc. is a subsidiary of the Occidental Petroleum Corporation. Its one-million barrel per year COM ~300 plant in Jacksonville, Florida, has been in operation since September 1981 to supply COM fuel to customers in the region for use in boilers and kilns. Only about 35% of plant capacity is committed to production for regular customers; the rest has not yet been sold or else is used to supply COM for test runs.

The plant has full handling, production and storage facilities. The COM fuel is usually 55% coal, 44% No. 6 oil and 1% water and additives, all by weight. Island Creek Coal Company, another Occidental Petroleum subsidiary, supplies the coal. This gives COM Energy, Inc. access to a wide variety of coals, making it possible to custom-blend COM fuel for different applications. COM Energy, Inc. has plans to build a larger plant when demand for COM fuel rises.

7. COMBUSTION APPLICATIONS

Determining the feasibility of converting a specific oil fired unit to COM firing requires a detailed technical and economic assessment. Many of the technical aspects of COM use and conversion have already been covered in Section 6. The following items must be considered in an economic assessment of a COM conversion:

- COM cost vs oil cost
- Facility modification costs
- Performance changes
- Maximum continuous rating
- Boiler efficiency
- Auxiliary power requirements
- Capacity factor
- Remaining facility life
- Space available at facility site
- Access routes to site
- Availability of skilled operating and maintenance personnel

7.1 Conversion of Utility Boilers to COM Firing

Utility boilers designed for oil are prime candidates for conversion to COM firing. For utility boilers which are presently firing oil but originally designed for coal firing, the practicality and cost of conversion to COM firing depends largely on present conditions at the units.

Modifications such as the following must be considered in converting an oil fired unit to COM firing:

- Adding facilities or modifying existing facilities for COM preparation (for on-site preparation) or for COM unloading (for off-site preparation).
- Adding facilities or modifying existing facilities for COM storage and handling.
- Burner and windbox modifications to accommodate changes in combustion characteristics and combustion product composition.
- Provisions for ash removal handling, and disposal systems.
- Adding equipment or modifying existing equipment for emissions control to meet environmental regulations.
- Adding instrumentation and controls appropriate for COM utilization.

7.1.1 Changes in Boiler Performance

Efficiency and maximum continuous rating (MCR) are of concern for a boiler operating on COM fuel. Boiler efficiency may be slightly reduced when firing COM fuel because incomplete coal particle combustion may reduce carbon burnout. Excess air may be increased for COM firing to minimize the reduction in carbon burnout. Boiler efficiency may be reduced in the range of 1 to 4 percent when switching from oil firing to COM firing.

A boiler must be operated under conditions which does not permit coal slagging to reduce reliability. Under some circumstances, this may require boiler derating. The two major conditions which must be avoided are carryover of molten or sticky ash particles from the furnace exit to the boiler tubes, and excessive surface erosion in the convective sections and the economizer. Ash carryover may be of concern in boilers in which furnace height is minimal. If it is not possible to specify a coal with an ash fusion temperature high enough to prevent molten ash carryover, it may be necessary to derate the unit to maintain a lower temperature at the furnace exit. Figure 4 shows the relative size of coal and oil designed furnace.

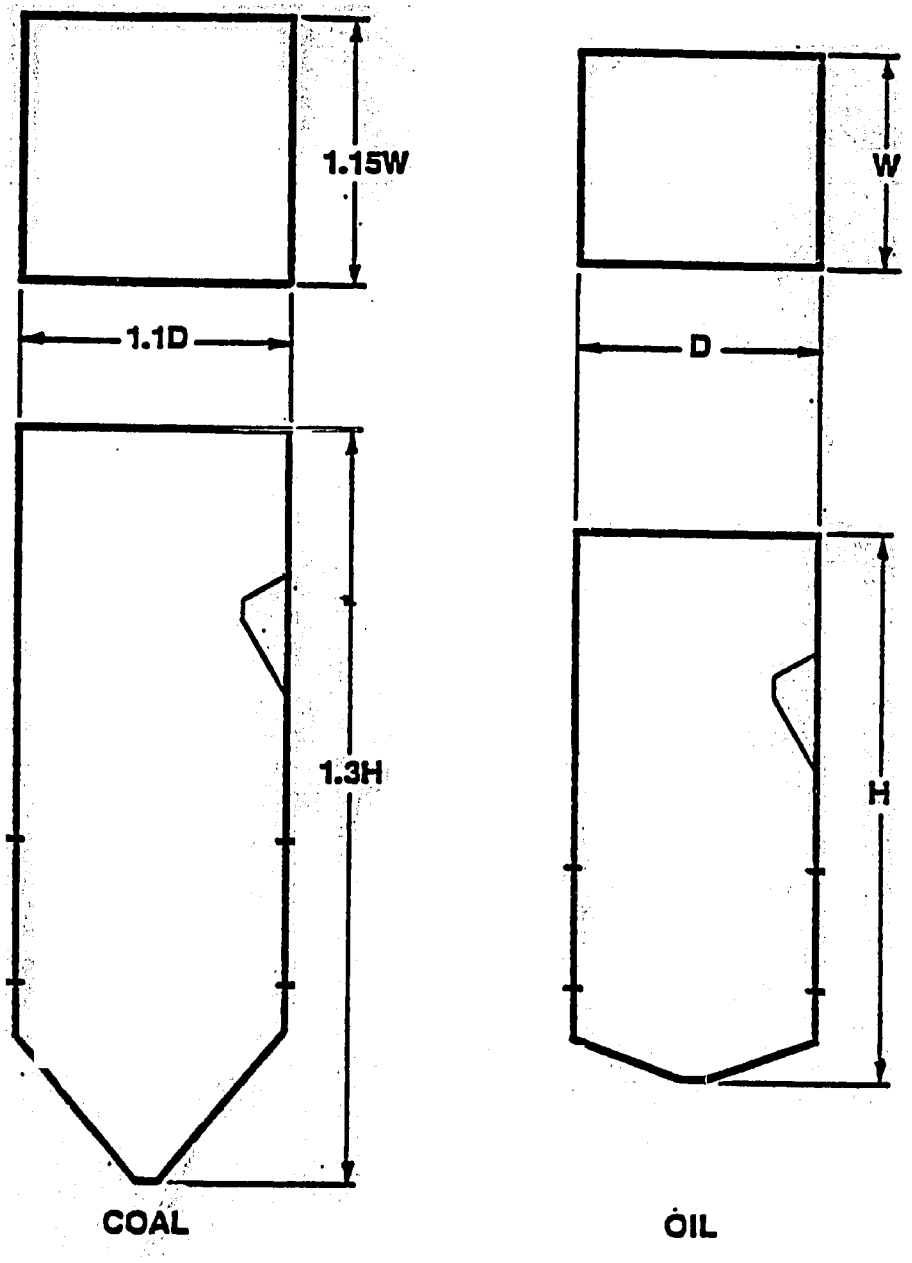

Figure 4. Furnace Size Comparison

Source: Reference 30

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Surface erosion downstream of the furnace due to ash particles is dependent upon the quantity of ash, the ash constituents, the ash particle size distribution and the gas velocity. Coal fired boilers are typically designed for lower gas velocities than oil fired boilers because of ash erosion. An oil fired boiler converted to COM may have velocities which exceed the recommended range, especially if the volumetric flow rate is increased due to a larger amount of excess air. Thus a boiler may have to be derated to maintain reliability. Removing or rearranging tube surfaces to increase flow area can reduce the derating required. Also, some derating can be avoided by using a low ash or cleaned coal.

If it is necessary to derate a boiler for any of the circumstances indicated, consideration should be given to retaining its oil firing capability. The original MCR can then be achieved by switching to oil firing when boiler demand exceeds the MCR capability for COM firing. The oil-firing mode is also available as a backup for use when there is an interruption in COM fuel supply.

7.1.2 Facility Modifications for COM Unloading, Storage and Handling

A COM fuel plant can be located at a site where COM fuel is prepared or at a remote location. Plant location will determine the sort of COM unloading storage and handling facilities needed. An on-site COM plant requires less extensive COM unloading and storage facilities than does a site where COM fuel is shipped from a remote location.

Existing oil handling and storage facilities can be used for COM if oil is not to be used as a backup fuel or for peaking. This may require such modifications as installing new pumps, heaters, valves, and metering equipment, placing agitators in the storage tanks, and upgrading the piping heat tracing and insulation. If dual COM/oil firing capability is desired, a new COM storage and handling system is necessary. Using COM handling and storage equipment for oil (and vice-versa) is not recommended.

7.1.3 Burner and Windbox Modifications

Boilers designed for coal firing are provided with large furnace volumes to achieve lower heat release rates and complete combustion. A coal flame is highly luminous, but the combustion product emissivity is lower than that for oil. As a result, the furnace exit gas temperature is generally higher for coal fired boilers than for oil fired boilers. The furnace volume is also governed by the requirements that ash particles at the furnace exit be below the

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ash fusion temperature to prevent liquid or sticky ash particles from reaching downstream surfaces. The ash fusion temperature depends upon the ash composition. The tube spacing is larger in coal fired boilers to accommodate some ash deposit build-up. The gas velocities through convection pass tubing are lower than in an oil fired boiler, to reduce ash erosion. Soot blowers are required to remove ash deposits in a coal fired boiler.

Boilers designed for oil firing have smaller furnace volumes than boilers designed for coal. Oil combustion is relatively rapid, oil flames are quite luminous, and the combustion gases have a relatively high emissivity. High heat transfer rates are acceptable in an oil furnace, resulting in relatively low furnace exit temperatures when compared with coal fired boilers. Boilers designed for either oil or natural gas firing, normally have a furnace sized for oil firing and convection passes sized to accommodate the higher furnace exit gas temperatures which occur when firing natural gas. Oil fired boilers generally have fewer sootblowers than coal fired boilers. Also, provisions for ash removal may be minimal in boilers designed for oil firing.

Each boiler which is considered a candidate for conversion to COM firing must be treated separately. The modifications required depend upon existing conditions and equipment as well as the unit size and configuration. The burners are likely to require replacement or modification to achieve proper fuel atomization, flame shape and luminosity, controllability and stability of the flame, and/or to prevent burner overheating, erosion and clogging. Relocating existing sootblowers, as well as adding more sootblowers, may be required for boilers originally designed for oil firing.

In addition to considering boiler modifications required for conversion to COM firing, conversion feasibility depends upon the performance of the unit after conversion to COM fuel. Cost and downtime considerations limit the extent to which modifications can be made to an existing furnace. Inadequate furnace volume and height may require derating the boiler, rather than making extensive furnace modifications. In cases of severe derating, a new boiler may be a more attractive option than using a severely derated existing boiler.

7.1.4 Convection Section

Wide traverse tube spacing is required throughout the convection passes on units firing coal to prevent ash deposits from bridging between assemblies. The flow area

for coal fired plants is also large to keep the velocities low enough to minimize erosion rates. When converting a coal designed boiler to COM firing, adequate tube spacing and low velocities may make derating unnecessary. However, when converting an oil designed boiler to COM firing, some derating is normally required. Replacing or modifying some surfaces may alleviate such concerns, but the long downtime and high costs make this alternative unattractive. As already mentioned, using low ash coal in COM fuel can reduce the amount of boiler derating. Additional sootblowers are a necessity to convert an oil fired unit to a COM fired unit.

7.1.5 Fans, Ducts and Stack

The design margins for the forced draft and induced draft fans must be examined to be sure they are adequate to handle a modified boiler. If an electrostatic precipitator or fabric filter is installed, fan head requirements will increase, ductwork may have to be rerouted, and the stack may require modification or replacement.

7.1.6 Provisions for Ash Removal, Handling and Disposal

Boilers designed for oil firing generally have very limited provisions for bottom ash and flyash collection and removal. The slope of the walls at the bottom of the furnace and the bottom throat area may have to be increased to preclude buildup and allow proper drainage. Furnace hopper supports may also require reinforcement to enable them to withstand the weight and impingement of slag falling from the furnace walls. Adequate space must be available beneath the furnace bottom to allow for modifying the ash collection and removal system. Flyash collection and handling systems must be installed under particulate collection equipment hoppers. An ash handling and disposal system must be added to an oil fired unit or to a unit originally designed for coal firing which does not presently have an ash handling and disposal system, in order to fire COM fuel.

7.1.7 Emissions Control

The major pollutants of concern for a COM fired unit are particulates, sulfur oxides (SO_x) and nitrogen oxides (NO_x). Particulate removal equipment for oil fired boilers may not be adequate for particulate removal after conversion to COM firing. Such conversion may therefore require upgrading or replacing existing particulate removal equipment. Flyash particles in the size range anticipated from COM combustion can be removed by an electrostatic precipitation (ESP) or fabric filters. The selection of an ESP or a fabric filter depends upon the stickiness, resistivity, and size distribution of the particles.

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Sulfur oxide emissions can be controlled by limiting the fuel sulfur content and/or by installing scrubbers to remove sulfur oxides from the flue gas. COM fuel sulfur content can be reduced by using some combination of low sulfur oil, low sulfur coal or cleaned coal. The cost of flue gas scrubbers tends to be prohibitive, so that conversion to COM firing is not generally feasible if SO_x emission control cannot be achieved with existing equipment or by using low sulfur fuel.

Nitrogen oxides emissions are primarily determined by combustion conditions rather than by fuel composition. NO_x emissions can be reduced by combustion process control techniques such as flue gas recirculation or two-state combustion. Special flue gas scrubbing systems are also available for NO_x emissions control.

7.2 Conversion of Industrial Combustion Systems to COM Firin

Much of the above discussion of converting utility boilers to COM firing is applicable to converting industrial combustion equipment. The wide variation in types of industrial equipment makes it difficult to make general statements about COM conversions. Combustion tests with COM have been conducted on many types of industrial equipment, thus providing a data base for expected performance and required modifications. It is usually necessary to replace or supplement fuel feed systems and burners with new equipment suitable for COM. Additional modifications depend on the type of combustion system and its application as well as the type of coal used to make the COM. Only a few examples will be cited here.

Tests conducted on using COM fuel in blast furnaces indicate that coarsely ground coal is suitable for combustion because of the long residence time. Tests have also been performed on forging operations using COM fuel. The test forgings indicated little difference between forging with oil and forging with COM fuel. Various metals and ceramic materials have been tested in forging furnaces. The tests showed that several ceramic materials which are suitable for furnace construction with oil combustion are not suitable with COM combustion, while metal suitability is temperature dependent.

Tests performed on hot wall furnaces showed that ash deposits within the furnace combustion chamber are readily removed from surfaces where the wall temperature is consistently below the ash fusion temperature. However, ash deposits are more difficult to remove where slagging occurs due to elevated wall temperatures. Perhaps the most unsuccessful demonstration utilizing COM was an attempt to

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operate a slow speed diesel engine on COM. Not unexpectedly, the diesel demonstration indicated that considerable development work is required to adapt a diesel engine to burn COM fuel. The main problem was the ash eroding the moving parts of the engine.

8. ECONOMICS

The projects described in section 6 are all either test or demonstration projects. Even the COM Energy and Coaliquid plants fit into this category because they are small capacity plants which are supplying COM mostly to demonstration projects. All of these projects have demonstrated that all aspects of COM production and combustion are technically feasible. Despite the fact that COM fuel is a technically attractive substitute for fuel oil, it is not in widespread commercial use, because the economics of producing COM fuel and converting facilities to COM firing have been for the most part unfavorable in the cases studied thus far.

The most viable way to produce COM fuel is in a large plant to take advantage of the economy of scale and ship the finished product to where it is used, as is the case for other major fuels. Nevertheless, widespread commercial use is unlikely unless the price differential between COM fuel and oil increases. But an oil price rise will always raise the COM fuel price, since oil is a major component of COM.

An important factor in deciding whether to convert to COM fuel is the COM price relative to the prices of other fuels. Elements which enter into determining COM prices are: Oil cost (delivered), Coal cost (delivered), COM plant fixed costs, and COM plant operating costs.

Oil and coal costs, the greatest portion of COM fuel costs, are determined in the world energy market. The selected COM production method determines the plant costs.

The following table from a Mitre Corporation[1] study illustrates COM pricing for fuel produced in a 100,000 bbl/day plant (based on 1981 dollars):

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Capital cost 88.3×10^6 \$ (\$24.6/kW)

Operating & maintenance cost 14.2×10^6 \$/yr (\$4.00/kW/yr)

Fuel cost

Coal \$1.60/10^6 Btu (\$38/ton)
(S 1.5%)

Oil \$6.07/10^6 Btu (37/bbl)
(S 1.0%)

Oil \$6.56/10^6 Btu (\$40/bbl)
(S 3%)

Levelized cost of COM \$5.15/10^6 Btu (1982 dollars)

Savings over oil \$1.64/10^6 Btu (1982 dollars)

This particular study indicates a saving in fuel cost of \$1.64/10^6 Btu by converting from oil to COM fuel. The fuel cost figures used in the Mitre Corp. study also indicate a fuel cost saving of about \$4.70/10^6 Btu by switching from oil to 100% coal.

Conversion costs for combustion equipment depend on the type of fuel to be used and the state of the equipment. The necessary modifications for COM fuel have already been discussed; they include fuel storage and handling facilities, furnace modifications, and ash handling equipment. Another problem, especially for electric utilities, is the reduction in boiler performance (derating) that is often necessary when converting from oil to COM fuel. A derated boiler is not able to perform at its original maximum capacity. If the capacity lost to derating is needed, it must be made up either by additional boilers or by purchasing power. In either case this represents an additional cost of converting to COM fuel.

A final consideration in converting to COM fuel is the remaining economic life of the facility which must be longer than the time it will take to recover the investment.

Figures 5 through 8 summarize a study done by Richard Furman called Power Plant Conversion to Coal-Oil Mixtures and Coal-Water Mixtures and presented at the 1982 Coal Slurry Combustion Symposium. The study is for an electric utility plant with two typical 400 MW oil fired units. Table 8 presents the final summary and bottom line of the study which shows a saving when converting from oil to 100% coal and to yet unproven coal-water slurry fuel while showing an increased cost when converting from oil to COM. The report neglects any increased costs due to boiler derating; including them would only make COM fuel less attractive.

Figure 5

POWER PLANT CONVERSION COSTS
COAL, COM AND CWM

Two (2) 400 MW Units

SYSTEM	COAL	COM	CWM
		($ Million)	
Coal Unloading and Handling Facilities	50.7	-0-	-0-
Steam Generator Modifications	47.5	8.9	35.0
Control Systems for Steam Generator	2.9	1.7	2.0
Bottom Ash Removal System	6.3	5.1	6.0
Electrostatic Precipitators	31.0	30.9	34.1
Fly Ash Removal System	5.1	4.0	5.1
Flue Gas Desulfurization System	-	-	-
Ash and Sludge Disposal (Off-site)	24.1	18.9	24.1
Plant and Site Modifications	9.7	6.4	6.4
Electrical Systems Additions and Modifications	16.0	12.7	10.7
TOTAL DIRECT CONSTRUCTION COST	193.3	88.6	123.4
Indirect Construction Costs	31.9	14.6	20.4
Contingencies (16%)	35.9	16.5	23.0
Land	1.1	0.5	0.5
TOTAL CONSTRUCTION COST	262.2	120.2	167.3
Utility Costs (Taxes and Overhead)	30.9	14.2	19.7
TOTAL CAPITAL COST	293.1	134.4	187.0
AFUDC (@ 20%)	58.6	26.9	37.4
TOTAL CONVERSION COSTS ($1980)	351.7	161.3	224.4
% OF COAL CONVERSION COST	100%	46%	64%
CAPITAL CARRYING COST (@ 22%)	$ 77.4/Yr	35.5/Yr	49.4/Yr

Source: Reference 19

Figure 6

FUEL COSTS
OIL, COAL, COM AND CWM

Two (2) 400 MW Units

UNIT FUEL COST	OIL	COAL	COM	CWM
		($/MBTU)		
Oil ($33.88/Bbl.[1])	$ 5.46			
Coal ($50.00/Ton[2])		$2.00		
COM ($25.27/Bbl.[3])			$4.08	
CWM ($8.20/Bbl.[4])				$2.00
ANNUAL FUEL COST[5]		($M/Year)		
Oil (9,400 BTU/KWH)	$215.8			
Coal (9,680 BTU/KWH)		$81.4		
COM (9,465 BTU/KWH)			$162.3	
CWM (9,960 BTU/KWH)				$83.7

[1]Oil - January 1981; 1% S; 6.2 MBTU/BBL Oil.

[2]Coal - $30.00 /Ton at mine + $20.00/Ton transportation; 25/MBTU Ton coal.

[3]COM - 50/50 by wt.; 60% oil/40% coal by heating value; 6.2 MBTU/BBL COM.

[4]CWM - 75% by wt.; 4.1 MBTU/BBL CWS.

[5]Annual fuel cost for two (2) 400 MW units at 60% capacity factor.

Source: Reference 19

Figure 7

PREPARATION PLANT COSTS
COAL CLEANING, COM AND CWM

Two (2) 400 MW Units

CAPITAL COST	COAL CLEANING	COM ($/MBTU)	CWM
Coal Cleaning ($5/Annual Ton Coal[1])	$ .05		
COM Preparation ($10/Annual Ton Coal[2])		$ .10	
CWM Preparation ($20/Annual Ton Coal[1])			$ .20
O+M COST			
Coal Cleaning ($5.00/Ton Coal[1])	$ .20		
COM Preparation ($5/Ton Coal[3])		$ .20	
CWM Preparation ($10/Ton Coal[1])			$ .40
TOTAL	$ .25	$ .30	$ .60
ANNUAL PREPARATION COSTS[4]	($M/Year)		
Coal (9,680 BUT/KWH)	$10.2		
COM (9,465 BUT/KWH)		$11.9	
CWM (9,960 BUT/KWH)			$25.1

[1]Coal - 12,500 BUT/LB.

[2]COM - $2.48/annual BBL. COM = $10/annual ton coal equivalent.

[3]COM - $1.24/BBL. COM = $5/ton coal equivalent.

[4]Annual Preparation Cost for two (2) 400 MW units at 60% capacity factor.

Source: Reference 19

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Figure 8

ECONOMIC COMPARISON OF CONVERSION ALTERNATIVES

Two (2) 400 MW Units - Oil-Designed, Coal Capable

ECONOMIC CONSIDERATION	OIL	CLEAN COAL	COM	CWM
Oil Displacement (%)	0	100%	40%	100%
Conversion Cost ($M)	-	$351.7	$161.3	$224.4
Annual Costs ($M/Year) Capital Carrying Charge	-	77.4	35.5	49.4
Additional O+M Costs	-	6.2	3.2	4.4
Preparation Plant Costs	-	10.2	22.1	35.3
Fuel Costs	215.8	81.4	162.3	83.7
Total Annual Cost ($M/Year)	$215.8	$175.2	$223.1	$172.8
Annual Conversion Savings ($M/Year)	-	40.6	- 7.3	43.0

Source: Reference 19

One of the reasons why COM is not an attractive alternative is that it only replaces 40% of the oil by heating value. COM fuel reduces fuel cost by $1.38/MBtu when switching from oil to COM, which is not enough to justify conversion. Switching from oil to 100% coal results in a fuel cost saving of $3.46/MBtu. Even though coal conversion costs are greater than COM conversion costs (351.7 vs 161.3 million dollars) the fuel cost savings are so great in a 100% coal conversion as to make the conversion economic.

