Cosponsors:

Ukrainian Ministry of Energy and Electrification
U.S. Department of Energy
U.S. Agency for International Development

Ukraine/U.S. Joint Conference on Ukraine Clean Coal Power Plant Upgrade Opportunities

Kiev, Ukraine

April 21–24, 1998

Спонсоры:
Министерство Энергетики и Электрификации Украины
Департамент Энергетики США
Агентство Международного Развития США

УКРАИНСКО-АМЕРИКАНСКАЯ
Объединенная Конференция
Возможности Модернизации
Украинских Угольных Электростанций

Киев, Украина

21-23 апреля 1998 г.

LIST OF REPORTS DEVELOPED FOR THE LUGANSK GRES UPGRADE PROJECT

1. **US/Ukraine Joint Power Plant Upgrade Project**
Rehabilitation of Lugansk GRES
October 1995. 290 pp.

Burns and Roe Enterprises, Inc.

The report describes methodology and results of a feasibility study for the rehabilitation of the Lugansk GRES. Technical definition and cost estimates were developed for several rehabilitation scenarios, including refurbishment of one or several existing 200 MW units, and replacement of decommissioned 100 MW unit with two 62.5 MW CFB boilers and one 125 MW steam turbine. The results were used by others to perform financial analyses on the various alternatives.

2. **Lugansk GRES. Rehabilitation Program. Economic and Financial Analysis.**
Final Report.
194 pp. November 1996

Parsons Power Group Inc.
Lynn Rubov, Albert Herman, Norma Kuehn, Roman Zaharchuk

Taylor-DeJongh.
Kevin McNamara

The report includes results of economic and financial analyses of technically viable options for rehabilitation of existing plants, as well as the addition of new CFB units. The economic analysis consists of structuring a number of options and estimates of capital and operating costs for each option to facilitate comparison on the basis of cost of electricity and other figures-of-merit. The least cost option was determined as refurbishment of one of existing 200 MW units, and replacement of decommissioned 100 MW unit with two 62.5 MW CFB boilers and one 125 MW steam turbine.
A financial analysis was then prepared to determine the ability of Lugansk GRES and Donbassenergo operations to support the project selected in economic analysis.

3. **Waste Coal Resources Investigation.**
148 pp. 1996.

Coal Energy Technology Center (CETC) of the National Academy of Sciences of Ukraine and Minenergo of Ukraine.

Dr. Alexander Maystrenko, Dr. Natalya Dunaevskaya, Eng. Anatoly Roskolupa, Dr. Nikolay Chernyavsky.

Technical Committee of Ukraine of Standard TC-92"Coal and Products of its Refabrication"
Dr. Yury Filipenko.

This report contains evaluation of possibilities to use anthracite waste as a fuel for CFB boilers, and determination of amount and quality of anthracite waste located in dry waste banks and wet waste precipitation ponds.

4. **To Determine the Resources Of Fine Anthracite (Schtyb) and to Develop the Strategy of its Preparation for Deliveries to Luganskaya State District Power Station**
45 pp. 1996.

Ukrainian R&D Institute of Coal Preparation and Briquetting "UkrNII Ugleobogashchenie", Ministry of Coal Industry of Ukraine.

Dr. Ivan Kurchenko, Dr. Alexander Zolotko, Dr. Petr Skliar

The report contains the analysis of raw resources of anthracite in Lugansk region and prospects of its development till year 2030. Acting anthracite plants are observed. The selection of potential suppliers of prepared schtyb to Luganskaya GRES was made and their resource base for the period of the year 2000 to 2030 was determined.

5. **Fuel Sourcing for Upgraded Lugansk GRES Power Station**
15 pp. January, 1997.

Science Applications International Corporation
Dr. Victor Gorokhov

U.S. Department of Energy
Dr. John Ruether

This report was developed to generalize the results of two Ukrainian studies, namely: 1) "To Determine the Resources of Fine Anthracite (Schtyb) and to Develop the Strategy of its Preparation for Deliveries to Luganskaya State District Power Station," and 2)" Waste Coal Resources Investigation," and to describe the prospects for coal sourcing for a rehabilitated Lugansk GRES.

6. **Background and Cost Estimates for Measures to Compensate Electric Power Deficit in the Lugansk Region**
83 pp. June 1997. Russian Language.