Studies such as the Furman study are an indication that COM fuel may result in increased costs or at best only marginal savings. Such a marginal economic situation makes decision makers reluctant to commit large amounts of money to COM conversions even though they are generally technically feasible. In the U.S. electric power industry, there is a tendency toward 100% coal conversion, because there is long experience with coal and as a result coal economics are well understood. Such a body of experience and information does not exist for COM fuel.

If COM fuel is ever to become widely used, it must be used where conversion costs are minimal. Otherwise conversion costs will negate any fuel cost savings. Figure 9 illustrates possible fuel cost savings for a COM conversion over a range of oil and coal prices. The savings indicated do not appear sufficient to justify the capital expenditures required for conversion, cases where conversion to COM is justified are more likely to be exceptions than the rule.

Figure 9

TYPICAL COM PRICES AND POTENTIAL SAVINGS

Oil Price (¢/Gal.)	Oil Price ($/MM Btu)	Coal Price ($/Ton)	Coal Price ($/MM Btu)	COM Price (¢/Gal.)	COM Price ($/MM Btu)	% Savings
70	4.67	45	1.73	63.6	4.24	9.1
		50	1.92	64.8	4.32	7.4
		55	2.12	66.1	4.41	5.6
		60	2.31	67.3	4.49	3.9
80	5.34	45	1.73	71.2	4.75	11.0
		50	1.92	72.4	4.83	9.5
		55	2.12	73.6	4.91	8.0
		60	2.31	74.8	4.99	6.5
90	6.00	45	1.73	78.8	5.26	12.4
		50	1.92	80.0	5.34	11.1
		55	2.12	81.2	5.42	9.8
		60	2.31	82.4	5.50	8.4
100	6.67	45	1.73	86.5	5.77	13.5
		50	1.92	87.7	5.85	12.3
		55	2.12	88.8	5.92	11.2
		60	2.31	90.0	6.00	10.0

Source: Reference 18

C. COAL-WATER MIXTURE FUELS

1. GENERAL

Coal-water mixture (CWM) fuel is a slurry of coal and water typically 60 to 70% pulverized coal by weight, sometimes with a small amount of chemical stabilizer. CWM has the advantages of COM, that it can be handled like oil and used where a 100% coal conversion is not practical. Its important advantage over COM is that it contains no expensive oil which significantly reduces its cost.

CWM is in the laboratory and pilot plant stage, with stability and combustion problems still waiting for a solution. Once these problems are solved, CWM will be ready for large scale testing.

The reasons for converting to COM are also applicable to CWM conversion, the main reason being the desire to reduce foreign oil consumption. In cases where conversion to 100% coal is not practical, CWM and COM are alternatives to oil worth considering.

Much of the preceding discussion of COM fuel also applies to CWM fuel. This section serves mainly to discuss areas where the technologies differ, and to present CWM economics.

2. HISTORY

CWM fuel has a history of little over 20 years as compared with over 100 years for COM. Current work on CWM fuel is based on work done in the United States, Germany and Russia during the 1960's and early 1970's. Some experience with coal-water slurry coal transport pipelines is also applicable to CWM fuel technology, particularly in the area of coal particle size and concentration.

Jersey Central Power and Light conducted a CWM fuel test at its Werner Station in South Amboy, New Jersey, in 1961. The purpose of the test was to demonstrate that CWM fuel could be burned successfully in a coal designed boiler. The test was part of an effort to promote coal-water slurry pipelines as a means of reducing coal transportation costs. The tests accumulated about 450 hours of firing a 70% coal, 30% water slurry over a range of boiler loadings. The test is generally considered to have been a success, with no fuel handling or combustion problems being encountered.

Investigators in the Federal Republic of Germany conducted CWM fuel tests from 1963 to 1970 mostly using a slurry of 60% coal, 40% water by weight. The tests demonstrated that such a slurry could be prepared using conventional wet grinding. They also showed that the fuel could

be stored and distributed without the need for a stabilizer, using instead mechanical stirrers and circulation pumps. Finally the tests demonstrated that CWM fuel burned well in a boiler designed for pulverized coal, with carbon burnout approaching 98%.

CWM fuel tests conducted in the Soviet Union from 1963 to 1975 produced the following results:

- CWM fuel can be produced by wet grinding in conventional ball mills.
- High viscosity with less than 40% water makes transportation costs excessive.
- Stabilizers are not required for storage, distribution, and combustion as long as the slurry is agitated.
- Excess air levels of 7 to 12% produced carbon burnout to the 98 to 99.5% range.

The 1973 oil embargo increased interest in CWM, and other possible alternatives to fuel oil. The projects already discussed serve as a base for continued work on CWM fuel. Although the early tests were successful, much more information is needed before CWM fuel can be considered a viable substitute for fuel oil.

Most of the CWM work going on in the United States started in the late 1970's, following the second oil crisis in 1979. This work consisted largely of research and small scale demonstration projects. In fact, a major CWM fuel research effort started by DOE in April 1981 is not expected to be completed until 1984. The DOE program is to provide basic information for private concerns so that they may pursue commercial CWM fuel development.

3. CWM PROPERTIES

CWM fuel is a slurry of pulverized coal, water, and sometimes a small quantity of stabilizer. It has characteristics similar to those of No. 6 fuel oil. CWM properties are almost entirely dependent on the coal from which it is made. Handling and combustion characteristics for CWM fuel are most important.

The more important properties that affect CWM handling are viscosity, stability, erosion potential, and reagitation ease. Viscosity determines how easily CWM fuel can be piped and pumped; the higher the viscosity the more difficult it is to handle. CWM fuel generally exhibits the rheological behavior of a Bingham plastic. The behavior of a Bingham

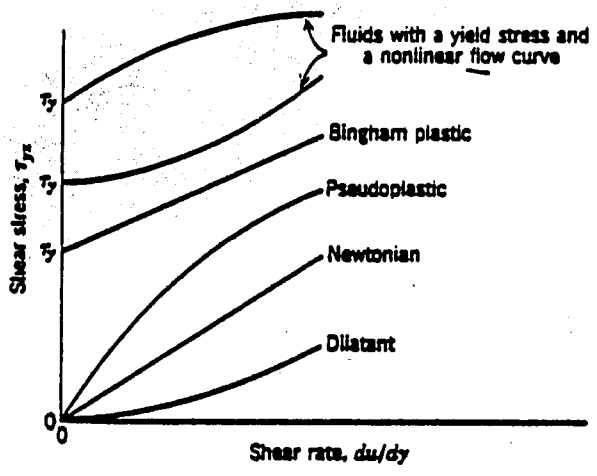

Figure 10. Flow Curves on Arithmetic Coordinates for Various Types of Time Independent Fluids

Source: Reference 25

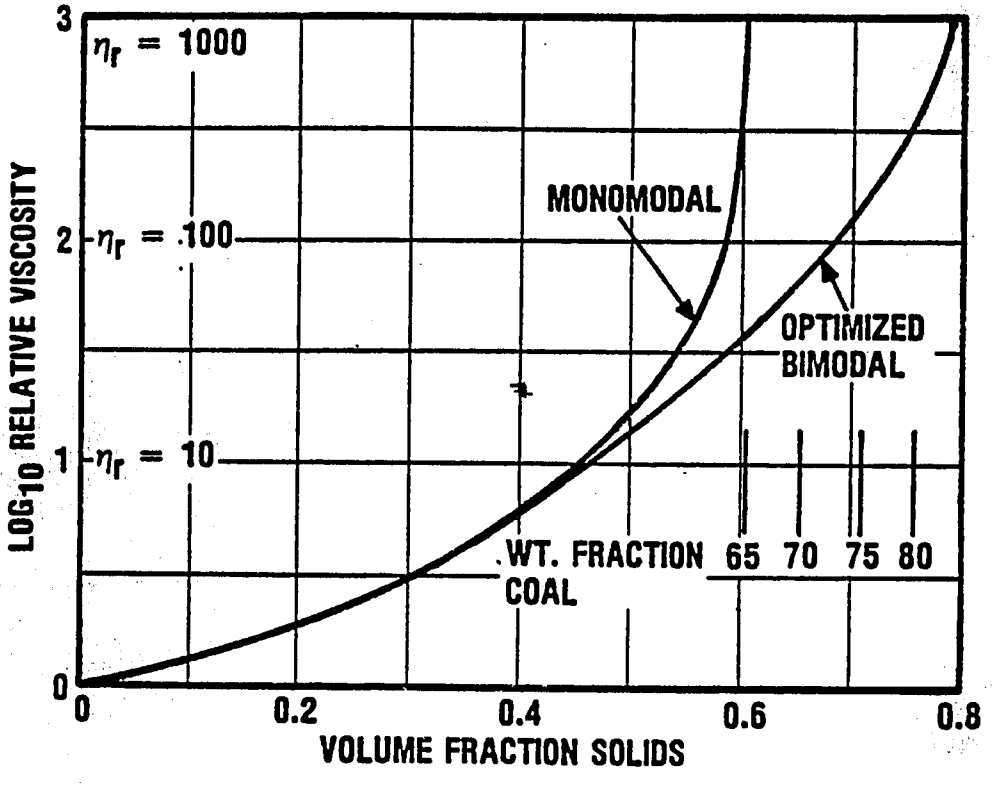

Figure 11. Effect of Bimodal Distribution on Relative Viscosity

Source: Reference 24

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plastic is shown in Figure 10. A certain amount of stress must be applied before the fluid will move distinguishing it from a Newtonian fluid. Stability refers to the extent to which coal particles remain suspended in water. For CWM fuel to be useful, coal particles must remain in suspension during transport and storage; otherwise, coal particles will plug pipes, pumps and storage tanks. Erosion potential is the ability of CWM fuel to erode pipes, pumps and burners. CWM fuel erosion potential depends on the coal mineral ash content. Erosion potential can be reduced by using either low ash coal or cleaned coal. Reagitation ease is the degree of difficulty in resuspending coal particles which have settled out of the slurry. A loose packed sediment is relatively easy to resuspend while a hard packed sediment can be nearly impossible.

Of the numerous properties that affect CWM fuel combustion characteristics, the more important will be discussed. Many combuston tests have found it important to use a coal with a high volatile fraction (as high as 40%) in order to achieve a stable flame. Also, since coal is the only source of heat in CWM fuel, coal content should be as high as possible without adversely affecting handling properties. The water in CWM fuel has the effect of reducing the CWM fuel heat content and improving burning characteristics.

Water has no heating value, so that for equal weights of coal and CWM fuel, the 100% coal has a higher heat content. The water causes CWM fuel to have a flame temperature 200 to 400°F below that of oil. This, in turn, reduces boiler efficiency by about 3% when firing CWM fuel. On the other hand, the water content improves CWM fuel burning characteristics. CWM fuel burns with a short, intense flame very similar to that of No. 6 fuel oil. The intense flame results from hydrocarbon cracking in the presence of water, similar to what occurs in coal gasifiers. This sort of flame is especially desirable in an oil-designed boiler which has a smaller furnace volume than a coal-designed boiler.

To be completely useful, CWM fuel must have a low ash content in order to reduce erosion and boiler slagging. Low ash coal can be either natural or achieved by cleaning. Without low ash coal, a boiler burning CWM fuel may suffer a severe derating penalty in order to reduce ash slagging and convection pass erosion. In addition, a low ash coal, especially a washed coal, has a higher heating value per unit weight than a similar weight of high ash coal because of the reduced ash content.

An added advantage of using washed coal is reduced sulfur content. Together, reduced ash and sulfur contents help to reduce emissions from CWM fuel combustion. If the ash and sulfur content are sufficiently low, minimal addition to emissions control equipment may be required for conversion to CWM firing. Without low ash, low sulfur coal, a CWM conversion is similar to an ordinary coal conversion. The full range of ash handling and emissions control equipment for a coal conversion is then required.

4. CWM PRODUCTION METHODS

U.S. and foreign inventors have developed and patented numerous CWM preparation methods in recent years. They are all variations of coal grinding method, proportion of coal to water, and (often) additive to stabilize the CWM fuel. Dry grinding, wet grinding, micronizing, and a combination of wet and dry grinding have been used to produce CWM fuel. Most of these grinding methods use standard equipment, but equipment scale-up is required before some methods can be used on a large scale.

Most CWM production methods start with cleaned coal to reduce ash slagging and sulfur emissions as well as raise the fuel heat content. Cleaned coal is then ground by the method chosen for a particular CWM production system. CWM production methods vary chiefly in coal particle size and distribution, as well as the type of stabilizer used, if any. Monomodal and bimodal particle distribution are most often used in CWM fuel.

A monomodal particle distribution has a simple particle size goal, with a distribution of particle sizes about that goal. Usable mixtures of up to 60% coal by weight have been prepared without using special additives. A monomodal mixture of greater than 60% is too viscous to be useful. However, a higher proportion of coal is desirable to increase the fuel heat content. In order to accomplish this, a bimodal coal particle size distribution must be used.

There are two distinct coal particle sizes in a bimodal distribution. A typical bimodal distribution has 70% of the coal with a mean particle size of about 120 microns, while the remaining 30% of the coal has a mean particle size of about 15 microns. The smaller coal particles tend to fill the interstices among the larger coal particles and actually help to reduce the overall fluid viscosity. Thus an increase in coal concentration (up to about 70% coal by weight) can be had with a bimodal particle distribution without the unacceptable viscosity increase associated with a monomodal

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mixture. Figure 11 demonstrates the value of a bimodal CWM fuel over a monomodal CWM fuel, an increase in coal concentration without a great increase in viscosity.

After coal is ground and mixed with water, some processses add a small portion of additive to stabilize the CWM. Additives also help to depress the freezing point of CWM fuel.

5. CWM PRODUCTION EQUIPMENT

A CWM fuel production plant is in most ways similar to a COM fuel production plant. Thus most of the previous discussion of a COM fuel plant applies here. A CWM fuel plant should be located near a port or a railroad for easy coal delivery and product shipment. A CWM fuel plant requires no provisions for large oil deliveries. Instead, it requires an adequate water supply since water comprises about 30 to 40% of CWM fuel. The type of coal grinding equipment depends on the exact process being used to produce the CWM fuel. Progressive cavity pumps have been found to be most effective for pumping CWM fuel. Also, adequate agitation and/or recirculation is required to prevent coal particle settling during processing and shortage.

6. COMBUSTION EQUIPMENT

Since the problems encountered in converting to CWM fuel use are very similar to those encountered in a COM fuel conversion, most of the previous discussion on COM fuel combustion equipment applies here. The extent of boiler modifications for a CWM fuel conversion depends on whether the boiler was originally designed for oil or coal firing. Accommodations must be made for coal firing before CWM fuel can be used. In general a high ash hopper slope, bottom ash removal, sootblowers, hardened burner nozzles, and provision for fuel heating are needed to fire CWM fuel.

When considering a CWM fuel conversion a 3 to 4% reduction in boiler efficiency can be expected, due mainly to the high CWM fuel water content. Flame type for CWM fuel is very similar to that of oil. Provision must be made for a higher volume of stack gas for CWM fuel combustion than for oil combustion, because of the lower heat content of CWM fuel. A higher stack gas volume often causes excessive ash slagging and convection pass erosion when firing CWM fuel, just as occurs for COM fuel combustion. Erosion and slagging can be reduced by derating a boiler. However the amount of derating can be minimized by using low ash coal.

On-site handling equipment for CWM fuel is essentially the same as for COM fuel. Storage tanks must be agitated. Progressive cavity pumps are considered most effective for pumping.

7. CURRENT PROJECTS

Among both private and U.S. government-sponsored CWM fuel research and development projects, most are not nearly as advanced or extensive as for COM fuel. Numerous technical problems, mostly in the areas of stability and combustion, must be solved before CWM is ready for commercial use. The only large scale CWM fuel test in the United States was a Jersey Power and Light Werner Station test in 1961. This section summarizes some representative current or recent CWM fuel projects in the United States.

7.1 Atlantic Research Corporation (ARC)

ARC is doing research on CWM fuels under DOE contracts. Various types of additives in combination with different coals are being screened in an effort to produce a stable CWM fuel. Rheological studies are also being conducted. Combustion tests in a 1.3 million Btu/hr test furnace produced stable CWM flames without using an auxiliary fuel.

ARC is continuing its CWM fuel research and development efforts with a 75 bbl/day pilot plant that started operation in the spring of 1982. ARC is also scheduled to begin operating a 600 bbl/day CWM fuel plant in late 1982. The plants are to supply fuel for additional ARC tests and for outside tests. ARC has successfully produced CWM fuel with a coal content of 61 to 73% coal by weight from a variety of coals.

7.2 Gulf-Western Industries, Inc.

Gulf-Western has developed chemical grafting techniques to produce low ash, low sulfur coal for COM and CWM production. This is an important development because a low ash, low sulfur coal reduces the ash fouling and emissions problems normally associated with COM and CWM usage. Tests have found these techniques applicable to a wide variety of coals, giving flexibility in coal feedstock sources.

In early 1982 Gulf-Western completed a pilot plant capable of producing cleaned coal, COM or CWM. A commercial size plant is planned, if two years of pilot plant operation and product tests are successful.

7.3 Massachusetts Institute of Technology (MIT)

The U.S. Department of Energy (DOE) and private companies are funding an MIT investigation of COM/CWM combustion mechanisms and flame stabilization. The tests are performed in a highly instrumented combustion tunnel, with a controlled heat sink to simulate actual furnace operation. The tests examine heat transfer patterns, ash deposition, burner design, and fuel atomization. Laser diagnostic measurements are made to study the combustion mechanism for various test fuels. The initial work should be completed in early 1983.

7.4 Pittsburgh Energy Technology Center (PETC)

The DOE CWM research facilities at PETC consist of a 100 hp fire-tube boiler, a 700 hp water-tube boiler, a fuel preparation facility, and a laboratory which studies CWM rheology. The PETC test facilities have been in use since April 1981 to prepare, store, transport, and burn CWM fuel. Specific research areas include low ash/low sulfur CWM, boiler performance, impact of coal ash, and impact of coal type on CWM rheology and combustion.

A CWM fuel of 57% Pittsburgh seam coal by weight has been burned in both boilers, the 100 hp boiler first. Burner modifications allow the CWM to burn without any supplementary fuel, though gas must be used for ignition. The 100 hp boiler has reached full load in tests; the 700 hp boiler has only reached 85% of full load. In-situ SO_2 removal using limestone or hydratest lime in CWM fuel has been evaluated during short tests with only about 20% of SO_2 being removed.

7.5 Slurrytech, Inc.

J. Funk of Alfred University has developed and patented a CWM fuel with good pumping characteristics. The fuel, called Co-Al, has been tested with concentrations of up to 75% coal by weight using a variety of coals. Twelve tons of Co-Al have been burned with good results in tests in the basic combustion test unit at the Babcock and Wilcox Alliance Research Center.

7.6 Burns and Roe, Inc.

Burns and Roe, Inc. has conducted an engineering feasibility study of oil-designed utility boiler conversion options, under a DOE contract. After deciding the retrofit criteria for dual CWM-oil firing, three units were selected for conceptual design studies. The studies will define capital and operating costs for each unit to be converted to dual CWM-oil firing.

8. CWM Economics

Absence of large scale test experience is the main reason for a lack of information needed for valid economic evaluation of CWM fuel. All price projections indicate that CWM will cost less per million Btu than COM fuel since CWM fuel uses water instead of expensive oil. The major CWM cost elements are coal, coal cleaning, water, and processing costs. One study indicates a CWM cost of $3.00 per million Btu compared with a COM cost of $4.00 per million Btu under similar conditions. The study is based on a coal cost of $1.47 per million Btu and an oil cost of $4.75 per million Btu. Costs vary according to raw fuel prices, transportation costs, and production scale. Much more large scale experience is required before CWM can be more firmly priced.

The Furman study cited in the COM section and summarized in Figures 5 through 8 estimates a CWM fuel price. The study also estimates the cost of converting a representative oil fired power plant to CWM fuel. The study estimates a COM cost of $4.08 per million Btu and a CWM cost of $2.00 per million Btu, based on a coal price of $2.00 million Btu and an oil price of $5.46 per million Btu. This is shown in Figure 6. Figure 8 shows the annual savings for converting a typical oil fired power plant to either coal, COM or CWM (CWS). Coal shows a saving of $40.6 million/yr, CWM a saving of $43.0 million/yr, and COM an increase of $7.3 million/yr. The conversion to 100% coal or to CWM is more expensive than a conversion to COM: $351.7 million and $224.4 million in comparison with $161.3 million (Figure 8). However, the fuel cost savings with 100% coal or CWM instead of COM make the higher costs of a 100% coal or CWM conversion worthwhile. The Furman study case is hypothetical, but it is indicative of fuel conversion economics. A site specific study is needed for an actual conversion to account for factors unique to a particular case.

D. OTHER COAL SLURRY FUELS

COM fuel and CWM fuels have received the most attention in coal slurry fuel research efforts. COM fuel is ready for commercial use, but economics are preventing its further development. CWM fuel needs much further research and development before it is ready for commercial use. Most work with other liquids is in the very early laboratory stages. The main area of interest has been in coal-methanol mixtures.

PETC has conducted tests with coal-methanol mixtures using 55 to 60% coal and varying amounts of water and methanol. Carbon conversion efficiency was in the range of 86 to 92%. without using preheated air. Much more work is needed to gather experience with coal-methanol mixtures and exploit their two possible advantages: the methanol makes the slurry easier to ignite and allows a stable flame at a lower air preheat temperature than for CWM fuel.

E. REFERENCES

The following from:

Third International Symposium on
Coal-Oil Mixture Combustion
April 1-3, 1981, Orlando, Florida

1. "U.S. DOE Coal-Oil Mixture Combustion Program"
   C.B. Foster

2. "FPL's Sanford COM Demonstration Project"
   L.D. Slepow, A.S. Mendelssohn

3. "Result of the Salem Harbor Coal-Oil Mixture Demonstration"
   R.M. Dunn, S.K. Batra

4. "Status of the Occidental Coal-Oil Mixture Program"
   E.W. Knell, H.F. Bauer

5. "A Scenario for Regional COM Preparation"
   W.D. Holbrook, T.A. Schelat

6. "A Comparative Study of COM Preparation Technologies"
   J.K. O'Neil, D.J. Kinneberk, M.A. Viola

7. "Design Considerations and Operating Experience of the Stanford COM Test Facility"
   A.J. Kasprik, H. Causilla, P. Kartzke

8. "Planning for COM Conversion"
   A.F. Bavington, E.A. Kimel

9. "Commercial COM Operation, an Update"
   G.T. Hawkins

10. "Conversion of Oil-Fired Industrial Boilers to Coal-Liquid Mixtures"
    J.C. Blake, O.K. Foo, E.M. Jamgochian

11. "Full Scale Tests Firing Coal-Oil Mixtures in a 400 MW Steam Generator"
    A.D. Schmidt, J.L. Friedrich

12. "Performance Tests of Ultra-Fine Grind Coal-Oil Mixtures in a 150 H.P. Boiler"
    M.J. Rose, T.A. Butcher, E. Rogers, R. Dietz, R. McDonald

REFERENCES (Cont'd)

The following from:

Fourth International Symposium on
Coal Slurry Combustion
May 10-12, 1982, Orlando, Florida

13. "The U.S. Coal-Water Mixture Combustion Program"
C.B. Foster

14. "Conversion of the 120 MW Paul L. Barton Unit 1 to COM"
M.E. Higgins

15. "Commercial Production and Use of Coal-Oil Mixtures"
E. Knell, G. Short, D. Adams, T. Gresham, L. Dirickson

16. "Coal-Oil Mixture and Coal-Water Mixture Fuels for Steam Generators"
R.W. Borio, M.J. Hargrove

17. "Coaliquid Coal Slurry Fuel Program-1982"
G.T. Hawkins, T. Capes, M. Copple

18. "Coal and Oil Mixtures Marketing Project"
L.G. Hill, J.E. Mogk

19. "Power Plant Conversions to Coal, Coal-Oil Mixtures, and Coal-Water Slurries"
R.C. Furman

20. "The Fuel Use Act and Electric Utilities - An Update"
S.A. Frank, L.E. Farrar

The following from:

Proceedings of the Coal Water
Fuel Technology Workshop
March 19-20, 1981, Pittsburgh, Pennsylvania

21. "Coal-Water Fuel Technology: A Perspective"
Paul Marnell

22. "Coal-Water Fuel Development"
Charles B. Henderson

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REFERENCES (Cont'd)

Also the following individual reports:

23. Coal-Oil Mixture as a Utility Boiler Fuel
Volume I: Conversion Guidelines Handbook
EPRI CS-2309, March 1982

24. Coal-Water Slurry as a Utility Boiler Fuel
EPRI CS-2287, March 1982

25. Study of Conversion of Utility Oil-Fired Boilers to Dual Coal-Oil Firing Task II
Burns and Roe, Inc., December 1981

26. Coal-Oil Mixtures
E.A. Kimel, October 31, 1979
Burns and Roe, Inc.

27. Determination of Coal-Oil Mixture Stability
R.W. Kugel.

28. Combustion of Clean Coal-Water Slurry
A.K. Manfred, S. Ehrlich
American Power Conference, April 1982

29. Coal-Water Slurry as a Utility Boiler Fuel
R.K. Manfred, Draft Report

30. Evaluation of Mixing Equipment for NEPSCO Coal-Oil-Mixture Demonstration project S.K. Batra, S.Y. Tsai, J. Dasher and S. Jakatt

31. Exploratory Coal-Water and Coal-Methanol Mixture Combustion Tests in Oil Designed Boilers
Y.S. Pan, G.T. Bellas, R.B. Snedden, D.E. Wieczenski, J.I. Joubert
PETC, U.S. DOE

32. Recent Coal-Oil Mixture Combustion Tests at PETC
Y.S. Pan, G.T. Bellas, M.P. Mather, J.I. Joubert, D. Bienstock
PETC, June 1980

33. Coal-Oil Mixtures as Utility Boiler Fuels
A. Azarnoosh, R.K. Manfred, J.O. Siemssen

34. 1979 Goals Program
Goal No. IV-A-3 Survey of Present Technologies for Conversion to Coal of Oil-Fired Utility Boilers
E.A. Kimel, April 1980
Burns and Roe, Inc.

Annex II

Country Situations

November 1982

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1.0 SUMMARY: STUDY FINDINGS, PORTUGAL AND KENYA

1.1 Information Sources

This section is a summary of Portugal's and Kenya's energy requirements and energy sources. The information was obtained during interviews of government and industry representatives and visits to plants that consume fuel oil. Based on these interviews and visits, some concerns of these representatives of government and industry are identified here. Sections A and B present a more detailed view of the energy situation in each country as well as summaries of meetings and plant visits in Portugal and Kenya.

The paths to the adaptation of coal slurry fuel used in the developing countries, Portugal and Kenya, is expected to include many obstacles and barriers that will have to be removed or bypassed before the slurries can be considered viable alternatives to fuel oil.

1.2 Stages of Development

Portugal's gross domestic product (GDP) per capita in 1977 was $1,501. This compares with an average GDP for European countries of over $5,000. The per capita consumption of energy in Portugal is 908 KGOE (kilograms of oil equivalent), the lowest among European countries, except for Turkey.

Kenya's GDP per capita in 1979 was about $260, while commercial energy consumption in 1979 was 133 KGOE.

Based on these comparisons, Portugal is in a more advanced state of industrial development than is Kenya. Although there is a large difference in the state of development of the two countries, the issues and problems regarding transfer coal slurry fuel technology are very similar.

In both Portugal and Kenya, petroleum has served as the primary energy source for decades. In both countries, the only other major source of energy has been electricity from hydro power plants. Development and growth in Portugal and Kenya has been based largely on imported oil and hydro power. Coal has found an insignificant role in the energy sectors of both countries to date. As a result, a large infrastructure and social and political framework has built up in these countries based on imported oil and hydro power.

Nevertheless, similar developments have taken shape in both countries which have forced them to seek avenues by which oil imports can be reduced and protect each country against the effects of severe recent droughts.

Both Portugal and Kenya have recently suffered severe droughts for prolonged periods. Portugal had to import large amounts of electric power via its interconnection with Spain, at high cost, to replace the hydropower. In a normal year, net electric energy flows in the opposite direction. In Kenya, power had to be rationed during the drought, causing hardship and losses in industrial production. Portugal and Kenya have also suffered severely from the worldwide oil price increases.

Because of the pervasive effects of oil costs, many costs of exports have increased as oil prices have increased In addition, the prices for exports, on which Kenya and Portugal have depended to pay for the oil imports, such as refined petroleum products in both countries and coffee, tea, sisal in Kenya, have been depressed, making the incomes from exports insufficient to pay for oil imports. Because of the foreign trade deficit, imports essential to further development are curtailed and limited to those which meet immediate needs. High tariffs have been placed on imported equipment to limit these imports so that funds for crude oil will be available. Thus it is essential that Portugal and Kenya wean themselves of imported oil, so that economic growth can continue in these two countries.

1.3 Coal and Oil Based Fuels

Eighty-two percent of the energy used in Portugal and eighty-four percent of the energy used in Kenya is obtained from oil.

Coal is an obvious energy substitute for oil where coal supplies are found. It is not an obvious choice when it has to be imported. Kenya has no indigenous oil or coal supplie and imports coal for one of its cement plants. Portugal has one inefficient mine supplying poor quality coal to one power station, because the quantity is insufficent the coal is supplemented by oil. Portugal's known lignite reserves are small, of low quality and remain undeveloped.

In Portugal, a coal-fired power plant is being contructed at Sines and coal will have to be delivered to the site. Petrogal is consdering importing coal to Sines, the location of its modern refinery, to to Secavem. In either case, new harbor and coal handling and distributing facilities will be required.

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In Kenya, the ship unloading facilities at Mombasa, the only ocean port in the country, has coal handling capacity only to serve the cement plants. Plans to expand the port's capacity await government decision, participation and development of a firm market for coal. A coal-fired power plant is being considered for the year 1993 but such a plant is in competition for funds with additional hydro which some officials consider to be preferable for the country.

In both countries, therefore, major investments will be required to achieve a significant replacement of fuel oil by coal or coal slurry fuels. Capital for the investments will probably be more readily available in Portugal than in Kenya because the size of the assured market for coal is greater in Portugal.

1.3.1 Coal and Coal Slurries in Portugal

Portugal has identified a limited quantity of coal reserves in the country. Figure 1 is a map locating the anthracite coal and lignite deposits in Portugal. Table 1 lists the estimated reserves. The table indicates that the anthracite plus bituminous coal reserves are meager. The lignite reserves at Rio Maior are of very poor quality and are not being developed.

Coal from the Pejao mine is dedicated to one power generating station, Tapada do Outeiro, and is transported by tram directly from mine to plant. The Pejao mine is the only one presently in production.

Table 2 lists the source and amounts of coal imported in 1980. The U.S. is the main supplier of metallurgical coal. The next largest supplier in the table is Poland, but this supply has been cut off due to Poland's current political and economic problems. Imports from Spain and other European countries have increased to compensate for loss of this supply.

The major coal users are listed in Table 3. The total consumption in 1980 was 575,578 metric tons. Projections of future coal requirements will increase coal imports to 2,600,000 metric tons by 1985 and 6,500,000 metric tons by 1990. The increases in demand are due to the planned expansion of steel production, conversion and expansion of cement plants and construction of new coal-fired thermal electric generating stations. A large portion of the additional coal imports is likely to come from the United States.

Figure 1 Coal deposits of Portugal.

Table 1

Portugal

Domestic and Imported Coal Supplies

Location	Estimated reserves (10^6T)	
	Anthracite and Bituminous	Lignite
Pejão *	5	
Cabo Mondego	5	
Palhagueira		
Casal do Negrelho		5
Guimarota		1
Rio Maior		37
	10	43

(*) - The only one presently producing.

1980 production - 1,778,451 T

Table 2

Portugal

Imported supplies 1980 (steam coal + metallurgical coal)

Europe	St.Coal+M.Coal	Anthracite
Belgium	7,781	
Netherlands		1,438
West Germany	937	18
France	8	
U.K.	1,660	
Poland	120,379	
Spain		23
S. Africa		3,454
USA	255,451	
Others	7,043	
	393,259	4,933

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Table 3

Major Consumers of Coal (1980)

Plant	Metric Tons
Tapada do Outeiro Power Plant	212,471
Siderurgia (Steel Plant)	306,864
Metallurgical plants	51,288
Textile plants	2,025
Food	2,400
Ceramic	530
Total	575,578

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The cement industry in Portugal is committed to convert its kilns entirely to coal insofar as it is technically feasible. Many kilns now burning fuel oil were originally designed for coal, which will help to ease the conversion.

Electricidade de Portugal's (EDP's) present generating system includes only hydro and oil-firing units. Table 4 lists the present operating units as well as planned future stations and units. The table shows that after 1985, new thermal units will be coal-fired. EDP investigated whether or not the oil-fired units at Setubal, due in 1982 and 1983, could be converted to coal before they were completed. EDP concluded that it was not feasible in view of the large derating that would be required to operate the units reliably on coal.

In view of the very large increase in coal imports that is planned for the next five and ten years, major investments will be required in physical facilities and structures. Harbor facilities for unloading ships and barges are limited. Table 5 lists the maximum tonnage that can be handled at Portuguese ports where coal is presently delivered. New harbor facilities for unloading coal ships and barges will be required. At present, to unload coal near Lisbon requires that the coal be transferred from ships in mid-river, first to barges and then, from the barges, to in-plant conveyors.

Petrogal, the government oil refining and distributing company, is considering becoming the coal supplier as well as the oil supplier. Petrogal has surveyed industry to ascertain the potential market and where a coal depot might best be located. A depot near Sines, in or near the oil refinery property, would be a logical location to serve the planned four 300 MW coal-fired power units at Sines. A second location would be at Sacavem, up the Tajo River from Lisbon. This latter location would be near the load center of the cement industry and the existing distribution facilities serving industry north of Lisbon. If Petrogal does not construct a coal facility at Sines, EDP will have to construct facilities to supply the planned coal fired plants.

Petrogal also is considering producing and distributing coal slurry fuels, as part of its coal supply facilities, if a market can be developed to justify the investment required. A coal slurry production facility requires access to oil and coal supplies and to a distribution network.

Petrogal surveyed industries, other than the power plants, to estimate the potential market for coal slurry fuels. Table 6 lists the industries that responded to

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Table 4

Existing and Planned Thermal Station, 1981

Station	Set	Year Comissioned	Capacity (MW)	Type a)	Production GWh/year
Existing:					
Tapada Outeiro	1	1960	50.0	C/O	350.0
	2	1964	50.0	C/O	350.0
	3	1967	50.0	C/O	350.0
Carregado	1	1968	125.0	O	875.0
	2	1969	125.0	O	875.0
	3	1974	125.0	O	875.0
	4	1974	125.0	O	875.0
	5	1976	125.0	O	875.0
	6	1976	125.0	O	875.0
Barreiro	1	1978	32.0	O	245.0
	2	1978	33.0	O	245.0
Setúbal	1	1979	250.0	O	1 750.0
	2	1980	250.0	O	1 750.0
Alto de Mira	1	1975	22.0	G	75.0
	2	1975	22.0	G	75.0
	3	1976	22.0	G	75.0
	4	1976	22.0	G	75.0
	5	1976	22.0	G	75.0
	6	1977	22.0	G	75.0
Tunes	1	1973	16.0	G	58.0
	2	1973	16.0	G	58.0
Planned:					
Setúbal	3	1982	250.0	O	1 750.0
	4	1983	250.0	O	1 750.0

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Table 4 (Cont'd)

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Station	Set	Year Comissioned	Capacity (MW)	Type a)	Production GWh/year
Sines	1	1985	300.0	C	2 100
	2	1986	300.0	C	2 100
	3	1987	300.0	C	2 100
	4	1988	300.0	C	2 100
Tunes	3	1982	83.3	G	290
	4	1982	83.3	G	290
North	1	1989	300	C	1 840
	2	1990	300	C	1 840
	3	1992	600	C	3 680
	4	1994	600	C	3 680
TOTAL EXISTING: 1629 MW (Capacity)					10 856 GWh/year (production)
TOTAL PLANED : 3587 MW (Capacity)					23 520 GWh/year (production)

a) Fuel Type: G (Gas turbine); O (Oil); C (Coal).

Table 5

Coal Harbor Capacities

Location	TDW
Lisboa	40-50,000
Leixoes	40,000
Setubal	20,000
Figueira da Foz	1,000

Table 6

Portugal

Industrial Boilers

A. Paper Industry

Inapa

1 - 25,000 kg/hr	70 kg/cm^2	water tube
2 - 35,000 kg/hr	17.5 kg/cm^2	water tube
1 - 12,000 kg/hr	10.0 kg/cm^2	fire tube

Portucel

Setubal

3 water tube boilers

Fuel oil consumed in 1980: 37,641 tonnes

North Portugal - Aveiro

4 water tube boilers

Fuel oil consumed in 1980 55,000 tonnes

B. Chemical Industry

Soda Poroa (near Lisbon): Pora de Santa Iria

2 water tube boilers	33 kg/cm^2	43,000 kg/hr
1 water tube boiler	33 kg/cm^2	27,000 kg/hr

Consumption 40,000 tonnes in 1980

C. Food and Beverage

Central CER (Vialonga)

3 water tube boilers

1 - 14 kg/cm^2	40 tonnes/hr
1 - 17.5 kg/cm^2	32 tonnes/hr
1 - 17.5 kg/cm^2	32 tonnes/hr

Consumption 15,000 tonnes/year in 1980

D. Edible Oils

Macedo & Coelho (Alhandra)

2 water tube boilers

1 - 30 kg/cm^2	7 tonnes/hr
1 - 30 kg/cm^2	10 tonnes/hr

2 fire tube boilers

1 - 14 kg/cm^2	9 tonnes/hr
1 - 17.5 kg/cm^2	4 tonnes/hr

4,000 tonnes/year oil usage in 1980

E. Margarine

Fima (Santa Iria de Azoia)

2 fire tube boilers

1 - 15 kg/cm^2	7,200 kg/hr
1 - 17.5 kg/cm^2	15,000 kg/hr

Usage 4,312 tonnes in 1980

F. Sugar Refinery

Sores (Santa Iria de Azoia)

No information on boilers

For steam production uses 12,940 tonnes in 1980

G. Chemical Industry (Fertilizer)

Quimigal - Alverca

3 water tube boilers

1 - 21 kg/cm^2	20,000 kg/hr
1 - 21 kg/cm^2	20,000 kg/hr
1 - 27 kg/cm^2	25,000 kg/hr

Total 1980 consumption: 9,500 tonnes

H. No textiles near Lisbon - small boilers

Copper

COPAM (Sacavem)

Consumption in 1980: 3,818 tonnes for steam generation

No information on boiler conditions

Medicine

CIPAN (Corregado)

3 water tube boilers

2 - 20 kg/cm^2	4 tonnes/hr
1 - 12 kg/cm^2	10 tonnes/hr

Consumption in 1980: 3,814 tonnes

I. Food Industry (oils)

Tagol (Almada)

2 water tube boilers

1 - 12 kg/cm^2	10 tonnes/hr
1 - 12 kg/cm^2	14 tonnes/hr

Fuel consumption in 1980: 4,134 tonnes

Petrogal's inquiry. It indicates that the listed industries burned over 185,000 metric tons of fuel oil in 1980, some of which might be candidates for conversion to coal slurry fuels.

EDP is in the process of investigating the feasibility of converting its oil-fired units at the Carregado and Setubal stations to coal slurry firing. Foster Wheeler Corp. in New Jersey has submitted a proposal to evaluate the conversion of one 125 MW unit at Carregado. If the investigation is conducted, the findings may be available the latter part of 1982. The 125 MW thermal units use about 1,380,000 metric tons of fuel oil per year. If COM were substituted for oil, oil consumption would be reduced by at least 500,000 metric tons per year.

It is apparent that the potential for adaptation of the coal slurry technology to industry in Portugal is good, should the large cost differential between coal and oil persist during the next half dozen years. Portugal's national energy policy favors conversion to coal and coal slurry fuels. The fact that EDP, the largest industrial oil consumer in the country, is seriously considering adapting coal slurry technology to oil-fired generating units is indicative of the potential of coal slurry fuels. As a coal infrastructure will be developed independently of the application of coal slurry technology, production and distribution of coal slurries will not require as large capital investments as might otherwise be required. Once the supply of coal slurry fuels is assured and their costs established on a commercial basis, smaller industries (such as those listed in Table 6) will be in a position to realistically consider substituting coal slurry fuels for fuel oil. It is expected that the substitute fuel will be accepted if industries are shown that it is technically feasible to convert, that production and reliability of a plant will not be adversely affected and that production costs will be reduced

1.3.2 Coal and Coal Slurries in Kenya

Kenya does not have any indigenous coal reserves. Consumption of coal and coke fell sharply from 44,900 metric tons oil equivalent in 1976 to 16,900 metric tons oil equivalent in 1980. Coal and coke comprised only 1 percent of energy usage in 1980.

Coal is imported from Swaziland, primarily for use in the Bamburi cement plant in Mombasa. Additional cement kilns at this plant will be designed to use coal. The facilities for delivering and unloading coal at Mombasa

harbor are owned by the Bamburi Portland Cement Co. and are adequate to serve only the requirements of this plant. Additional harbor facilities will have to be constructed to handle any significant increase in coal imports.

The East African Portland Cement Co. plant near Nairobi, now primarily oil-fired, is also considering converting to coal. Coal for the plant will have to be transshipped from Mombasa by rail. The cost of transportation and technical problems with the compatibility of the coal and process requirements have slowed the actual conversion. In addition to harbor facilities, bulk storage, rolling stock and a distribution network need to be established for coal in Kenya. Before major expenditures for these facilities are made, a market for the material has to be assured. The only significant coal consumer at present is the cement plant at Mombasa requiring about 180,000 metric tons per coal per year. No market for coal slurry fuels exists at present, though such a market, however, could be developed within the industrial sector.

Although the transfer and application of coal slurry technology has not reached the stage of actual consideration for a specific project or has aroused the same degree of interest found in Portugal, the technology may be even more applicable in Kenya. There is no infrastructure for coal in Kenya as there is in Portugal. Due to lack of available funds for investment and because the investment requirements for coal slurry production and conversion are modest compared to those required for conversion to coal or to build coal firing facilities; the climate may be more favorable for coal slurry conversion than direct conversion to coal.

A likely scenario for the adaptation of coal slurry technology would include providing harbor facilities at Mombasa for delivery of imported coal, a production facility in Mombasa and fuel delivery via the existing rail and road facilities to Nairobi and industries in the western part of the country. Shell Kenya, Ltd.'s present oil storage facilities are located near the Mombasa harbor thus providing the oil supply for a production plant. Because the situation is similar to that in Portugal, Shell Kenya would probably consider supplying coal and constructing a coal slurry production plant, provided of course that economic incentive exists.

1.4 Oil Refinery Capacity Problems

Petroleum and its derivatives provide more than 80 percent of total energy needs of both Portugal and Kenya.

Major industrial oil users in Portugal are listed in Table 7. Portugal's refinery capacity, 20,000,000 metric tons per year is 8,000,000 tons in excess of its present requirements. The Sines refinery, a modern refinery, is operating at 60 percent capacity, while the other refineries are operating well below this level. The Porto refinery will be phased out when the Sines refinery is fully developed.

Table 7

Portugal

Major Industrial Oil Users (1980)

Industry	Metric Tons
Cement	513,433
EDP	1,388,000
Paper	190,000
Textile	180,000
Chemical	130,000

Table 8 lists the ten largest heavy oil customers of Shell Kenya, their recent annual consumption and projected future demand. The total demand of approximately 300,000 metric tons per year in 1981 is expected to remain constant, or even decrease by about 5 percent in the next two years. The decrease would be due to conservation and expectation of normal rainfall so that hydropower generation returns to normal levels causing reduction in generation by thermal power plants. The East African Refinery in Mombasa is operating at 60 percent of capacity.