General Contractor: Kharkov Central Design Bureau "Energoprogres"
Subcontractors: Ukrainian Ministry for Power and Electrification
Ukrainian National Dispatch Center
Donbass Regional Dispatch Center
Donetsk Power Industrial Company
Ukrainian Coal Energy Technology Center
Design Company "Elektrosetproekt"

Project Manager Vasily Karachevtsev

The report includes evaluation of feasibility and cost estimates for two options for obtaining an additional 350 MW in Lugansk region as alternatives to the project of upgrade the Lugansk GRES. Evaluated options are as follows: 1) construction of a new electric transmission line from the Central region of Ukraine with extensive power production, and 2) construction of a greenfield power unit consisting from two 62.5 MW CFB boilers and one 125 MW steam turbine, located in close proximity to one or more coal beneficiation plants and using coal beneficiation waste as fuel.

7. **Additional Analyses for the Lugansk GRES Upgrade Project.**
82 pp. June 1997.

Science Applications International Corporation
Dr. Victor Gorokhov

Parsons Power Group
Norma Kuehn

U.S. Department of Energy
Dr. Howard Feibus
Dr. John Ruether

This study evaluates two additional options for development of 350 MW in the Lugansk region: 1)refurbishment of one of existing 200 MW unit at Lugansk GRES and construction of a greenfield 125 MW CFB unit, and 2) the construction of a new transmission line between Lugansk region and Central region of Ukraine. The study includes estimation of capital and O&M expences for new construction and the refurbishment of generating capacity choosen for replacement of the capacity at Lugansk GRES. Cost estimation is used in economic comparison of all three options, including base case project.

FORWARD

Beginning in 1994, a Clean Coal Technology Task Force was formed to demonstrate in a concrete way how modern technologies for coal utilization could be used to benefit the thermal power sector of Ukraine. The Task Force was formed under sponsorship of the U.S. Agency for International Development, and membership consisted of the U.S. Department of Energy (Office of Fossil Energy), the Ukrainian Ministry of Energy (Minenergo), and the Ukrainian Academy of Sciences. The Task Force performed a project definition study for upgrading an anthracite-burning generating station in the Donbass region, named Lugansk GRES. The study was completed in 1997 with the preparation of engineering and financial analyses for the upgrade project.

On April 21-24, 1998, a conference was held in Kiev to present the results of the Task Force study. Two other types of papers were also presented at the conference. Members of the Ukrainian thermal power industry described investment needs and opportunities. As well, representatives of organizations with international experience in developing and funding power projects described their perceptions of the Ukrainian thermal power sector and the roles their organizations were prepared to play to strengthen the sector.

The present report contains the proceedings of that conference.

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Power Sector of Ukraine: Investment Possibilities for Rehabilitation of Thermal Power Plants

Vladimir Luchnikov, First Deputy Minister, Ukrainian Ministry of Power

Power industry of Ukraine is highly developed sector of the national economy and represents a complete technological cycle, including design, manufacturing, distribution and selling electric and heat power.
Installed capacity of power plants in the integrated power system is 52.0 mln kW, of which 31.8 mln kW (61%) is the share of thermal power plants, 12.8 mln kW (25%) of nuclear power, 4.7mln kW (9%) of hydropower and 2.7 mln kW (5%) at spot units.

Length of electric high voltage lines of 0.4 kV to 750 kV in operation exceeds 1 mln kilometers, the length of heat networks is 3 thousand kilometers.

Nuclear power is represented by 15 nuclear power units (NPU) having capacities ranging 400–1000 MW (5 nuclear power stations in the total).
Beside this, another 4 nuclear power units are now at different stages of construction (Khmelnitsk NPS: units No. 2, 3, 4; Rovno NPS – unit No. 4).

All this potential is acting within scope of legal, administrative and dispatch-control functioning of Ukrainian power sector.

Power plants built in the period 1959-1975 do not comply with modern standards of economic efficiency and environment protection. As about 80% of fossil power units have exceeded their lifetime (100,000 operation hours), thermal power plants need extensive reconstruction.

Big share of NPS's in the power balance predetermines fossil power units operation at unrated maneuvering regimes.

Present condition of the equipment and experience of Chernobyl NPS dictate necessity of providing equivalent replacement of power, finishing of No.2 unit erection at Khmelnitsk NPS and No.4 unit at Rovno NPS, as well as rehabilitation of existing fossil power plants applying new technologies of Ukrainian coals firing at CFB, arch boilers, etc. This will allow to prolong lifetime of power plants, to improve ecological situation and decrease dependence on imports of fossil fuels. To improve investing climate in Ukrainian power sector, special program on transition to market relations has been launched for power branch. Members of Energomarket were defined, representing seven state generating stock companies and 27 distribution companies. Meanwhile, a single energy system of Ukraine was preserved.

After power branch restructuring, conditions were created for establishing market relations between suppliers and consumers of electricity providing competition of generating companies.