Both Portugal and Kenya have excess refinery capacity. Crude oil throughput is based on meeting the demand for light distillates, thus the resulting heavy fraction produced is in excess of domestic needs. This excess must be exported. The market and price conditions for this excess are presently unfavorable. There are, therefore, pressures for the fuel oil consumers to continue to use the fuel. These consumers, such as the thermal power plants that burn

Table 8 (Cont'd)

Fuel Oil Consumption in Kenya

CUSTOMER	TYPE OF PLANT	ANNUAL CONSUMPTION (M.TONS)	APPLICATION	PROJECTION OF FUTURE CONSUMPTION (M.TONS)	COMMENTS
E.A. Power & Lighting	Power generation	110,000	Steam generation	Decrease of about 5 to 10% per year to 1984	Estimated consumption for 1982 and 1983 is 105,000 & 92,000 metric tons respectively.
Bamburi Portland Cement	Cement manufacturing	62,000	furnace/high temperature application	Target of approx 9,500 M.Tons in 1984	Estimated consumption for 1982 and 1983 is 59,000 & 14,000 metric tons respectively.
E.A. Portland Cement	Cement Manufacturing	35,000	furnace/high temperature application	Could achieve 43,000 M.tons by 1984	Estimated consumption for 1982 and 1983 is 36,000 and 40,000 M.Tons respectively.
Magadi Soda	Manufacture of Soda ash	10,000	furnace/high temperature application	could achieve 14,000 M.Tons by 1984	Estimated consumption for 1982 and 1983 is 11,000 and 13,000 M.tons respectively.
Kenya Railways	Steam for automotive purposes	11,000	steam generation	declining	Estimated consumption for 1982 and 1983 is 9400 and 500 M.tons respectively.
Pan Paper Mills	Manufacture of pulp/ paper	45,000	Steam generation	Increasing	t is estimated they could achieve 47,000 M.tons in 1983, with a target of 60,000 M.tons when they start producing news print paper in 1984/ 1985.
Kenya Canners	Manufacture of canned fruit	4,700	Steam generation		-

Table 8 (Cont'd)

Fuel Oil Consumption in Kenya (continued)

CUSTOMER	TYPE OF PLANT	ANNUAL CONSUMPTION (M.TONS)	APPLICATION	PROJECTION OF FUTURE CONSUMPTION (M.TONS)	COMMENTS
Kenya Breweries	Manufacture/bottling of beer	11,000	Steam generation	possible growth of 1 to 2% p.a. during 1982 and 1983.	Estimated consumption for 1982 and 1983 is 15,500 and 16,000 M.tons respectively.
Kenya Cooperative Creameries	Milk Processing	6,000 (total) 2,300 (Nbi Plant)	Steam generation		-
Rivatex	Textile	4,500	Steam generation		-
		299,401			282,900

*We do not have adequate information on these customers. These are in agriculture/husbandry-cum-manufacturing sectors. However, it can be forecast that there will be restrained growth during 1982 and 1983, with a possible annual average increase in GDP of 2 to 4% for the economy as a whole. If these sectors (agriculture-husbandry-manufacturing) are assumed to grow at the same rate, growth in consumption of energy (at this low growth of GDP) can be assumed to be approximately of the same level of magnitude.

21.1.1982

residual fuel oil, are not considering reducing consumption by substituting coal or coal-based fuels. There are no pressures to convert to coal-based fuels because it would only increase the excess of the heavy fractions and aggravate present problems. This problem is greater in Kenya than in Portugal because the modern Sines refinery does have the capability of changing its process yield to favor the lighter fractions. To do the same, Kenya would have to add a cracking unit at a cost of about $100,000,000. Because coal has to be imported and residual oil does not, residual oil is currently cheaper to burn than coal. In addition, the price of domestic residual oil is government controlled, which creates an artificial incentive to continue oil use, which would not exist if world oil prices prevailed.

From the long-term view, however, Kenya's officials see a future need for developing and applying oil-substitute fuels such as coal based reserves.

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A. PORTUGAL

1.0 ENERGY SECTOR - FACTS AND FIGURES

1.1 Energy Policies and Goals

After the nationalization of 1975, several energy supply enterprises were established and placed under the administrative purview of the Ministry of Industry and Technology. The Electricidade de Portugal (EDP) controls electric power development. Petrogal is the only domestic company permitted to engage in oil exploration, refining and distribution. The Empresa Nacional de Urano (ENU) is in charge of uranium development, processing and marketing. Both domestic and foreign companies interested in energy development operate in Portugal.

Table 2A-1 lists the coal and coke, petroleum-based fuel, electricity and non-commercial fuels in 1977 by various sectors of the economy.

Petroleum and its derivatives meet more than 80 percent of Portugal's total energy needs. One of Portugal's immediate goals is to explore for and exploit indigenous resources to reduce its dependence on imported petroleum. To this end, foreign participation in exploration, particularly oil, is encouraged. Abundant hydro power resources exist and are being developed. Thermal generating stations are also being constructed in view of recent experience with back-to-back drought years, which limited hydro power output.

Portugal is experiencing the same economic problems as western Europe and non-OPEC nations throughout the world, high inflation, balance of payment deficits, increasing external debts and unemployment.

1.2 Oil and Natural Gas

No indigenous deposits of petroleum and natural gas have been found in Portugal. Off shore exploration for oil and gas is being promoted.

In 1977, 7.43 million tons of oil were imported, 6.19 million tons of crude and 1.24 million tons of refined products. Eighty-four percent was used for domestic consumption, 12.9 percent was exported and 3.2 percent used to replenish stock. Table 2A-2 indicates the movement of oil in and out of the country.

The market for refined oil is served primarily by Petrogal. Mobil and Shell each have been allocated 20 percent of market and BP has 5 percent. Thermal power plants consume 1,338,000 metric tons per year of fuel oil. The steel plant uses 60,000 metric tons of oil per year.

Table 2A-1

Energy Demand Summary for 1977

Units: TEP unless otherwise indicated
1 TEP = 10^7 Kcal

	COAL AND COKE				TOTAL MANUF. GAS	PETROLEUM-BASED FUELS					NON-COMMERCIAL FUELS				PURCHASED ELECTRICITY		TOTAL	Self-Gen Electricity	
	Imported Hard Coal	Domestic Coal	Coke and Briquettes	TOTAL		Propane -LPG	Fuel Oil	Gasolin Kero, diesel	Gasoline & Other	TOTAL	Wood	Charcoal	Other Residues	TOTAL	10^6 KWH	TEP		10^6 KWH	TEP
AGRICULTURE	-	-	-	-	-	2902	5719	277243	216	286080	7000	-	-	7000	79.3	6821	299901	-	-
FISHING	-	-	-	-	-	-	18209	79334	25	97568	-	-	-	-	-	-	97568	-	-
SUBTOTALS	-	-	-	-	-	2902	23928	356577	241	383648	7000	-	-	7000	79.3	6821	397469	-	-
MINING INDUSTRIES																			
COAL MINING	-	-	-	-	-	88	-	-	-	88	-	-	80	80	6.3	543	711	-	-
OTHERS	-	-	-	-	-	81	1498	6345	8	7932	2016	-	232	2248	80.0	6879	17059	5.2	451
SUBTOTALS	-	-	-	-	-	169	1498	6345	8	8020	2016	-	312	2328	86.3	7422	17770	5.2	451
MANUFACTURING IND.																			
FOOD	2776	-	34	2810	-	11597	142062	15150	444	169253	94937	3640	4907	103484	454.1	39048	314595	6.9	595
TEXTILES	1120	275	-	1395	-	2966	180857	1548	34	185405	14926	-	119	15045	895.9	77050	278895	24.5	2105
PAPER	-	-	-	-	-	782	237086	3116	61	241045	11001	-	34066	45067	198.7	17087	303199	408.7	35150
CHEMICALS	1351	-	21247	22598	-	1341	140181	2971	415	144908	14244	-	2508	16752	1013.2	87133	271391	17.6	1513
CERAMICS	743	-	-	743	-	32661	95793	4060	57	132571	181157	5460	19239	205856	206.0	17718	356885	.1	0
GLASS	-	-	-	-	-	19048	62552	3575	90	85265	4197	-	-	4197	129.2	11113	100575	0.2	18
CEMENT	-	9126	-	9126	-	542	477279	7698	54	486174	4555	-	1	4556	578.0	49706	549562	-	-
NON-FERROUS METALS	19483	-	52512	71995	-	4469	9115	1395	14	14993	93	100	10	203	767.1	65972	153163	4.1	354
IRON & STEEL	-	-	154056	154056	13200*	4639	25103	1573	56	31371	5904	810	4	6718	174.2	14980	220325	44.9	3862
OTHERS	647	-	1205	1852	2688	22553	267254	23781	1638	315226	45139	4550	3752	53441	1418.9	122029	495236	6.5	561
SUBTOTALS	26120	9401	229054	264575	15888	100599	1637882	64867	2863	1806211	376153	14560	64606	455319	5833.3	501836	3043829	513.5	44159
WATER SUPPLY	-	-	-	-	-	-	29	132	109	270	-	-	-	-	208.2	17902	18172	-	-
CONSTRUCTION	-	-	-	-	-	774	6034	59655	1334	67797	-	-	-	-	52.6	4523	72320	-	-
SERVICES	4496	178	3026	7700	12054	12560	46682	112451	52822	224515	-	-	-	-	1481.7	127424	371693	-	-
SUBTOTALS	4496	178	3026	7700	12054	13334	52745	172238	54265	292582	-	-	-	-	1742.5	149849	462185	-	-
TRANSPORTATION																			
AIR	-	-	-	-	-	-	-	524956	1261	526217	-	-	-	-	-	-	526217	-	-
SEA	-	-	-	-	-	-	432117	124989	123	557229	-	-	-	-	-	-	557229	-	-
RAIL	12732	-	307	13039	-	-	728	54277	-	55005	-	-	-	-	231.5	19908	87952	-	-
ROAD	-	-	-	-	-	-	-	709824	761519	1471343	-	-	-	-	-	-	1471343	-	-
SUBTOTALS	12732	-	307	13039	-	-	432845	1414046	762903	2609794	-	-	-	-	231.5	19908	2642741	-	-
DOMESTIC RESIDENTIAL	1960	-	-	1960	42504	398462	1032	44604	-	444098	143500	3640	-	147140	2765.9	237866	873568	-	-
TOTALS	45308	9579	232387	287274	70446	515466	2149930	2058677	820280	5544353	528669	18200	64918	611787	10740.7	923702	7437562	518.7	44610

*Coke oven gas.
All other manufactured

Table 2A-2

Movement of Oil Products in Portugal (1977)
(Tons 10^6)

ACTIVITY	Imports			Exports	Bancas e Aviacao (1)	Domestic Consumption (2)	Stocks e Acertos	Totals
	Petroleo bruto	Refined	Sum Total					
ENTERS								
t	6.19	1.24	7.43	-	-	-	-	7.43
%	83.3	16.7	100.0	-	-	-	-	100.0
LEAVES								
t	-	-	-	0.04	0.92	6.23	0.24	7.43
%	-	-	-	0.5	12.4	83.9	3.2	100.0

(1) Includes foreign aviation

(2) Includes sales to domestic aviation, and losses and consumption in the refineries.

Source: Sintese Anual, Supplement 1977

Fuel oil prices are government controlled and, at present, fuel oil is sold below production costs ($200 per metric ton); middle distillates are sold at cost. It is expected that these will change to more closely reflect the cost of production.

Portugal has adequate refinery capacity, nearly 20,000,000 tons per year, more than 8,000,000 tons in excess of present requirements.

The Cabo Ruivo refinery near Lisbon has a capacity of 2 million metric tons per year. The Porto refinery has a current capacity of 7.5 million metric tons per year. The size of the handling equipment limits shipments to Porto to 4 million metric tons per year. Porto is scheduled to close when the Sines refinery reaches its planned capacity. The Sines refinery is a modern, fully automated plant and can process most Middle Eastern crudes.

Portugal does not have any long-term oil suppliers, and one of its major concerns is to ensure a supply of crude oil for its refineries. Suppliers in 1977 are listed in Table 2A-3.

Portugal plans to diversify its crude oil supply to reduce its vulnerability to supply interruptions. Additional suppliers like Mexico, Venezuela, Nigeria and Abu Dhubai are possible.

1.3 Coal

Portugal's coal reserves are scant, consisting of approximately 15,000,000 metric tons of poor quality anthracite (4100 kcal/kg) and between 27 and 33 million tonnes of lignite (1300-1750 kcal/kg). Figure 2A-1 shows the location of the coal fields, the largest anthracite field (50%) is at Pejao, more than one third is at San Pedro de Core, and the rest is at Cabo Mondego. Lignite is located at Rio Maior near Santaren.

In Table 2A-4 Portugal's annual production and imports of coal from 1960 through 1978 are listed. Portugal's coal production is limited to use for steam production at the Tapada de Outiero power station. The Pejao mine is the only operating mine run by Empresa Cardifera de Douro (ECD). The coal supplies about one-third of Outiero's fuel needs; the remaining two-thirds is met by fuel oil. About 10 percent of total coal output is allocated to nearby lime and textile factories. Pejao mine coal is transported by aerial tramway to the Tapada de Outiero plant and by truck to other users.

Portuguese coal imports have fluctuated between 400,000 and 550,000 metric tons, primarily metallurgical and steam coal. Most imported coal is unloaded in Lisbon and shipped directly to the steel works, while remaining coal is trucked to other users. The steel company, Siderurgia National (SN) imports nearly two-

Table 2A-3

Oil Imports by Country

SAUDI ARABIA		
Arabian Light	1,609,902 t	26.0%
IRAN		
Gash Saram	108,804 t	1.7%
Iranian Heavy	663,918 t	10.7%
Iranian Light	408,975 t	6.6%
IRAQ		
Basrah Light	1,659,438 t	26.8%
Basrah Medium	390,870 t	6.3%
Kirkuk	136,444 t	2.2%
KUWAIT		
Kuwait	53,501 t	0.9%
OMAN		
Oman	158,763 t	2.6%
EUROPE		
Soviet Union		
Romachkino-Ural	1,000,621 t	16.2%
TOTAL	6,191,236 t	100.0%

Source: Sintese Annual, Supplement 1977

Figure 2A-1

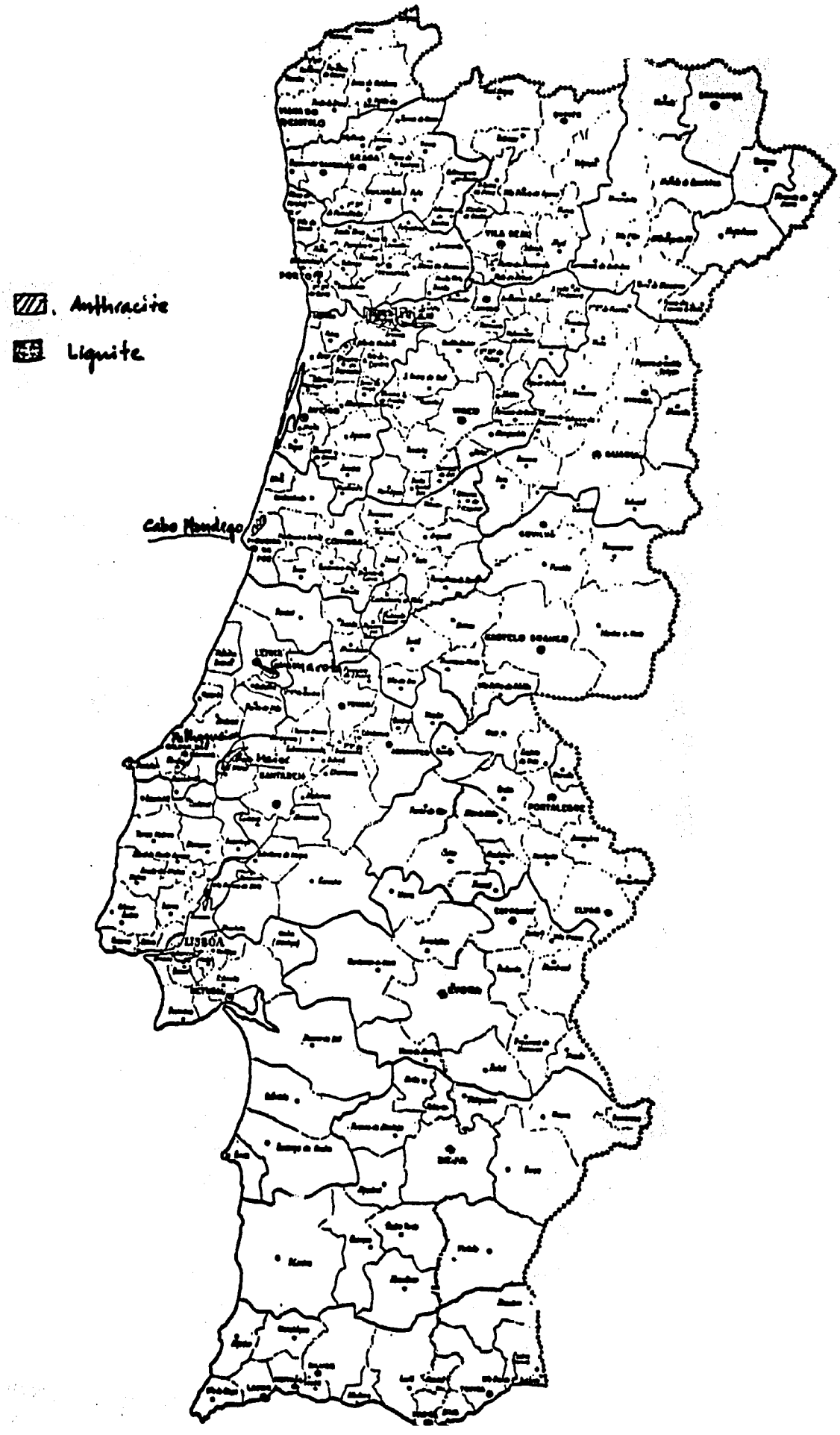


Table 2A-4

Portugal Coal Production and Imports

(1000 metric tons)

Year	Other Mines	Pejao	Domestic Production	Imports
1960	143	292	435	392
1961	143	327	470	563
1962	134	271	405	557
1963	135	281	416	667
1964	137	307	444	650
1965	123	304	427	670
1966	109	311	420	728
1967	109	333	442	696
1968	94	303	397	605
1969	83	274	360	678
1970	26	243	271	835
1971	16	237	253	411
1972	8	244	252	509
1973	-	221	221	467
1974	-	230	230	417
1975	-	221	221	429
1976	-	193	193	NA
1977	-	195	195	NA
1978	-	180	180	548

thirds of all coal imported and 90 percent of all metallurgical coal.

SN is the largest coal user, 52 percent of domestic consumption. EDP uses 25 percent. Smaller users include lime, textile and metallurgical industries.

The cement industry is converting from oil to coal. For a complete switch to coal, demand for coal would increase by one million metric tons. In addition, a coal-fired power plant is being constructed at Sines for about 1985, so that coal requirements by 1987 would be 3,500,000 metric tons per year.

Regulated coal prices and competition from heavily subsidized fuel oil has contributed to lack of development of the coal industry, which leaves little incentive to switch from oil to coal. A comparison of 1978 prices for coal and oil is shown in Table 2A-5.

Table 2A-5

Unit Costs for Coals and Fuels

Type	Weight Price	Energy Price
	$/metric ton	$\$10^6$ BTU
Domestic coal (regulated price)	31	1.55-1.92
Imported coal (SN)	60-70	2.04-2.54
Imported coal (others)	80-110	2.72-4.00
Subsidized Fuel Oil	110	2.76
Unsubsidized Fuel Oil	176	4.42

Since 1974 there has not been an oil to coal switch in Portugal due to the weakness of the domestic coal industry and subsidized oil prices.

There are no economic incentives under present price conditions to switch from oil to coal because current fuel oil prices contain a $66 per ton subsidy, yet, on a world market price basis, coal is more economically attractive than fuel oil by at least 10 percent. To counter this, the Pejao coal price has been equated to the market subsidized price of fuel oil.

1.4 Electricity

Electricidade de Portugal (EDP) provides about 97 percent of total electrical energy generated in Portugal, corresponding to about 15 x 10^9 kWh per year and about 70 percent of the electric energy distribution. The facilities now in small distribution systems are being integrated into the national grid.

Power generation is by 44 hydro plants with a total installed capacity of about 2268 MW and 19 thermal units with an installed capacity of 3900 MW. Annual mean energy capability of the hydro units is 9562 gWh. The thermal plant capacity will be 3100 MW with the completion of the oil-fired Setubal Units 3 and 4 in 1983, two coal-fired units at Sines in 1984-85 and two 334 MW gas turbines in 1982. Table 2A-6 lists the existing and planned thermal stations as of 1981. Table 2A-7 lists the hydroelectric plants in operation and those planned.

The system has low power reserve at present and has had to import large amounts of electricity from Spain and France because of recent drought conditions. To remedy the low system reserve, studies are underway for new hydro stations, a third and fourth coal-fired unit at Sines, a new coal station at Viana do Castilo harbor, close to Figuera da Foz and Lisbon, a gas turbine facility near Matosinhos, a Rio Maior station to exploit the lignite at Rio Maior and for the first nuclear power station.

The EDP transmission grid, with a 1981 installed capacity of 6,860 kVa runs from north to south of the country and includes 60,150,220 and 400 kV lines. The transmission grid is controlled from a Control Center in Lisbon. A new modern control center for generation and transmission management is planned. Figure 2A-2 is a map of EDP's generation, transmission and interconnection grid.

EDP is interconnected to the international European transmission grid through Spain via 220 and 440 kV lines. A program of rural electrification was adopted in 1977. Load management based on lower costs for consumption at off-peak hours and cut-off of some appliances at peak load hours.

At start of 1981, EDP employed 620 engineering graduates, 233 other university graduates, and 402 technical engineers. Total number of employees amounted to 18,345. EDP has several professional training departments throughout the country.

1.5 Non-Energy Consumption of Oil Products

Crude oil is an important source of industrial raw materials in addition to its primary use as a fuel. Although these raw material applications are strictly speaking outside the scope of an energy demand study, some attention is considered justified as

Table 2A-6

Existing and Planned Thermal Station, 1981

Station	Set	Year comissioned	Capacity (MW)	Type a)	Production GWh/year
Existing:					
Tapada Outeiro	1	1960	50.0	C/O	350.0
	2	1964	50.0	C/O	350.0
	3	1967	50.0	C/O	350.0
Carregado	1	1968	125.0	O	875.0
	2	1969	125.0	O	875.0
	3	1974	125.0	O	875.0
	4	1974	125.0	O	875.0
	5	1976	125.0	O	875.0
	6	1976	125.0	O	875.0
Barreiro	1	1978	32.0	O	245.0
	2	1978	33.0	O	245.0
Setúbal	1	1979	250.0	O	750.0
	2	1980	250.0	O	750.0
Alto de Mira	1	1975	22.0	G	75.0
	2	1975	22.0	G	75.0
	3	1976	22.0	G	75.0
	4	1976	22.0	G	75.0
	5	1976	22.0	G	75.0
	6	1977	22.0	G	75.0
Tunes	1	1973	16.0	G	58.0
	2	1973	16.0	G	58.0
Planned:					
Setúbal	3	1982	250.0	O	1 750.0
	4	1983	250.0	O	1 750.0

Table 2A-6

2

Station	Set	Year Comissioned	Capacity (MW)	Type a)	Production GWh/year
Sines	1	1985	300.0	C	2 100
	2	1986	300.0	C	2 100
	3	1987	300.0	C	2 100
	4	1988	300.0	C	2 100
Tunes	3	1982	83.3	G	290
	4	1982	83.3	G	290
North	1	1989	300	C	1 840
	2	1990	300	C	1 840
	3	1992	600	C	3 680
	4	1994	600	C	3 680
TOTAL EXISTING: 1629 MW (Capacity)				10 856 GWh/year (production)	
TOTAL PLANED : 3587 MW (Capacity)				23 520 GWh/year (production)	

a) Fuel Type: G (Gas turbine); O (Oil); C (Coal).

Table 2A-7

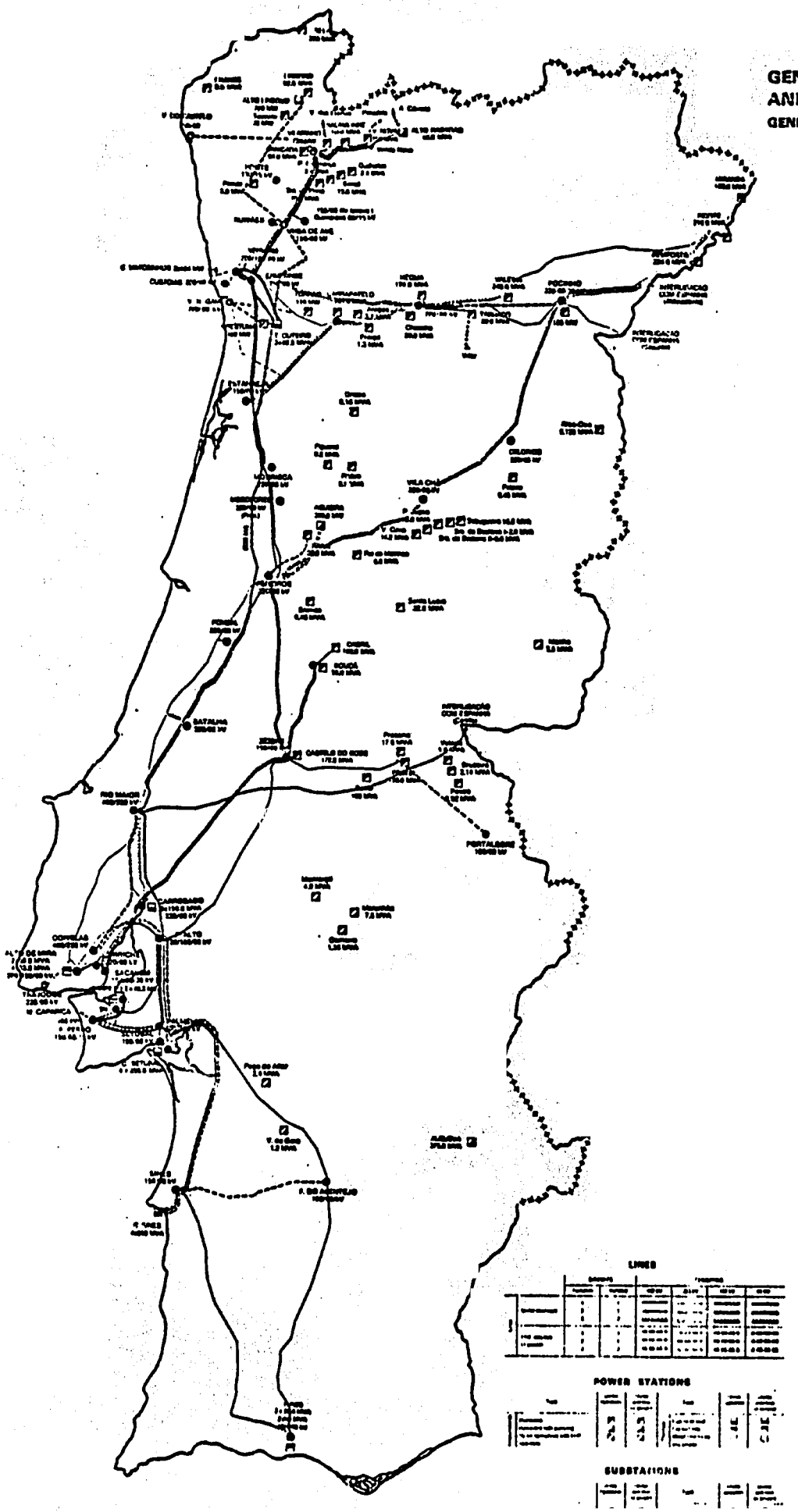
Hydroelectric Plants in Operation and Firmly Planned

PLANT	RIVER	YEAR COMMISSIONED	INSTALLED CAPACITY MW	AVERAGE YEAR PRODUCTION GWh	TYPE OF PLANT[a]
Venda Nova	Cavado	1951	81	360	S
Castelo do Bode	Zezere (Tejo)	1951	139	470	S
Salamonde	Cavado	1953	42	220	S
Cabril	Zezere (Tejo)	1954	97	355	S
Canicada	Cavado	1955	60	335	S
Bouca	Zezere (Tejo)	1955	50	190	S
Paradela	Cavado	1956	56	225	S
Picote	Douro	1958	180	,045	ROR
Miranda	Douro	1960	174	890	ROR
Bempasta	Douro	1964	210	1,100	ROR
Alto Rabagao	Cavado	1964	72	115	S
Tabuaco	Tavora (Douro)	1965	64	155	S
Carrapatelo	Douro	1971	180	1,005	ROR
Regua	Doura	1973	156	745	ROR
Vilarinho das Furnas	Cavado	1973	64	190	S
Fratel 1	Tejo	1974	43	430	ROR
Other Hydro[b]	--	--	167	460	--
Fratel 2/3	Tejo	1975	86	--	ROR
Valeira	Douro	1975/76	216	850	ROR
Aquieira	Mondego	1978/79	300	240	ROR
Raiva	Mondego	1979	18	40	ROR
Pocinho	Douro	1980/81	192	550	ROR
Crestuma	Douro	1982	126	370	ROR
Cavado Additions[c]	Cavado	1983	410	--	S
Alqueva	Guadiana	1984	300[d]	470[e]	S
Future Hydro	Minho and Lima[f]	1986	295	250	--

[a]S (storage), ROR (run-of-river).
[b]Plants in operation as of mid 1970s.
[c]Includes increasing capacities at Vilarinho das Furnas (80 MW) and Salamonde (90 MW).
[d]The second stage will involve three additional 100 MW units.
[e]Irrigation operation will cause production to decrease to about 350 GWh.
[f]Future projects have not been outlined, but the Minho and Lima have been mentioned as possible sites.

Source: World Bank. Appraisal of Sixth Power Project, June 8, 1976. Updated with information from various news reports (see bibliography).

Figure 2A-2


GENERATION, TRANSMISSION
AND INTERCONNECTION GRID
GENERATING CENTRES
LINES
POWER STATIONS
SUBSTATIONS

they have a significant impact on Portugal's total crude oil requirements. In 1977, for example, the non-energy uses of oil products accounted for 7% of national crude oil consumption.

The major non-energy oil consumption by economic sector are:

- Chemicals: very large use of naphtha for the production of ammonia (for fertilizers).
- Construction: use of asphalt for the construction of roads and as a general building material.
- Transportation: use of mineral oil lubricants in internal combustion engines.

1.6 Energy Consumption

Energy consumption in Portugal has grown at greater than 10 percent during the last several years. Table 2A-8 lists energy consumers. Industry uses approximately 30 percent of oil products, 39 percent of coal supplies and almost 50 percent of electricity produced. As the country's economic policy is aimed at stimulating expansion of industry, it can be expected to remain the major energy consumer.

Table 2A-8

Energy Consumption (%)

Sector	Coal	Crude Oil	Oil Products	Electricity
Transformation	56.5	99.7	18.2	0
Energy	0	0	4.8	16.6
Transportation	3.1	0	34.4	2.0
Industry	39.1	0	30.5	47.9
Other	1.5	0	11.8	33.4
Agriculture	0	0	0.3	0.6
Commercial	0.5	0	2.6	11.9
Public Service	0.5	0	2.2	2.0
Residential	0.6	0	6.6	18.8

It may be seen from Table 2A-9 that the major consumption of solid fuel is in the iron and steel industry, while major consumers of petroleum-based fuels are the cement, paper, textiles and food industries. Large amounts of wood and other plant residues are consumed as energy sources, especially in the ceramics, food and paper industries. There are significant uranium ore deposits which are already being exploited to manufacture yellow cake.

A summary of electricity data is given as Table 2A-10. Of the total electricity consumed in Portugal, about 5% is self-

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Table 2A-9

Summary of Electricity Consumptions (1977)

SECTORS	SELF-GENERATED ELEC.		PURCHASED ELEC.		TOTAL ELECTRICITY		
	10^3 KWH	TEP	10^3 KWH	TEP	10^3 KWH	TEP	10^{12} J
Agriculture	-	-	79314	6821	79314	6821	286
Fishing	-	-	-	-	-	-	
Mining Industries							
Coal	-	-	6318	543	6318	543	23
Other	5246	451	79988	6879	85234	7330	307
Total	5246	451	86306	7422	91552	7873	330
Manufacturing Industries							
Food	6935	595	454051	39048	460986	39643	1660
Textiles	24471	2105	895933	77050	920404	79155	3314
Paper	408725	35150	198684	17087	607409	52237	2187
Chemicals	17592	1513	1013175	87133	1030767	88646	3712
Ceramics	4	0.3	206026	17718	206030	17718	742
Glass	210	18	129218	11113	129428	11131	466
Cement	0	0	577976	49706	577976	49706	2081
Non-Ferrous Metals	4115	354	767119	65972	771234	66326	2777
Iron and Steel	44913	3862	174187	14980	219100	18842	789
Other	6491	561	1418943	122029	1425434	122590	5133
Total	513456	44159	5835312	501836	6348768	545994	22861
Water Supply	-	-	208163	17902	208163	17902	750
Construction	-	-	52600	4523	52600	4523	189
Services	-	-	1481676	127424	1481676	127424	5335
Transportation							
Rail	-	-	231484	19908	231484	19908	834
Domestic Residential	-	-	2765887	237866	2765887	237866	9959
TOTALS	518702 4.6%	44610	10740742 95.4%	923702	11259444 100%	968311	40543

Sources: 1) "Estatisticas de Energia 1977": self-generated electricity

2) "Estatisticas Industriais 1977" (Vol I and II), and "Estatisticas de Energia 1977" for total electricity consumptions.

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generated, the balance being provided by Electricidade de Portugal (EDP). About half the self-generated electricity is derived from the combustion of wood and other wastes or by-product fuels. Over 70% of electricity is provided by hydroelectricity.

Table 2A-10

Electricity Generation, 1977

	10^3KWH	%
Hydroelectricity	10,009,929	72.4
Thermal		
By conventional power plants	3,176,841	23.0
Self-generated with commercial fuels	362,930	2.6
Self-generated with non-commercial fuels (wood etc.)	268,778	2.0
Total Production	13,818,478	100.0

Source: "Estatisticas de Energia 1977", INE.

The production of hydroelectricity at this level represents utilization of about 55% of the national potential for exploitable hydroelectricity. An increase of approximately 340,000 kWh per year is expected through 1985 as further hydro resources are developed.

2.0 VIEWS AND INTERVIEWS

The following summarizes, in chronological order, the interviews and visits made in Portugal between November 16 and November 25, 1981.

2.1 Present:

Dr. Michael Lukomski, AID

at AID Mission, 165 Rua Catilho, Lisbon

A copy of the "Status of Coal Slurry Combustion Technology in the U.S." and a "List of Data and Information Required" were given to AID. Dr. Lukomski scheduled a meeting with representatives of the U.S. State Department in Lisbon for a briefing and preparation for meeting with the Portuguese Secretary of State.

2.2 Present:

AID	State Dept. Embassy
Mr. Donald Finberg, Director Dr. M. Lukomski	Larry Butcher, First Secretary Laurie Anne Johnston, Second Secretary

at AID Mission, 165 Rua Castilho, Lisbon

The present status of COM technology development in the USA, its viability as a technology and whether it would be presented to the Portuguese as a commercially developed alternative were discussed.

The status of COM combustion technology was outlined. It was stated that the electric power and the cement industries were probably the industries to which COM technology could best be applied. The steel industry uses considerable energy, but there was uncertainty whether coal, coke or fuel oil was used as the primary energy source.

Sines was mentioned as the possible location of a port for unloading imported coal. A meeting with Petrogal, the Portuguese oil company owned by the government, was recommended to ascertain who are the major fuel oil users.

2.3 Present:

Secretary of State for Energy

Eng-Joao Nuno Boulain de Carvalho Carreira

AID, Lisbon

Dr. M. Lukomski

U.S. Embassy

Ms. Laurie Anne Johnston

at offices of Secretary of State for Energy, Rua da Horta Seca, 15, Lisbon.

A copy of the "Status" and "Data" documents were given to Secretary of State Carreira. The scope of the investigations being made by Burns and Roe for AID were outlined. It was suggested that, depending on the results, the present investigation be followed up by studies of the feasibility of the application of COM to specific plants.

Portugal is preparing a National Energy Plan (P.E.N.) that is expected to include consideration of coal and COM.

There are concerns about the introduction of coal to industry. The cement industry appears to be the prime candidate for replacing fuel oil with coal. Uncertainty exists as to the relative costs of coal and oil. The investments required to implement the use of coal are large. Causing fear is that, if the cement industry converts to coal, it will be irrevocably committed to coal and will be unable to return to oil if relative energy costs change. With COM, oil remains a viable option and therefore offers an alternative without requiring an unalterable commitment.

COM should be considered as a fuel alternative for power stations. It is being considered for the units at Carregado and Setubal.

Petrogal is conducting a survey to determine if a market for COM exists. Thus the AID Study may fit into Petrogal's own investigations.

Meetings with Petrogal and Electricidade de Portugal were arranged.

It was indicated that Portugal may be the best country with which to start the investigation in view of its interest in COM.

Samples of COM and CWM were shown to the Secretary.

2.4 Present:

Petrogal

Pedro Pires de Miranda, Manager and Director

Carlos Manuel Ferreira Dos Santos, Gas Director - Planning and Special Studies

at Offices of Petrogal, Rua das Flores, 7, Lisbon, Portugal

Petrogal is planning to import and sell coal in Portugal. It is anticipated that coal use will become significant in 1984 and 1985. A new energy plan for Portugal will be completed by the end of the year, and it is expected that it will stress coal use.

Sines is being considered as the location for harbor facilities for unloading coal. A coal-fired electric power station is also planned for Sines; thus the planning for the power station and Petrogal's facilities can be considered in combination. If Petrogal constructs a COM preparation facility, a logical location would be at Sines as both oil and coal would be unloaded there. The coal facility could be located next to the present refinery.

At this time the introduction of coal is planned first for the cement industry since many cement plants were originally designed for coal use but were converted to oil. Cement plants, whether they once used coal or never have used coal, can substitute coal for fuel oil and therefore are unlikely to be interested in COM.

Petrogal is studying the use of COM together with EDP. The 6-125 MW units at the Carregado Power Plant and two-250 MW units at Setubal (plus two future units being constructed) which fire fuel oil are potential COM users. Petrogal would build the COM preparation plant and deliver the COM to the plants by rail or barge. However, Petrogal would only proceed with the COM production facility if a suitably sized market is established.

The coal for COM would probably have to come from the United States since Portugal does not have the high quality coal necessary for COM. An alternative source of coal might be South Africa.

All the oil-fired units at Carregado and Setubal use Bunker C fuel oil with 3.5 percent sulphur, heating value of 10,000 kcal/kg, and viscosity of 300,000 sec (@ t = °F)

At present, fuel oil is subsidized by the government. It is expected that this will change. Middle distillate is sold at cost; heavy fuel oil is sold below production cost. Present fuel oil price is $200/per ton, delivered.

The present government target for conversion to coal is the cement industry; the ceramic industry is expected to follow in a later stage.

Coal presently imported is primarily metallurgical coal. For the new conversions, major new facilities and large investments are required. Coal delivery can be linked to railroad and barges for delivery to cement and other industrial plants. For the cement industry about 1,000,000 tons/year will be required by 1986. About 3,500,000 tons/year will be required for the power plant units by 1986-1987.

The present crude oil supply comes from Mexico, Venuzuela, Nigeria, USSR, Iraq, Saudi Arabia, Abu Dhubai, and Kuwait. Diversification of suppliers is desired so that supply is less vulnerable to interruptions.

Coal is considered less vulnerable to sudden large price changes than oil so that the risk of conversion is not considered to be serious.

At present, coal is the economic choice. One ton of coal is equivalent to about four barrels of oil.

The steel industry uses about 60,000 tons of oil per year and may be a potential COM user. Other industrial uses are smaller, but such industries may consider COM if a COM production plant actually becomes a reality.

A copy of the "Status" and "Data" documents were given to Petrogal. Petrogal will respond to those items of information in the "Data" list for which it has the information. Where is this

2.5 Present:

Joachim L. Rocha Cabral, Managing Director,
Board of Directors, EDP

at Offices of Electricidade de Portugal Ave. Jose Malhoa,
Lote A, 13-6, 1000 Lisbon

A copy of the "Status" and "Data" were given to EDP. A copy of EDP's Annual Report for 1980 was received by Burns and Roe.

EDP is aware of the potential of COM in power generation and the major supplier of its boilers - Mague (a licensee of Foster Wheeler Corp.) is evaluating its use for one unit at the Carregado Power Station. The potential boiler conversions include six-125 MW at Carregado (four are Mague units, two are CUF/John Thompson of England). All units were designed for fuel oil, and EDP has decided that they are not suitable for conversion to coal; thus COM is a possibility. An investigation by Mague will determine what changes will be required. Preliminary findings from Mague indicate that the boiler being studied will be derated approximately 25 percent to minimize changes to the boiler. Oil firing capability is to be retained for peak loads and flexibility in fuel selection.

Mague has built 90 percent of EDP's boilers.

EDP is working with Petrogal since Petrogal is interested in producing COM. The COM production plant and unit conversions would be parallel developments.

The oil price is set and subsidized by the government. The study of whether or not to convert to COM will be done based on market prices. If Petrogal decides not to go ahead with a COM production plant, EDP may produce it on its own if it decides to convert any plants to COM.

The Outeira Power Plant in the north of Portugal must burn anthracite coal produced in the region and therefore, cannot consider conversion to COM. The coal is not sufficient quality to fuel Outeira alone and must be supplemented with fuel oil. The plant will be kept in operation as long as the coal holds out, probably until the end of this century, as part of a policy to keep miners employed.

Because the construction of power plants has been delayed, Portugal has low power reserves and would not want to have a long shutdown period for conversion or lose capacity to boiler derating.

EDP has strong interconnections with Spain and, through Spain, to France. Because of the recent drought, EDP has imported large amounts of electricity. In the past, power was exported to Spain and France.

EDP future plans are to reduce its use of fuel oil. COM is a relatively simple way to reduce consumption without the large investments required for coal.

EDP believes that there is little special technology required to prepare COM. In Spain, COM is being prepared by simple grinding and mixing. (The implications were that there was little or no technology to be transferred and the EDP could probably introduce COM technology with its present staff.)

EDP is planning to build coal-fired plants starting in 1985 and plans to add 300 MW of capacity per year through 2010. It is planning for coal contracts to supply these plants with coal.

2.6 Present:

Jose E. Ribeiro de Noronha, Engineer

at Offices of Siderurgia National, E.P. (Steel)
Rua Braankamp 7

Power generation in the steel plant operates off blast furnace gas, which is a byproduct of the steel making process. Steam generators burn tar or fuel oil. In the future, for new facilities, SN plans to use blast furnace gas for both the power plant and steam boiler fuel as the gas will be in excess of other needs so that no natural gas or fuel oil will be required.

Fuel oil, 70,000 tons per year, at present is used only when necessary. It is not economically sensible to use fuel oil for the power plant in view of the need to use as much blast furnace gas as possible.

Coking coal is imported primarily from the USA. About 30 percent was once imported from Poland, but the supply has been off since economic difficulties developed there.

Fuel oil may be injected into a blast furnace instead of coke to a limited extent, but coke is essential. Pulverized coal cannot be considered because of the explosion hazard of P.C. near a blast furnace.

Present pig iron capacity is 400,000 tons/year. New blast furnace capacity being added will increase capacity to 1,400,000 tons/year.

SN has informed Petrogal that about 70,000 tons per year of COM could be used in blast furnaces to replace fuel oil presently used, if the economics of a switch are advantageous. SN doesn't think these conditions exist at present. There is no information on the effect of COM on steel making process efficiency.

Present cost of coke is about 6.5×10^3 escudos per ton. Fuel oil costs are 10.8×10^3 escudos per ton. Because 1 kilo of coke is approximately equal to 1 kilo of fuel oil, coke is less expensive.

The present SN facilities are operating at maximum capability. To justify use of fuel oil or COM in place of coke would require that the process productivity be increased 5 or 10 percent to justify the substitution.

The steel plant in north Portugal uses electric blast furnaces, so that they need not be considered for fuel conversion.

The production cost of coke is 1.3 to 1.4 times the cost of coking coal. Coal costs $70/ton resulting in coke at about $98/ton. However, the savings achieved by recovery and use of blast furnace gas compensates for the production costs of coking so that the net costs of the coke is about the same as the cost of the raw material.

Armco Steel in the USA is experimenting with the use of ground coal for blast furnace injection. Mr. Noronha considers that the cost of grinding and the hazards are serious obstacles to coal use.

Coal is delivered by river near Lisbon and is transhipped to barges which are unloaded to belt conveyors at the plant site.

Petrogal's coal facility will probably be located near Lisbon - not Sines.

Portugal imports 50 percent of its steel. SN produces, primarily, reinforcing rods, and beams for construction and plates. About 200,000 tons/year of these items are produced.

SN maintains about a three-month supply of coal for emergencies.

Not more than 10-15 percent of coal or COM can be substituted for coke in the blast furnace process in any case.

2.7 Present:

Prof. Jose J. Delgado Domingos
Prof. Cal. Do. Instituto Superior Technico, Lisbon

at Offices of Petrogal
P. Marques de Pombal, 12, Lisbon

Prof. Domingos is a consultant to Petrogal on COM technology.

COM would be a useful technology for Portugal and for other European countries as well. European oil fired boilers are less liberally designed than those in the USA. The USA boilers were developed from coal-fired designs to fire oil; the European boilers are more compact. Therefore, testing a European designed boiler would be a more valid test for the use of COM in an oil-fired boiler than those boilers tested in the USA.

Prof. Domingos has followed the COM work done in the USA. In Portugal, the questions asked were why Florida Power & Light Co. and other utilities have not continued to operate with COM beyond the demonstration test phase. The reasons may be economic rather than technical and that, in several cases, coal can be fired thus making COM less attractive.

An important consideration for Portugal is that COM can be used as an instrument of national policy to provide fuel flexibility. Since Portugal has to import both oil and coal, Portugal is vulnerable to price fluctuations in both sources of energy. By being able to switch from oil to coal or from coal to oil, some control of energy costs may be achieved.

Since the cement industry can use coal directly, it is not a potential COM user, unless dictated by national policy.

Payback for investments generally should be short (say, two years). The limits of the risks and benefits involved in decision making should be defined.

Setubal has no space for coal, which makes COM an attractive substitute for oil there.

A combined effort by Petrogal, EDP and US companies in applying COM technology to industrial applications may be useful since EDP is already doing a feasibility study for a unit at its Carregado Power Station.

Industrial plants will be interested in using COM once COM becomes available in the market place. Small industrial units will not consider COM unless a COM production plant was in place, then some small plants might consider conversion.

Under the present pricing structure, where oil is subsidized, there is no incentive for change. It is expected that subsidiaries will eventually end to provide the needed incentives for conversion to coal or COM.

2.8 Present:

Francisco J. Cortez Lobao, Director, Thermal Production and Transmission

Lopes Monteira, Head of Technical Department for Power Plants

at Offices of EDP, Av. Julio Dinis, 9, 1000 Lisbon

A copy of the "Data" list was given to EDP. Table 2A-11 lists the generating data for the Barreiro, Carregado, Setubal and Outiero power stations. Table 2A-12 is a typical analysis of the fuel oil used at the stations. Table 2A-13 lists the characteristics of boilers, at the Carregado and Setubal plants, which would be significant in assessing the effects of their conversion to COM-firing.

EDP is planning a demonstration unit for one of the four Mague-designed 125 MW boilers at Carregado. Mague has been requested by EDP to investigate what would be required to fire COM. (The scope of the investigation is not clear.) EDP has specifically requested that Foster Wheeler be involved in the investigation, since Foster Wheeler did the original design for the boiler. The oldest Carregado unit may be selected for conversion. Mague has stated, primarily, that the boiler will be derated about 25 percent when using 50%-50% COM.

Mr. Labao suggested that the paper and pulp industry may be an industry which could be considered as a potential COM users. It was ascertained that the paper mill boilers burn mostly paper wastes and use very little fuel oil; thus no application for COM can be foreseen.

EDP pollution control consists of using a tall stack and low ash fuel. Precipitators are not now being considered for the COM demonstration unit.

A list of industrial boilers that burn fuel oil can be obtained from the Ministry of Energy.

Petrogal will build facilities to receive coal. It is not decided yet who would build COM production facilities, Petrogal or EDP.

Table 2A-11
Generating Plant Performance Information
Barreiro Power Station

		Year				
		1976	1977	1978	1979	1980
- Gross output	MW	-	-	70	70	70
- Net output	MW	-	-	66,5	66,5	66,5
- Gross plant heat rate	Cal/KWh	-	-	2.408	2 418	2 192
- Net plant heat rate	Cal/KWh	-	-	2 672	2 654	2 374
- Gross generation	GWh	-	-	87,7	301,0	386,6
- Net generation	GWh	-	-	77,2	274	357,0
- Unit load factor	%	-	-	55,2	75,5	95,9
- Average boiler efficiency	%	-	-	87,7	88,9	90,0
- Tons oil fired per year	10^3 ton	-	-	a) 8,7	a) 121,4	a) 135,4
- Average oil heat value	Cal/Kg	-	-	10 200	10 200	10 200
- Tons of coal burned per year	10^3 ton	-	-	-	-	-
- Average coal heat value	Cal/Kg	-	-	-	-	-

a) This plant supply both electric power and process heat.

Table 2A-11
Generating Plant Performance Information
Carregado Power Station

		Year				
		1976	1977	1978	1979	1980
- Gross output	MW	750	750	750	750	750
- Net output	MW	715	715	715	715	715
- Gross plant heat rate	Cal/KWh	2 328,7	2 307,4	2 339,6	2 340,7	2 355,5
- Net plant heat rate	Cal/KWh	2 459,2	2 452,7	2 497,7	2 485,4	2 504,9
- Gross generation	GWh	3 286,4	2 636,2	2 412,1	2 897,1	3 475,5
- Net generation	GWh	3 145,8	2 515,6	2 259,4	2 728,4	3 268,2
- Unit load factor	%	89,5	65,7	60,6	74,3	95,6
- Average boiler efficiency	%	89,0	88,2	88,4	88,0	89,0
- Tons oil fired per year	10^3 ton	748,4	594,9	a) 551,9	a) 663,2	a) 800,6
- Average oil heat value	Cal/Kg	10 225	10 225	10 225	10 225	10 230
- Tons of coal burned per year	10^3 ton	-	-	-	-	-
- Average coal heat value	Cal/Kg	-	-	-	-	-

a) - Include oil fired in auxiliary boilers for atomizing and heating.

Table 2A-11
Generating Plant Performance Information
Setubal Power Station a)

		Year				
		1976	1977	1978	1979	1980
- Gross output	MW	-	-	-	250	500
- Net output	MW	-	-	-	238	238
- Gross plant heat rate	Cal/KWh	-	-	-	2 805,3	2 237,1
- Net plant heat rate	Cal/KWh	-	-	-	2 953,2	2 325,0
- Gross generation	GWh	-	-	-	183,7	1 415,5
- Net generation	GWh	-	-	-	174,5	1 362,0
- Unit load factor	%	-	-	-	-	99,7
- Average boiler efficiency	%	-	-	-	-	90,2
- Tons oil fired per year	10^3 ton	-	-	-	50,4	309,7
- Average oil heat value	Cal/Kg	-	-	-	10 225	10 225
- Tons of coal burned per year	10^3 ton	-	-	-	-	-
- Average coal heat value	Cal/Kg	-	-	-	-	-

a) The steam for atomizing and heating is delivered from the main boilers.

Table 2A-11
Generating Plant Performance Information
Tapada Do Outeiro Power Station a)

		Year				
		1976	1977	1978	1979	1980
- Gross output	MW	150	150	150	150	150
- Net output	MW	142	142	142	142	142
- Gross plant heat rate	Cal/KWh	2 887,6	2 626,2	2 765,5	2 622,9	2 680,3
- Net plant heat rate	Cal/KWh	3 166,6	3 027,6	3 050,6	3 131,2	2 956,3
- Gross generation	GWh	662,0	414,0	466,5	546,4	644,9
- Net generation	GWh	603,7	359,1	422,9	492,6	584,7
- Unit load factor	%	87,0	40,9	60,6	79,0	95,1
- Average boiler efficiency	%	80,0	79,0	78,0	77,0	78,0
- Tons oil fired per year	10^3 ton	120,3	65,4	61,6	62,3	84,2
- Average oil heat value	Cal/Kg	10 300	10 300	10 300	10 300	10 300
- Tons of coal burned per year	10^3 ton	158,4	100,2	162	219,0	212,5
- Average coal heat value	Cal/Kg	4 246	4 128	4 047	4 113	4 053

a) The boilers are equiped with coal and oil burners.

Table 2A-12

List of Fuel Oil Characteristics as received

Moisture	1.5% maximum (volume)
Ash	0.02% maximum (weight)
Hydrogen	11.2%
Carbon	85.4%
Sulfur	3.5% maximum
Sp. Gr.	.940 - .985
API Gravity	19.03 - 12.88
Flash Point	65°C minimum
High Heating Value	10,100 - 10,300 cal/kg
Sodium ($O\ Na_2$)	12% (ash) (weight)
Vanadium (V_2O_5)	45% (ash) (weight)
Viscosity	CST 300-860 (37,8°C)
25°C	
50°C	
75°C	
100°C	
Sediments	0.5% maximum

Table 2A-13
Boiler Design Parameters

BOILER UNIT	CARREGADO	SETÚBAL
FURNACE HEAT RELEASE RATE (10^3 BTU/HR.FT^2)	110.0	123.0
GAS TEMP. LEAVING FURNACE (^oF)	1905	2090
MAX. FLUE GAS VELOCITY (FT/SEC)	50.0	50.0
CONVECTION PASS BANKS TUBES CLEAR SPACING (INCH):		
REHEATER	1.83	2.0
	6.41	6.75
	6.67	6.50
PRIMARY SUPER H.	2.08	6.75
		2.25
ECONOMISER	2.08	2.5

2.9 Present:

Mr. Lopez Monteira, EDP
Mr. Cabegadas, Setubal Plant Superintendent

at Corregado and Setubal Power Stations

Both the Corregado and Setubal plant sites were visited to survey the installation and ascertain potential diffic s to converting to COM firing. Copies of the following do s were received from Mr. Monteira:

1. A simplified plant description and drawings of Major Plant Features of the Central Termica de Corregado 6 x 125 MW units.

2. Mague Drawing No. 48-9004-666-20 General Arrangement Cross Section Drawing of the Foster Wheeler Corp. Steam Generator for the Corregado Station.

3. Electricidade de Portugal
EDP/Empresa Publica.

4. Description of the Setubal Thermal Power Plant.

5. A booklet describing the Electric Energy Consumption of Portugal in 1980.

6. A booklet titled "Sintese Estatistica De Exploracao," 1980.

7. Drawing C3-CHS-071 of the Foster Wheeler Boiler for the Setubal Units (size 250 MW).

The thermal plants are being used to their capacity because of the current drought situation. The load pattern and peaks do not vary much between winter and summer.

Barges carrying COM would have a maximum capacity of 2000 tons for river transport. Railcars for COM would have a maximum capacity of 60 tons. For the demonstration boiler about 2500 tons/day of COM would be needed. Thus, two or three barges would be required to keep the demonstration plant supplied with COM.

Each of the four-250 MW units at Setubal use 771 tons of fuel oil per hour. The unloading facilities at Setubal can handle a 15,000 ton vessel.

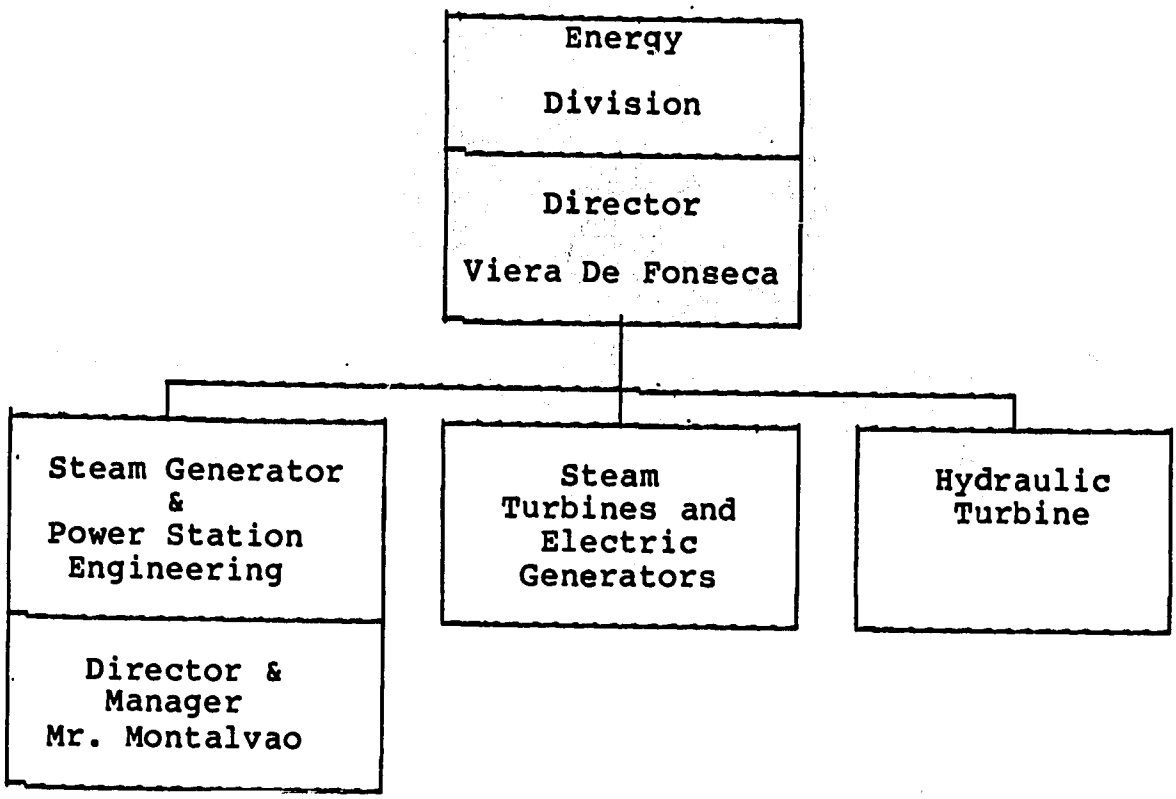
2.10 Present:

Jose A. Bandeira
Project Engineer, Steam Engineering Department

at Offices of Mague, Estrada Nacional - Alverca

Mr. Bandeira described the organization of the Mague Energy Division. The Energy Division is organized as follows:

Mague Organization



Mague is a licensee of Foster Wheeler Energy Corp. for large utility boilers and a licensee of Brown Boveri for Steam Turbines and Electric Generators. They are also licensed to fabricate hydraulic turbines.

Mague has an agreement with the government which was signed in 1980, and runs for 10 years, to supply Boilers, Auxiliaries and Steam Turbines for all EDP Power Stations. This agreement also applies for the larger industrial boilers i.e., 190 tons per hour os greater, 121.5 kg/cm^2 pressure and 520°C temperature.

Mague is presently building a coal-fired boiler for EDP at the Sines Power Station.

Industrial boilers with lower ratings are assigned to Quimigal - a licensee of Combustion Engineering through a French Company - Stein-Urbain.

During September 1981, representatives of EDP, Petrogal, Mague and the Technical Institute visited COM demonstration installations in the United States.

Mr. Bandeira stated that, to date, only the department directors have been involved in the COM investigation for EDP.

Messrs. de Fonseca and Montalvao are in the US this week to discuss the conversion from fuel oil to COM of a Carregado unit, with Foster Wheeler. The purpose of the visit to the USA by Mague is to discuss how both Mague and Foster Wheeler should proceed with this project and which firm should perform the analyses. The study of details had not begun. It awaits decisions by the directors and, perhaps, the results of the meeting with Foster Wheeler in the USA.

Mague designs and constructs the boilers strictly in accordance with Foster Wheeler standards. In particular, Foster Wheeler designed about 90 percent of the first Carregado units because these were the first units furnished by Mague as licensee of Foster Wheeler. Therefore, Foster Wheeler would be directly involved with the COM conversion of the 125 MW boiler.

The first conversion at Carregado will be a demonstration unit. If successful, the remaining boilers at Carregado and Setubal will be considered for conversion to COM.

Carregado Units 3 and 4 are John Thompson (England) units, and were erected by CUF (a Portuguese Company). CUF has since been nationalized and is known as Quimigal.

In 1977 a study was made by Mague for EDP to convert the Setubal 250 MW boilers, then under construction, from fuel oil to coal firing. It was determined at that time that the boilers would have to be derated from 250 to 175 MW, but because of space limitations, full conversion to coal was not feasible, making them candidates for COM conversion.

The Carregado 125 MW boiler can probably operate using COM mixtures of 40-50 percent coal by weight, when the unit is derated to 75 percent of capacity to minimize boiler modifications.

The boiler modifications for COM at this stage of the investigation would probably be:

1. small adjustments to superheater tube spacing
2. adjustments to fans and ductwork
3. new burners capable of burning COM & fuel oil
4. change angle of inclination of sloping bottom
5. provide pit under bottom for ash removal
6. add wall and soot blowers
7. eliminate or change gas recirculation
8. check fan margins for Hp, flow and head
9. steel structure and furnace geometry will remain
10. the furnace throat should be adequate.

Forney burners and combustion controls may require changes.

Arrangement of burners may be a problem because of furnace geometry; the flame size and pattern may be different for COM.

The burner throats should be adequate because they were designed to handle magnesia slurry injection for vanadium control, a practice which has been abandoned.

Soot blowers were provided in the boiler, but the number of soot blowers may be less than required for COM firing.

Gas recirculation is used to control temperature at low loads at present. This feature may require rearrangement for COM conversion.

The coal used for COM would probably be imported and purchased by EDP. Source of coal would be USA, South Africa or Australia. An eastern USA bituminous coal, with heating value between 10,500 and 11,000 Btu/lb and normal sulphur content would probably be considered.

A copy of the following information was given to Burns and Roe by Mr. Bandeira:

1. List of Utility Boilers supplied by Mague in Portugal - Table 2A-14.

2. List of Large Industrial Boilers supplied by Mague - Table 2A-15.

3. List of Maritime Boilers - Table 2A-16

4. Drawing of Carregado 125 MW Boiler

5. Drawing of 70 tonne/hr Refinery Boiler

6. Drawing of 50 tonne/hr Paper Mill Boiler

2.11 <u>Present</u>:

Carlos Manuel Ferreira dos Santos
Gas Director - Planning and Special Studies

Offices of Petrogal, P. Marques de Pombal, 12, 1111 Lisbon

The following information was obtained:

1. A list of imported hydrocarbon products, their source and quantities.

2. Map showing locations of Anthracite and Lignite Coals in Portugal.

Table 2A-14

Generateurs De Vapeur

Centrales Thermiques

Designation de la Centrale	Client	Puissance MW	Vaporisation T/H	Pression Kg/cm2	Température °C	Combustible	Observations
Centrale Thermique Carregadol	E.T.P. (Portugal)	125	360	130	545/545	Huile nº6	Anée de mise en service : 1967
" " " 2	E.T.P. (Portugal)	125	360	130	545/545	Huile nº6	" " " " " : 1968
" " L.Marques 5	SONEFE (Moçambique)	15	80	36	415	Charbon	" " " " " : 1970
" " Carregado 5	C.P.E. (Portugal)	125	380	130	545/545	Huile nº6	" " " " " : 1975
" " " 6	C.P.E. (Portugal)	125	380	130	545/545	Huile nº6	" " " " : 1976
" " Setúbal 1	C.P.E. (Portugal)	250	771	170	543/543	Huile nº6	Premier allumage : 1978
" " " 2	C.P.E. (Portugal)	250	771	170	543/543	Huile nº,6	" " : 1979
" " Setubal 3	"	"	"	"	"	"	" " " "
" " Setubal 4	"	"	"	"	"	"	" " " "
Sines Power Station 1	EDP	300	950	170	535/535	Coal	
" " " 2	EDP	300	950	170	535/535	Coal	

Table 2A-15

Generateurs De Vapeur
Installations Industrielles

Designation de l'installation	Utilisation	Client	Vaporisation T/H	Pression Kg/cm2	Temperature °C	Combustible	Observations
Cellulose Billerud	Cellulose	Celbi(Porto)	50	74	500	Huile	Anée de mise en service : 1967
Centrale de la Raffinerie Nord A	Raffinerie	Sacor (Porto)	70	68,5	455	"	" " " " " : 1969
" " " " " B	"	Sacor(Porto)	70	68,5	455	"	" " " " " : [illegible]
" " " " " C	"	Sacor(Porto)	70	68,5	455	"	" " " " " : [illegible]
" " " " " D	"	Sacor(Porto)	70	68,5	455	"	" " " " " : 1969
Centrale de CNP (Sines) 1	Petrochimie	CNP(Portugal)	190	121,5	520	Huile/Gas	Premier Allumage : 1978
" " " " 2	"	CNP(Portugal)	190	121,5	520	" "	" " : 1979
" " " " 3	"	CNP(Portugal)	190	121,5	520	" "	" " : 1979

Table 2A-16

Generateurs De Vapeur
Installations Maritimes

Designation de l'installation	Client	Chaudière	Vaporisation T/H	Pression Kg/cm2	Température °C	Combustible	Observations
Navire Pétrolier Neiva	Eriksberg (Suécia)	Principale	125	64	515	Huile	Année de mise en service: 1976
		Auxiliaire	60	64	320	Huile	Année de mise en service: 1976
Navire Pétrolier S 102	Eriksberg (Suécia)	Principale	125	64	515	Huile	Premier allumage: 1977
		Auxiliaire	60	64	320	Huile	Premier allumage: 1977
Navire Pétrolier S104	Setenave (Portugal)	Principale	75	64	515	Huile	Premier allumage: 1978
		Principale	75	64	515	Huile	Premier allumage: 1978
Navire Pétrolier S106	Setenave (Portugal)	Principale	75	64	515	Huile	Premier allumage: 1978
		Principale	75	64	515	Huile	Premier allumage: 1978

3. Colored map of Portugal showing rail lines, roads, rivers, cement plants, etc.

4. Data for typical industrial boilers in the paper, chemical, food and beverage, edible oil and margarine, and sugar refining industries. The data include steam generation rates, steam pressure and temperature and total fuel oil used in the year 1980. (See Table 6 in the Summary of this Annex.)

An ongoing study for a coal depot location is considering a site at Sacavem. This is near Lisbon and would be the distribution point for the cement industry and possible for the COM preparation plant for the Carregado demonstration unit. The location can handle a 3000 ton barge.

The list of boilers, Item 4 listed before, and the information was obtained by Petrogal by submitting a questionnaire to the companies.

2.12 Present:

Petrogal

Pedro Pires de Miranda, Manager and Director

at Office of Petrogal, Rua dos Flores, 7, Lisbon

Petrogal wishes to bring coal to industry before 1985 or 1986 when EDP's coal fired unit at Sines is to be completed. Petrogal is considering a coal barge unloading site at Sacavem from which coal can be delivered by rail or road to cement plants and to Carregado via the Tejo River. A COM plant could be added to this site.

2.13 Present:

Mr. Donald Finberg
Dr. M. Lukomski

at Offices of Agency for International Development
Lisbon, Portugal

An oral summary was given of the overall findings which indicate a potential for application of COM technology in Portugal. The interest in COM antedates Burns and Roe's visits; thus considerable technical knowhow already exists in Portugal and EDP with US expertise being obtained by Mague, supplier of utility and large boilers, from Foster Wheeler in the USA.

Opportunities for further technical assistance through AID may be limited to further evaluation of specific applications.

AID is to follow-up on responses to questions that EDP promised to forward.

2.14 Present:

Secretary of State for Energy Carvalho Carreira
AID: M. Lukomski
U.S. Embassy: Ms. Laurie Anne Johnston

at Offices of Secretary of State for Energy
Rua da Horta Seca, 15

The Secretary of State was briefed on findings of the project.

The interviews determined that the approach being used by the Portuguese to making decisions on the application of COM is professional and that it is evident that many individuals in Portugal are very knowledgeable about COM.

It was suggested that it might be preferable to first convert a small industrial boiler in the chemical industry to COM instead of starting with a utility boiler, such as the one at Carregado.

3. References

1. "Political, Economic and Energy Profile - Portugal" ANL-PMS-TR-79-4, Prepared for the U.S. International Energy Development Program by Office of Program Management Support, Argonne National Laboratories, July 1979.

2. "Portugal Energy Assessment - Fossil Fuel Evaluation" Prepared for Argonne National Laboratories by Booz-Allen & Hamilton & Inc., Energy and Environment Division, Menlo Park, California, March 1981.

3. Tempo Report No. GE80TMP-3
   Draft Report - Development Analysis Report (Task 4)
   Portugal/U.S. Cooperative Energy Assessment
   Cycle I
   Volume I: Portugal, Including Antonomous Regions
   January 1980 (Revised January 29, 1980)
   Prepared for: Argonne National Laboratories
   Under Contract: 31-109-38-5361
   Prepared by: General Electric Company - Tempo Center for Advanced Studies, Washington, D.C. 20005

4. Portuguese Republic - Ministry of Industry and Technology - Directorate General of Energy, "Medium-Term Plan - 1979-1984 - Energy Sector" - October 1978.

5. "Sectoral Demand - Analysis Report for Portugal" - March 1980 - Prepared for Argonne National Laboratories by Gordian Consulting Service, Ltd.

B. KENYA

1.0 ENERGY SECTOR - FACTS AND FIGURES

1.1 Energy Policies and Goals

No oil or coal has been discovered in Kenya to date. As a typical developing country with no indigenous oil or coal resources, Kenya has limited opportunities to curtail its use of imported energy if it is to continue to develop at a reasonable rate. Economic growth in Kenya has been and is still largely dependent on oil.

Table 2B-1 gives figures on consumption of all forms of energy from 1976-1980.

In 1980 about 84 percent of commercial energy (as distinguished from non-commercial sources such as fire wood) was derived from oil. The rest is derived from electricity, primarily from hydroplants. Less than 1 percent is derived from coal.

Imported oil has been the major contributor to trade deficits since 1973. The cost of petroleum was more than a third of the value earned from non-oil exports in 1980. On the other hand, export of surplus refined oil products to other African nations was the main source of foreign exchange credits.

In late 1979, a Ministry of Energy was created to initiate energy planning, formulate policy, promote oil conservation and promote alternative energy sources.

1.2 Oil and Natural Gas

Crude petroleum imports increased from 2,471,000 metric tons in 1979 to 3,075,500 metric tons in 1980 and costs rose from 120.1 million K pounds in 1979 to 256.6 million K pounds in 1980. The net oil costs for commercial energy consumption, after gain for sale of refined products, increased from 68.8 million in 1979 to 116 million K pounds in 1980. Refinery capacity has potential output of 4 million tons per year.

Oil is imported from the Middle East and is refined in Mombasa. Refined products are pumped by pipeline to Nairobi where they are distributed by truck and rail to industrial plants nearby and to western Kenya. A pipeline supplies fuel oil to the Kipavu power plant directly.

About 8 percent of the total oil imported was used for thermal generation in 1980. This was an increase from 5 percent in 1979. The large increase was due primarily to the serious

Table 2B-1
Production, Trade and Consumption of Energy*
Expressed in Terms of the Primary Sources, 1976-1980

'000 Tonnes Oil Equivalent

	1976	1977	1978	1979	1980
Coal and Coke Imports	44.9	43.8	34.8	11.3	16.9
Oil -					
Imports of crude oil	2,496.7	2,551.5	2,369.2	2,471.5	3,075.5
Net exports of petroleum fuels	-1,324.3	-1,260.3	-915.0	-713.4	-1,415.3
Stock charges and balancing item	391.1	316.6	205.7	-88.8	108.0
Total Consumption of Liquid Fuels	1,563.5	1,607.8	1,659.9	1,669.3	1,768.2
Hydro Energy -					
Local production of hydro-power	140.0	167.4	257.5	314.0	254.4
Imports of hydro-power	58.1	65.2	52.1	38.4	75.6
Total Consumption of Hydro-Energy	198.1	232.6	309.6	352.4	330.0
Total Local Energy Production	140.0	167.4	257.5	314.0	254.4
Total Imports	1,275.5	1,400.2	1,541.1	1,807.8	1,752.7
Use of stock and balancing item	391.1	316.6	205.7	-88.8	108.0
Total Energy Consumption	1,806.5	1,884.2	2,004.3	2,033.0	2,115.1
Local Production as Percentage of Total	7.7	8.9	12.8	15.4	12.0
Per Capita Consumption in Terms of Kilogram of Oil Equivalent	130	131	135	133	132

*Modern sector only: fuelwood and charcoal are excluded.

drought in early 1980 which reduced power available from hydropower. Also, because of the drought, 18 percent of hydroelectricity consumed in Kenya was imported from Uganda.

Heavy oils are produced in excess because refinery capacity is sized to provide light fractions for transportation. The excess heavy oil is exported. Because of the glut conditions in the world market, sales were made at less than the cost of crude petroleum. The average price on all petroleum fuels imported in 1980 was 95 K pounds per metric ton. Table 2B-2 lists the value of imports and exports of petroleum products from 1976-1980.

The Mombasa refinery is working at about 60 percent of capacity and this is expected to handle any increased demand for some time to come. To reduce the surplus of residual and increase the yields of middle distillates from the same quantity of crude oil, an additional cracking unit is planned for the Mombasa refinery. The increase in middle distillates for domestic and export market will tend to reduce the imbalance between costs of imports and exports and improve the balance of payments situation.

The prices of petroleum products at Mombasa on selected days with 1973 as base are shown in Table 2B-3.

1.3 Coal

Most of the coal imported by Kenya comes from Swaziland with small amounts from the United Kingdom. The major coal user is the Bamburri cement plant in Mombasa which must import all the coal it uses. The cement company sells coal to some small plants near Mombasa.

The cement companies are planning to convert the Athi River and Bamburri plants to maximize coal use. Other potential conversions from oil to coal that were considered are the Pan African Paper mills. A future thermal power station using coal is under consideration.

The Shell Oil Company has been exploring the possibility of importing coal.

Coal and coke consumption has dropped continuously since 1976 to less than 1 percent of energy used by 1980. Consideration is being given to increasing coal use because of the drain on foreign exchange caused by high oil prices. Tariffs on coal have been reduced to encourage industry to use coal.

1.4 Electricity

Electric power is produced by hydro and thermal power plants. The East African Power and Lighting (EAPL) Company, of which the government owns 54 percent, is the main distributor of

Table 2B-2
Quantity and Value of Imports and Exports of Petroleum Products, 1976-1980

	1976		1977		1978		1979		1980	
	Quantity '000 tonnes	Value K£'000	Quantity '000 tonnes	Value K£'000	Quantity '000 tonnes	Value K£'000	Quantity '000 tonnes	Value K£'000	Quantity '000 tonnes	Value K£'000
Imports—										
Crude Petroleum	2,496·7	93,469·5	2,551·5	100,158·4	2,369·2	92,337·6	2,471·5	120,085·3	3,075·5	256,582·0
Petroleum Fuels	47·7	3,345·7	104·7	8,269·9	258·3	16,899·4	288·3	20,480·8	166·5	19,69[illegible]
Lubricating oils	53·0	5,678·9	73·9	6,927·7	65·4	6,636·1	47·9	5,100·0	54·8	919·6
Lubricating greases	0·1	41·5	0·2	65·[illegible]	0·2	75·2	0·1	47·5	0·1	84·1
Total	2,597·5	102,535·6	2,730·3	115,421·1	2,693·1	115,948·3	2,807·8	145,713·6	3,296·9	277,2[illegible]·0
Exports—										
Petroleum Fuels	1,372·0	57,603·4	1,365·0	72,39[illegible]·3	1,173·3	60,372·6	1,001·7	68,138·3	1,581·8	150,557·5
Lubricating oils	57·3	10,584·7	50·0	10,253·8	38·9	8,172·2	33·9	8,311·3	35·5	9,976·6
Lubricating greases	1·5	372·2	1·5	350·3	1·3	378·7	1·3	409·8	1·1	350·7
Total	1,430·8	68,560·3	1,416·5	83,002·4	1,213·5	68,923·5	1,036·9	76,859·4	1,618·4	160,884·8
Net Balance ..	1,166·7	33,975·3	1,313·8	32,418·7	1,479·6	47,024·8	1,770·9	68,854·2	1,678·5	116,392·2

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Table 2B-3
Wholesale Prices* of Petroleum Products at Mombasa, on 30th September, 1973, 26th September, 1979 9th March, 1980, 20th June, 1980, and 21st February, 1981

KSh. per tonne

	30-9-1973	26-9-1979	9-3-1980	20-6-1980	21-2-1981	Ratio 1981/73 *Percent*
L.P.G.**	2,060	3,644	4,044	4,050	4,345	210·9
Premium motor gasoline ..	1,551	5,135	6,022	6,714	7,670	494·5
Regular motor gasoline ..	1,468	4,703	5,475	6,003	7,280	496·0
Illuminating kerosene	736	2,029	2,539	2,612	2,994	406·8
Power kerosene	763	2,785	3,369	3,397	4,204	551·0
Light diesel oil	892	2,671	3,207	3,394	4,109	460·7
Industrial diesel oil	471	1,774	2,245	2,256	2,554	542·3
Fuel oil	334	1,214	1,639	1,639	1,639	490·7

*Including duties and sales taxes.

**Liquified petroleum gases.

power. From 1970 on, EAPL, together with the Kenya Power Company, Ltd. and Tana River Development Company, the latter two being wholly owned by the government, developed hydroelectric and thermal stations.

Total installed generating capacity in 1980 was 485.1 MW Total electric usage in 1980 was 1490 gWh, - down from 1567.6 gWh in 1979, due to rationing instituted because of the severe drought in early 1980. The installed capacity is expected to reach 555 MW in 1983 by the addition of 40 megawatts of hydro and 30 megawatts geothermal power.

At present, five hydropower stations, with installed capacity of 335 MW, are operating and 140 MW of additional capacity is under construction, scheduled for completion in 1985. The total potential hydropower for the country is estimated to be 3000 MW; 1230 MW for the Tana River, 370 MW for the Athi/Sabaki Rivers and 1200 at mini-hydro sites. Hydro power is also imported from Uganda.

Table 2B-4 lists the installed hydro and thermal plant capacity and energy produced in 1976-1980 period. Table 2B-5 lists the projected future electricity demand to the year 2000. Table 2B-6 indicates the actual demand for electricity and how it was met by imports from Uganda during the 1976-1980 period.

A 30 MW geothermal station is now under construction with 15 MW to be completed in 1981 and the remainder by 1987. In additional 120 MW of geothermal power by 1988 is planned.

1.5 Cement

The only significant amount of coal used in the country is by the Bamburri Portland Cement Co. It has three coal-fired shaft kilns. The Bamburri plant serves the coastal areas and the export market. The Athi River factory of East African Portland Cement Co. is supplier of domestic industry in noncoastal and upcountry areas. The Bamburri Plant uses dry process kilns. The Athi River plant uses a wet process kiln - which requires much more energy than the dry process.

The 1980 consumption of cement is estimated at 725,000 metric tons. The combined capacity of Bamburri and Athi River mills have combined production capacity of 1.5 million metric tons of cement. Thus about half the production is available for export.

1.6 Alcohol

Two alcohol plants are under construction, one at Kisumui to be completed in 1982 and one at Muhoroni planned for 1983-4 completion. The alcohol is to be used as a motor fuel. The

Table 2B-4
Installed Capacity and Generation of Electricity, 1976-1980

	Installed Capacity* MW**			Generation* GWH†		
	Hydro	Thermal	Total	Hydro	Thermal	Total
1976	171·4	181·7	353·1	583·2	574·7	1,157·9
1977	173·5	182·9	356·4	749·3	364·0	1,113·1
1978	311·5	171·6	483·1	1,072·8	308·9	1,381·7
1979	318·0	162·9	480·9	1,308·2	259·4	1,567·6
1980	313·5	171·6	485·1	1,060·0	430·0	1,490·0

*Includes estimates for industrial establishment with generation capacity.

**1 megawatt = 1 million watts = 1,000 kilowatts.

†1 gigawatt hour = 1,000,000 kilowatt hours.

TABLE 2B-5

Projected Electricity Supply Potential and Demand 1983-2000

Megawatts

	1983	1988	1993	2000
Supply-Hydro	600	600	600	600
Geothermal	30	170	500	500
Total supply potential	630	770	1,100	1,200
Projected demand	362	517	747	1,267
Surplus or deficit	208	253	353	−167

TABLE 2B-6

Electricity Energy Supply and Demand Balance, 1976-1980

million KWH

	1976	1977	1978	1979	1980
DEMAND—					
Domestic and Small Commercial	302	339	360	385	402
Large Commercial and Industrial	709	812	884	961	1,014
Off-peak	130	111	117	123	111
Street Lighting	11	11	10	10	11
TOTAL	1,152	1,273	1,371	1,479	1,538
Transmission losses and unallocated demand ..	170	84	203	224	238
TOTAL DEMAND = TOTAL SUPPLY	1,322	1,357	1,574	1,703	1,776
Of which imports from Uganda	242	272	217	160	315
Net generation	1,080	1,085	1,357	1,543	1,461

plants are designed to produce 60,000 liters/day of alcohol each from molasses. A proposed ethanol production plant would produce 180,000 liters per day from sugar cane juice by 1984-5.

1.7 Economic Projections

It is expected that demand for Kenya's primary exports, coffee and tea, will be weak. Combined with increased costs of imports and imported oil and high interest rates for funds, the present problems will increase unless alternative energy sources to petroleum can be developed and a reduction in oil consumption achieved. Industry has a great interest in conservation or alternative energy sources that will reduce costs and make its products competitive on world markets.

2.0 Views and Interviews

The following summarizes, in chronological order, the interviews held and plant visits made during the trips while in Kenya between December 30, 1981, and January 17, 1982.

2.1 Present:

U.S. AID

C. Bliss

U.S. State Department

Richard Eney

Sally Patton, Energy Officer for East Africa Bureau

Burns and Roe, Inc.

E. Kimel

I. L. Chait

at Offices of AID, Energy Office
Rosslyn, Virginia

Burns and Roe was briefed on Kenya situation. Ms. Patton suggested that Economic Development International (Mike Jones) be contacted with regard to Kenya.

Nairobi is the transportation hub for entire area.

Industry development is based on substituting native products for imports.

Ports exist at Mombasa and on Lake Victoria.

Kenya is wholly dependent on imported oil though oil is being sought under Lake Victoria.

Oil is obtained from Saudi Arabia and Qatar.

An oil refinery is located in Mombasa.

Major oil users may be the cement and fertilizer industries.

The National Electric Authority supplies electric power between regions. Most power is from small local generators.

Geothermal plants exist in Kenya.

Wood is burned, which has led to deforestation problem.

The Bureau of Private Enterprise may have information pertinent to the study.

2.2 Present:

Mr. Habib, First Secretary, Commercial Attache

at Kenya's U.S. Embassy, Washington, D.C.

Electric power supplier is East African Power and Lighting Company.

Electricity is also obtained from Uganda, mostly hydro power.

Bamburri Cement Co. (private co.), at Mombasa, has begun to convert from oil to coal.

A Cement plant and oil refinery are located in Mombasa.

Kenya Association of Manufacturers is a good source of information about oil users.

The University of Nairobi has an engineering department.

2.3 Present:

Joe Pastic, AID Mission Energy Officer & Project Officer

at Union Tower Building, Nairobi

Burns and Roe was briefed on the arrangements for starting the project in Kenya. Meetings have been arranged with Mr. W. J. Wairegi, Director of Technical Division of the Kenya Ministry of Energy, and with Mr. J. K. Gecau, Chairman and Chief Executive of the East Africa Power & Lighting Co., Ltd. A copy of "CDSS Position Paper Energy" was furnished. A paper prepared by Lee Schipper et al on energy conservation was recommended.

About 11 percent of petroleum imports are used to generate electricity.

H. G. Mike Jones of Energy/Development International, Team Leader - Renewable Energy Project in Kenya, was particularly interested in knowing whether the present COM study would include the use of wood as an energy source to replace oil. Present practices of using wood for domestic fuel are adversely affecting the forests. Currently there is no plan to rectify the situation.

2.4 Present:

Mr. W. J. Wairegi

at Ministry of Energy, Harrembee Street, Nairobi

Copies of the "Status" and "Data" documents and of a paper on Coal-oil conversion by E. Kimel were given to the Ministry.

A seminar on COM Combustion Technology was planned.

2.5 Present:

Mr. J. K. Gecau, Chairman and Chief Executive
East Africa Power & Lighting Company, Ltd.

Mr. Jabbal, Chief Planning Officer
East Africa Power & Lighting Company, Ltd.

at Offices of East Africa Power & Lighting Company, Harrembee Street, Nairobi

The objectives of the project were described, and copies of "Status" and "Data" documents were presented to EAPL.

Mr. Jabbal stated that EAP&L uses no coal. He furnished a copy of the 1980 Annual report of EAP&L and an April 1981 "Preliminary Report on Coal-Fired Station at Mombasa" prepared by Development Consultants of India.

EAP&L is considering a coal-fired unit for operation by 1993 at Mombasa. There are currently no port coal handling facilities or any other parts of an infrastructure to deliver and receive coal. A 60 MW coal fired unit appears to be economically justified if unit load factor is above 50 percent. The present system load factor is 30 percent. System demand growth is down from 8.2% to 6-7%/year. The cost of a 120 MW coal station (2-60 MW units) is estimated to cost $150,000,000 (1981$).

Boilers presently in use were manufactured by Babcock & Wilcox, Ltd., and others. Hydro provides the major portion of the country's electric power.

The present oil refinery output, which is set by transportation sector requirements, results in an excess supply of residual oil. EAP&L requires only about 50% of residual output, and the rest is exported. The export price of residual is at "Opportunity Price" and, under present conditions, it is less than the price set by the government paid by EAP&L. Residual oil is presently priced on the world market at 10-15 percent lower than the crude oil price. Presently there is pressure for EAP&L to continue to burn residual oil because oil is plentiful and adequate storage does not exist.

Oil is imported from North African countries. An oil pipeline connects Nairobi and Mombasa. The thermal power plant at Mombasa obtains its fuel by pipeline directly from the oil refinery at Mombasa.

Coal, for use in the cement industry, is imported from southern Africa - Swaziland, Zimbabwe. There is inadequate data on the amount of coal available; data is being assembled.

2.6 Present:

Mr. P. Getecha, Technical Manager, EAP&L

Mr. Getecha indicated that present technology and knowledge of coal is practically non-existent. There is no existing coal infrastructure in Kenya. Coal may be obtained from India, Mozambique, Swaziland. The economics of coal fired plants have always been unfavorable when compared to new hydro power units. There is still plenty of opportunity for hydro power. Mr. Getecha thinks that the future favors geothermal and hydro over thermal plants, particularly coal plants. Average load growth has been 8% per year.

2.7 Present:

Mr. J. Ouma, Chief Engineer, Operations and Maintenance, EAP&L

Mr. Ouma had reviewed the list of data and information requested and indicated that information could be obtained at the Kipavu Power Station in Mombasa.

Mr. Ouma indicated his interest in the COM Combustion Technology seminar and, if requested, will assign his personnel to attend.

2.8 Present:

Mr. Francis Mayieka - Assistant Secretary for Energy

at Offices of Ministry of Energy

The fuel used in the refinery processes is surplus residual oil produced at the refinery. Since coal has to be imported and residual oil does not, residual oil is cheaper to burn than imported coal. No consideration to replacing residual oil has been given at the refinery.

Mr. Van Luijk, the General Manager of East African Refinery, has had previous contacts with the Ministry of Energy about COM.

The following list of items that are required for the study and a proposed itinerary was submitted:

1. Arrange for COM Combustion Seminar on January 15 in East African Power & Lighting's auditorium.

2. List of industrial companies using oil, the quantities used by each company per year and how it is used, such as steam generation for plant process heating, space heating or other service.

3. During visit to Mombasa:

   a. Visit the East Africa Power & Lighting Company's Kipavu Thermal Plant

   b. Visit East African Oil Refinery

   c. Visit cement plant (Bamburri)

   d. Visit other industrial oil users - chemicals, food processing, fertilizer, ceramics, etc.

4. In Nairobi:

   Visit industrial plants using oil and meet with organizations that have the oil usage data.

2.9 <u>Present</u>:

Mr. R. E. Nuttal, Thermal Plant Manager of Kipavu Power Plant

at Kipavu Power Station

The plant serves the entire coastline of Kenya, north and south.

Mr. Nuttal stated that Kipavu boilers were designed to burn fuel oil and no other fuel; he thinks they cannot burn coal.

The oil supply is piped directly from the Mombasa refinery. The line is about 4 kilometers long.

The boilers are John Thomson (JT) and Babcock & Wilcox, Ltd. (B&W) and have the following ratings:

Boiler Nos. Installed	No.	Mfr.	Pressure psi	Temp. °F	Steam Generation lbs/hr	Rating
1956	1	B&W	400	750	60,000	2-5 MW
1956	2	B&W	400	750	60,000	2-5 MW
1956	3	B&W	400	750	60,000	2-5 MW
1965	4	B&W	625	865	130,000	12.5
1965	5	B&W	625	865	130,000	12.5
1972	6	JT	900	900	300,000	30
1976	7	JT	900	900	300,000	30

Boilers are D-type, water-tube type with flat bottoms.

No ash removal facilities now exist. Air heater corrosion is a major problem. The boilers are washed down annually, and air heaters are washed every 3 months.

The plant is trying to reduce rate of corrosion of tubular air heater by operating the units at highest output so that the temperature in the air heater is above the dew point. Even so air heater tubes must be renewed annually.

Another problem is it is not possible to get spare parts for Units 4 and 5 as well as earlier units. They need completely new sootblowers which they must fabricate themselves. Tubes and other iron materials must be imported from Scotland.

Peak demand from plant was 63.5 MW. The plant capability is 98 MW, but it has never been able to produce that. 25 MW hydro comes from the Nairobi connection.

Station load factors have been low except for the drought year of 1980. Thus:

Year	Station Load Factors %
1978	58.45
1979	49.28
1980	70.1 (due to drought)

Overall efficiency of all units at plant last year was 22.5 percent.

0.371 kg of fuel is used per kWh generated.

Oil Usage/Year

1981 - 105,484 metric tons; Gross Power Generated 284.295 Gwh
1980 - 128,177 metric tons; Gross Power Generated 332.9 Gwh
1979 - 34,149 metric tons; Gross Power Generated 205.49 Gwh
1978 - 97,385 metric tons; Gross Power Generated 252.13 Gwh

EAP&L is planning two coal-fired 60 MW units to go on lin in 1993-1994.

2.10 Present:

Mr. M. B. Alwin, Manager of Technology

Mr. Van Luijk, General Manager of Refinery

at East African Oil Refineries Limited Plant

The refinery supplies oil to power plants, railroads and to depots owned by oil companies Caltex, Shell, BP, Mobil and Exxon. A pipeline to Nairobi carries gasoline and kerosene.

1981 consumption at the refinery was 40,000 tons of fuel oil and 35,000 tons of gas. One-third of the gas could potentially be condensed to LPG but the market is small, so the surplus is burned as fuel rather than flaring it.

Many factors currently limit developing an LPG market in Kenya. LPG distribution would be a logistics problem, and its costs would be prohibitive. Bottles would cost several thousand shillings, facilities to distribute LPG do not exist, and LPG is too costly for the rural population. Also, fewer than 10 rail tank cars are available to distribute LPG in Kenya.

Gasoline costs about $2.27/gallon. The high price has resulted in great decrease in demand. Growth is expected to be much less than was anticipated.

Diesel fuel has 1 percent sulfur as required by railroads which were converted from coal to diesel fuel. It would require new engines to convert back to coal.

About $200,000,000 (U.S.) has been spent to build an ethanol plant to make ethanol from sugar cane. The ethanol was expected to be mixed with "top" oil. It has not been completed as yet, and the fuel is not likely to be competitive with gasoline.

Mr. Van Luijk inquired about the state of COM technology, whether Japan had advanced in the field, and the state of coal gasification at this time.

2.11 Present:

Mr. James M. Klimanthi, Works Manager

at Bamburri Portland Cement Co., Mombasa

Bamburri Portland Cement, originally Standard Portland Cement Co., started operation in 1952; Bamburri is owned by English and Swiss investors with the government as minority owner.

The vertical kilns use coal. The coal was anthracite from South Africa and was the best fuel for this type of process. After trade with South Africa was stopped, other coal sources were sought. Swaziland coal is now used; it is of a lower quality than the S.A. coal but had to be accepted for political reasons. A graded washed and cleaned coal, still lower quality than the S.A. coal, Mozambique, and its supply is not secure.

Bamburri is constantly looking for better quality or better priced coal.

No other industry is importing coal in Kenya, though Bamburri supplies some small coal users in its area who burn about 100 tons of coal per year.

In 1967, one rotary type kiln was constructed and designed to use fuel oil. A second rotary kiln was added in 1976, which also was designed for fuel oil.

Total fuel oil used by the two rotary kilns is 250 metric tons per day.

Fuel oil is also used for auxiliary furnaces, to keep the kilns warm while the process is shutdown.

The fuel oil supplied to Bamburri is a blend of lighter fractions with heavy oil to meet cement plant requirements.

The vertical kilns are still in operation using coal.

An evaluation was made which indicated that it was worthwhile to convert the rotary A to coal firing.

Price of cement to Kenyan customers is controlled. Therefore, before owners invest in conversion equipment they require guarantees from the government that price will not be held down so that a good return on the investment will be achievable. Money for the conversion has been found from various sources; the decision has been made to convert to coal and will be completed next year (1983).

Bamburri will retain 100 percent fuel oil firing capability for the rotary kilns in case of interruption of coal supply.

Prices used in the evaluation were 900 shillings/ton for coal and 2,000 shillings/ton for oil.

Bamburri stated that if COM were competitively priced, they would prefer that COM be provided by a central production plant since they do not want to operate a COM production plant.

The East African Portland Cement Plant in Nairobi has two kilns using a wet process which consumes a large amount of energy. East African Portland Cement in Nairobi may be able to use COM. The Nairobi Cement Co. receives its oil from the Mombasa refinery. Coal is not being considered as there are no facilities for coal in Nairobi. The coal would have to be received from Mombasa. Barracha (Port of Mombasa) cannot handle coal for the Nairobi cement plant. The harbor cannot handle much more shipping, as it handles almost all types of imports, grain, food, molasses, soda, etc., and can only handle one ship at a time.

2.12 Present:

Mr. G. J. Okoth, Operation Superintendent

at Kenya Shell Ltd., Mombasa

A sample of COM was shown to Mr. Okoth; he asked if he could obtain a sample.

Shell-Supplied Fuel Oil for 1981:

110,000 tons/year is used in Nairobi and upcountry. Of this a small amount goes to Uganda and Ruanda.

There are six empty tanks at present at the Shell Storage depot in Mombasa which could be used to store COM.

Mr. Okoth identified the following oil users:

1. Bamburri Portland Cement, uses 65,000-70,000 tons per year, at present
2. Kipavu Power Plant, uses 100,000 tons/year
3. All other users in the Mombasa area use less than 5,000 tons/year
4. Remainder goes up-country or is exported.

Fuel oil is obtained by Shell from the refinery by pipeline. If Shell cannot get proper fuel oil to meet specifications for Bamburri, Shell will send fuel oil from its facility by truck.

Shell, BP Esso, Caltex form a single marketing group on the island.

The largest oil users in Nairobi Area are:

1. Bad & Cordade
2. BAT (British-America Tobacco)
3. BAT Thika
4. East African Portland Cement
5. Kenya Meat Commission
6. Bata Shoe Co.
7. Food Specialties
8. Thika Cloth Mills
9. Kenya Peppermills
10. Cadbury Sweets.

These facilities are supplied with fuel oil by a rail to depots near Nairobi.

Upcountry from Nairobi sub-depots exist to supply the tea and sugar industries.

2.13 Present:

Mr. Joe Pastic

at U.S. AID Offices, Nairobi

Joe Pastic was brought up-to-date on task progress.

Joe Pastic recommended a report by Lee Schipper et al. of University of California Berkeley on Energy Conservation.

2.14 Present:

Mr. N. J. Muriuki of Kenya Shell

at Offices of Kenya Shell, Harrambee Street, Nairobi

Mr. Muriuki offered the names of potential users of coal:

- Magadi Soda Co. - mfr. of soda ash and located 50 miles northwest of Nairobi
- East African Power & Lighting
- East African Portland Cement
- Pan American Paper Co. - paper made in West Kenya
- Tea Companies - large fuel oil users but are converting from oil to wood fuels.

In 1980 Shell contacted all potential coal consumers to project fuel requirements. Many were not interested; those who did respond apparently had not done their homework and were vague about their plans for possible coal use.

Bamburri Cement projections are for 180,000 tons of coal by 1982. Bamburri gets anthracite from Swaziland via Mancotti to Mombasa. Logistics are a difficult problem; consequently, Bamburri must maintain at least a 3 month coal pile.

Bamburri brings in coal in lots of 3000 tons because Barrochi Port has very limited capacity.

The Port Authority has plans for locating a bulk product unloading facility at an upstream location. However, dredging and new rail facilities are required and siting is a problem. For these reasons construction of new port facilities in the 1980's is unlikely.

Coal would provide relative savings on foreign exchange since fob price of coal is less than fob price or crude oil. However, the infrastructure for coal does not exist, to import and distribute it.

The possibility of applying COM in Kenya would depend on economics. The know-how would have to be acquired.

It is conceivable that Kenya could produce the COM and export it to the international market as is the residual fuel oil which is exported to international market. Potential markets are Uganda, southern Sudan.

Exploration for coal and oil are being pursued in Tanzania and South Sudan. The mines are deep mines, and problems of reaching market exist.

The average crude oil price today is $36/barrel (Saudi light).

The minimum price of Bunker C inland averages $170/metric ton.

The minimum price for marine diesel, set by the Kenyan government, is about $354/ton.

The refinery is 50 percent Government-owned, while Shell and B.P. have 12.75% each and Esso and Caltex have 12.25% each.

Over 40% of crude produced is residual at present.

An average barrel produced by the refinery is allocated as follows:

Essential Service (hospitals, armed forces, cement)	2.5%
Infrasturcture: railways, ports, power plants	30.0%
Agriculture:	3.1%
Manufacturing:	14.3%
Retail Trade:	18.1%
Bunkers (gas, oil):	5.7%
Exports:	26.0%

An investment of $100,000,000 would be required for cracking units to increase light fraction at expense of residuals. It would reduce residual production to about 20% of crude barrel.

Population growth is 4 percent per year.

Present terms of trade do not generate enough money to pe mit expansion to provide for this growth.

Also the export potential, to Zambia, Tanzania and Uganda, that Shell previously had, has deteriorated.

Not enough food was grown last year so extra food had to be imported.

Taxes received by government have declined because of the lost markets and power production. The present outlook for economy is poor.

2.15 <u>Present</u>:

Mr. Karanga of East African Portland Cement Co.

at Offices of East African Portland Cement Co.

Bamburri cement uses a dry process for cement production which is partly fired by oil and partly by coal.

In Nairobi, E.A. Portland Cement uses a wet process.

The energy consumption of the dry process is 2/3 of wet process energy requirements.

Conversion to a dry process and to coal would result in considerable energy savings and costs. However, the conversion would require a substantial investment. The Mombasa port has facilities to discharge, stock and transport materials. E.A. Portland Cement Co. has asked the government, port and railway authorities to provide facilities for handling and transporting coal to Nairobi. About 100,000 metric tons of coal per year would be required by E.A. Portland Cement.

It is expected that these investments will not be made before 1985.

Conversion to a dry process is not required to utilize coal.

It is estimated that cost of converting the wet process to coal would be 5,000,000 pounds (1 pound = $2 U.S.) in 1983.

An additional 50,000,000 Kenya pounds would be required to convert from the wet to the dry process (1985 completion).

The real savings will be achieved by converting to coal combustion though a lesser saving can be had with COM.

The coal price is estimated as 40 pounds K per metric ton delivered to Mombasa.

Foreign exchange savings of 6,000,000 pounds per year over the actual production costs of coal, including cost of conversion to coal, would be realized by switching from residual oil to coal.

E.A.P.C. analyzes investments over a period of about 5 years. If differential between oil and coal grows, the savings would be even greater.

2.16 Present:

W.J. Wairegi - Ministry of Energy
F. Mayieka - Ministry of Energy
H.S. Jabbal - East Africa Power & Lighting
E. Wasunna - East Africa Power & Lighting
G.M. Juanyara - East Africa Power & Lighting
Nicholas Dover - East Africa Power & Lighting

at Auditorium of East Africa Power & Lighting Co. in Nairobi

A seminar was held in which details of COM technology, experience with conversions and demonstration plants and the status of present technology were presented.

Copies of the COM State-of-the-Art Report and papers on coal conversion and COM were distributed to all attendees.

2.17 Present:

Mr. H.S. Jabbal, Chief, Planning Department

at East Africa Power and Lighting Co.

Mr. Jabbal presented written responses to the information questionnaire given to him in a previous meeting. Where is questionnaire

East Africa Power & Lighting has identified one site, named "Rifle Range," for its next generating station. Although this site was originally selected for oil-firing, it is suitable for two 60 MW coal-fired units.

The problem with coal firing is that a minimum expenditure of $67,000,000 would be required to bring coal to the Nairobi area.

To increase system reliability, East Africa Power & Lighting is considering adding a combined cycle unit and a new transmission line between Mombasa and Nairobi.

The present Kipavu thermal plant does not have space for pulverizers or coal storage. Thus, coal would have to be delivered in a pulverized state, which makes COM a possible alternative.

The Kipavu units operate at a load factor of 82 percent so that, if converted to coal or COM, the units would have to be derated and operated continuously at the new rated load. Switching from coal to oil and back to obtain outputs would not be possible except infrequently.

2.18 Present:

Mr. Wairegi of Ministry of Energy

at Offices of Ministry of Energy

It was stated that introduction of COM technology could take place in three stages:

1. The efficiency of all industrial boilers could be ascertained and steps taken to improve their efficiency where feasible.

2. Use of coal-oil-mixture as fuel for those boilers and furnaces in which it is feasible.

3. Construct COM Production plant to serve all converted boilers.

For example, the sugar industry uses energy inefficiently. Most of the industry is located in the Western Kenya Lake area. It would be difficult to deliver coal there, but COM could be delivered via the existing fuel oil network. There is no seasonal crop; it rains all year and sugar cane is harvested all year, making for uniform energy demand.

Bagasse can be used as fuel in sugar plants to generate power. Energy usage in the sugar industry could be used to increase production.

At least 20 factories would by candidates for conversion including soda ash, cement, breweries, paper, meat, confectioners, synthetic fibers, pineapples - about 10 plants are located in the Nairobi area, 10 in the Thika area and 5 in the Mombasa area.

2.19 Present:

Andrew H. Robson - Production Manager - EAPCCL
Francis Mayieka - Assistant Secretary - Ministry of Energy

at East African Portland Cement Company, Ltd. (EAPCCL)
Athi River Factory, Athi River, Kenya

The team visited the Athi River cement production facilities and paid special attention to the material handling, kilns, burners and fuel oil preparation equipment.

The Athi plant has a maximum production capability of 450,000 tons cement per year. It now operates at 366,000 tons per year. Presently, approximately 130 tons of residual fuel oil is used daily in this plant.

The plant consists of two kilns. The first was installed in 1958 and the second in 1974. The Athi River plant uses the wet process, which uses about twice as much fuel per unit of product as the dry process.

Conversion to coal or coal-oil-mixture fuels is technically feasible and could best be implemented together with the modification of the production process from wet to dry.

Converting the Athi River plant to the dry process is contemplated which would substantially reduce fuel oil consumption. Feasibility studies were performed, but since conversion would require large investments, no definite date for conversion is set.

Conversion to coal firing was studied, but due to the difficulty in transporting imported coal by rail from Mombasa, it is believed to result in marginal savings to the plant.

Improvements in present operations for better fuel utilization can also be made. These could include more efficient heat recovery from clinker coolers, burner modification for better efficiency, heat recovery from flue gases, etc.

2.20 Present:

R.W. Behmler - Director of Operations, KMC
B. Withers - Chief Engineer, KMC
F. Mayieka - Assistant Secretary, Ministry of Energy

at Kenya Meat Commission (KMC), Athi River Processing Plant

The KMC slaughters and processes about 500 cattle per day at the Athi River plant, and 250 to 300 per day at their plant in Mombasa.

The annual fuel oil consumption for process steam is about 3.5 million liters at a cost of 6.3 million K shillings. It is planned that in 1982 the plant production will increase by 70% with a corresponding increase of fuel oil usage.

There are four boilers, three of which are normally in operation with the fourth on standby. Boilers No. 1 and 2 are about 30 years old. They are of the fire tube design with two burners each and are 9.5 ft. diameter by 16 ft. The No. 3 boiler is of similar design and vintage, but has only one burner and produces about 70% of the output of Unit No. 1 boiler. The No. 4 boiler is a 130-13,000 Perkins Maestro, fire tube boiler 10 ft. in diameter by 20.75 ft. long, and with a steaming capacity of 21,000 lbs/hr.

An inspection of the boiler house shows generally good housekeeping, but the boilers are equipped with minimal instrumentation and controls. Improving the efficiency of these boilers by adding economizers, more efficient burners and better controls appears possible.

Firing coal, COM or CWM will require boiler modifications to permit ash removal.

The KMC's management appears very interested in reducing their fuel cost, which is a large portion of their production costs. It appears that they lack funds for implementation of energy conservation measures.

2.21 <u>Present</u>:

Brian D. Rolls - Chief Engineer - KBL
W. Albrecht - Production Manager - KBL

at Kenya Breweries Ltd., (KBL), Ruaraka, Kenya

A visit was made to the boiler house of the Tusker Brewery and some of the main production equipment.

The Tusker Brewery in Ruaraka (approximately 10 km from Nairobi) is the largest facility. It produces about 1.1 million barrels of beer per year. The annual cost of fuel oil for this plant is about 20.7 million K shillings. Fuel oil accounts for 82% of total energy costs. The price of fuel oil (residual oil) in April 1981 was 1.823 shillings per liter at the plant.

Four (4) Meura fire tube boilers are used to produce process steam at the Tusker Brewery. These boilers were installed between 1966 and 1973. Each boiler is rated 25,000 lbs/hr with 51°C feedwater. The peak steam requirement is 75,000 lbs/hr, which can only be supplied with 3 boilers in operation at maximum capacity. Annual fuel consumption is about 9.5 million liters.

In September 1980 an energy audit of the brewery was performed by the Allied Breweries Engineering Services Ltd. of the UK.

A comparison of measured boiler efficiencies (during the energy audit) and the calculated values for boiler efficiency provided by the boiler manufactured have shown that these units operated below their design efficiency. The reasons for this deficiency are fouling and scaling of the tubes on both the water side and fire side, poor condensate recovery, burners out of adjustment, etc. Just restoring the boilers to original shape could save about 5.1% in fuel oil which on an annual basis would be about 1 million K shillings.

During the visit, boiler No. 3 was in the process of being overhauled. The tubes removed from this boiler showed scale deposition of about 1 to 2 millimeters on the water side. Addition of water softening or demineralization equipment is highly recommended. Such equipment will pay for itself, just by savings in retubing, let alone the associate fuel savings which may be derived.

Additional improvements in boiler efficiency could be obtained by addition of economizers to further reduce the flue gas temperature. The test data indicate that the boilers use about 20 to 25% excess air. A reduction to 10 to 15% excess air by use of more efficient burners and the addition of measurement gages to control combustion as well as overall boiler operation could further improve the efficiency of operation.

The existing boilers cannot be converted to coal firing. However, coal-derived fuels with low ash content could possibly be used, but means of bringing these fuels to the plant will have to be developed. The boilers will require some modifications of burners and ash removal systems.

KBL's management and technical personnel are fully aware of the need to conserve energy. They appear interested in taking steps to reduce energy usage per unit of production. An initial step was taken by KBL to commission an energy audit.

The work of operating and maintenance personnel was observed. Housekeeping is excellent; however, for operation, the high technical skills required were lacking. Training of personnel requires a long time since trainees have to improve their

basic education as well specific technical skills. KBL is putting great emphasis on training of its workers.

The Kenya Breweries Maltings Plant, at Kampala Road, Nairobi produces about 28,000 tons of maltings. The annual cost of fuel oil at this plant is 5.4 million K shillings representing 78% of total energy cost. Electricity costs about 1.5 million shillings per year (22% of energy costs). There are 4 boilers for steam and hot water production. Two of these boilers are rated at 2.655 mega kcal/hr (10,600 lbs/hr) each, and the other two boilers at 8 mega kcal/hr (32,000 lbs/hr) each. Annually, 3.4 million liters of fuel oil are used at this plant. Improvement in efficiency for these boilers similar to those at the Tusker plant is believed possible.

A summary of fuel oil costs for fire KBL plants for July 1980 is as follows:

Plant	Monthly F.O. Cost K Shillings
Tusker Brewery & BSP	1,723,016
All Sopps	178,662
City of Nairobi Plant	219,538
Maltings	586,312
Mombasa	142,484
Total	2,850,012

The resultant total annual cost for fuel oil is about 34.2 million shillings. The annual cost of electricity for all these plants is 9.6 million shillings.

2.22 Present:

J.R. Kemp - Chief Engineer (EAIL)

at East Africa Industries, Ltd., Nairobi, Kenya (EAIL)

The East Africa Industries, Ltd., is a large producer of consumer goods such as detergents, soaps, toothpaste, cosmetics, etc. Its main factory is in the Industrial section of Nairobi.

EAIL uses about 6,500 tons of fuel oil per year, 95% for steam production and 5% in processes. The annual cost of fuel oil is about 2.4 million Kenyan shillings.

About two years ago an energy conservation audit was performed by a team from Unilever (UK) and plant personnel. Some of the recommendations of the audit have been implemented.

The plant has 6 boilers producing steam at about 250 psig.

- Two of the boilers, one 20,000 lbs/hr and the others 16,000 lbs/hr, are manufactured by Perkins (UK) and

operate on fuel oil reportedly at an efficiency of 85%. These boilers are of the fire-tube construction.

- Two of the newer boilers made by Mario Pensotti of Italy, rated at 16 tons per hour each, are of the water tube (Type D) design and operate also at about 85% efficiency.

- The remaining two boilers made by Babcock & Wilcox, UK, rated 16,000 lbs/hr and 10,000 lbs/hr respectively, are fired with wood and coffee chaff. Their efficiency is about 33%.

The cost of steam generation is 152 K shillings per tonne of steam produced with oil, 72 K shilling per tonne produced firing wood, and 20 K shilling for firing coffee chaff.

Boiler operation appears to be done by well trained personnel, and housekeeping is very good. The instrumentation on the oil fired boilers permits control of basic boiler parameters, but lacks devices for combustion efficiency indications. The makeup water is tested and to a great extent condensate is recovered and used.

An inspection was made of EAIL's maintenance shop which is equipped with a good variety of modern machine tools. The availability of high quality technicians and workers appears to be a great problem in general.

It also appears that EAIL would like to implement a number of projects towards better energy utilization, but capital seems to be a great problem.

EAIL is interested in any practical means possible to reduce its fuel costs. It appears that space is not available for coal storage and handling. The boilers burning wood as well as the D-type boilers could possibly convert to COM, CWM or coal firing, but first the economics and reliability will have to be clearly demonstrated.

3) References

1. "Economic Survey - 1980" - Republic of Kenya Central Bureau of Statistics - Ministry of Economic Planning and Development.

2. "Economic Survey - 1981" - Republic of Kenya Central Bureau of Statistics - Ministry of Economic Planning and Development.

3. "CDSS Position Paper - Energy 1981"

4. Kenya Newsletter - September 1981, Embassy of Republic of Kenya, Washington, D.C.

5. East African Portland Cement - Commemorative Booklet

6. East African Power & Lighting Co., Limited , "Directors' Report 1980."

7. "Energy Use in Kenya (Excerpt) Oyuko O. Mbeche University of Nairobi - from Proceedings International Workshop on Energy Survey Methodologies for Developing Countries, January 21-25, 1980-Jekyll Island, Georgia, National Academy of Sciences.

8. East African Breweries Limited, "Annual Report and Accounts 1981."

9. "Energy Conservation in Kenya: Progress, Potentials, Problems" L. Schipper et. al. - Energy and Environment Division, Lawrence Berkeley Laboratory - University of California - September 1981.

BURNS & ROE / COM

Country Programs:

1) Seminars - workshops → Discussions
2) Surveys of selected industrial plants to determine conversion feasibility: consumption
   retrofit: equipment
   land/space
   cost

   Train locals to do it?

3) Assist in evaluating availability of coal supply
4) " " " coal slurry sources
   production techniques/facilitie
5) Assist in selection of equipment for retrofit: pumps, burners, pollution.
6) Contacts/exchange with US conversions
7) Strategies for investment
8) Help prepare project proposals for financing institutions

TRANSFER AND ADAPTATION ISSUES:

1) Capital Investment Funds:
   - Imported finished coal slurry
   - After a period of testing can make final decision

2) Prices and Security of Fuel Supply:
   - Coal imported dependence
   - Excess heavy fractions available (no incentive)
   - Flexibility to go either way? 100% coal — 100% oil?

3) Institutional Issues
- National energy plan to stress use of coal and CWM
- Reduction/elimination of oil subsidies (let it raise to world pri
- Allows short term amortization of equipment.

4) Alternative Energy Sources
- For countries with NO coal, investment on other supplies may be more desirable
- Need high level planners to decide?

5) Technical Issues:
- Less than coal only
- Infrastructure to handle coal: indigenous exploitation? ports, imports, etc.
- Plant specific survey
- CWM first stage (transition) to final CWM or coal and starts running oil now

6) Manpower Capabilities:
- Success will depend on people who implements (at ALL levels)

7) Market Development
- Market uses and a reliable supply should be parallel

8) Benefits
- Slower (or stop?) demand for fuel oil
- If coal is indigenous: develop new economy, skills
- If coal imported: from where, costs?
- Choice of fuels, flexibility (oil, water, methanol etc)

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