Program for privatization of the state energy stock companies (SESC) at the first stage foresee the stabilization of the branch functioning by means of involving non-state investment and improvement of the control of the objects belonging to power sector. Typical approach will be applied for privatization of each energy company assuming their physical and economic conditions.

Privatization of SESC includes:

- selling 25% of shares on favorable conditions;
- selling to power distribution companies not less than 24% of shares on the fixed financial conditions applying tendering system. To raise the interest of investors, conditions of the tender will be extended with statement on transferring to the winner a definite package of state owned block of shares without competition, as it foreseen by Decree of the President of Ukraine "On State Program of Privatization for year 1998" No.40/98 dated 21 January 1998.
- 51% of the shares of generating companies and 26% of the shares of energy distribution companies will be withheld by the State.

After the first stage of privatization the State should remain in possession of not less than 26% of shares of each distribution company and 51% of shares of each generating company.

In fulfillment of the Charge No.1-14/913 of 97.12.18 given by the President of Ukraine Mr.L.D.Kuchma the Ministry of Energy of Ukraine and the Fund of State Property of Ukraine have elaborated a time-schedule for tenders on fixed conditions.

According to the plan of privatization, Ukrainian Fund of State Property have developed and confirmed in December 1997 the fixed conditions for tenders on selling blocks of shares of nine state energy distribution companies, according to which the obtained means will enter the state budget and will be assigned for improvement of financial situation of the companies. At the beginning of December, tender presentation for these companies was organized, at which both national and foreign investors were present. However, resulting from overestimation by the Fund of State Property of the costs of blocks of shares only two companies were sold (Ternopoloblenergo and Kirovogradoblenergo).

Another 13 energy distribution companies are still under preparation of commercial tenders during which the negative experience of selling blocks of shares of the first nine companies should be accounted.

The plans on allocating shares of the four energy distribution companies (Dnieperoblenergo, Vinnitsaoblenergo, Rovnooblenergo, Zaporozhyeoblenergo) are now on consideration at the Cabinet for making decision on the blocks of shares (26% of charter fund) that will be withheld by the State.

Concerning the state power generating company Donbassenergo the decision was taken to propose block of shares (24%) for open bidding arranged according the Guidelines on preparing and conducting open bidding (tenders). On competitive basis the charged advisor from State Property Fund was assigned to guide the open tender.

Commercial tenders are conducted according to the rules rigidly regulating the schedule of the stages.

The second stage of privatization could take place under condition of positive results and achieved objectives of the first stage of privatization.

Second stage of SESC privatization includes:
selling to investor the state owned block of shares which was under its control, in the case of fulfillment of obligations on investing (fixed conditions) and requirements of the agreement on shares control, or in the case that decision on further selling of the package by means of bidding was taken.

Realization of the National Ukrainian Program for Energy until year 2010 gives a background to investments for reconstruction and modernization of existing power objects, mainly fossil power plants, directing for this purposes 1.0 billion USD each year. Difficult economic and financial situation in power sector does not allow to arrange finance neither using own funds accumulation, nor the budget. So, involving of additional resources, both foreign and internal, becomes one of the key problems for power branch.

By these reasons, Minenergo is conducting consistent policy on attracting means of foreign investors and loans for rehabilitation of generating resources of power branch. The most available creditors at present time are The World Bank and the European Bank for Reconstruction and Development, whose activities are focused on developing infrastructure in the countries with transition economies.

In 1997 approximately 180 mln. UAH of foreign credits were attracted to finance projects.

At present time, another four projects financed from foreign credits are at the stage of realization.

Hydropower Rehabilitation and System Control Project
In this project, rehabilitation program will be implemented for hydropower stations at Dnieper river aiming the improvements of control of generating units, communication systems, dispatch facilities, management and safety at NDC and RDC (National and Regional dispatch centers).

Ukraine Electricity market Development
In this project, working capital will be provided to thermal power generators in Ukraine to purchase fuel and spare parts for delayed maintenance works.

Project for Modernization of Starobeshevo Power Plant
is assigned for reconstruction of 200 MW unit by means of replacing the existing boiler with CFB boiler.

Project for Reconstruction of 300 MW Power Unit No.8 at Zmiev TPP
Physical and moral weariness of Zmiev TPP main and auxiliary equipment is now at the utmost possible level. Power units of 300 MW were derated to 275 MW, but practically their capacity does not exceed 250 MW. Power units after 30 years of operation (200,000 operating hours) should be radically reconstructed or replaced.
Objective of reconstructing unit No.8 is to extend its resource and improve efficiency applying

modern West and nationally developed technologies aiming the reduction of expenditures for imported heavy oil fuel, lowering pollution to the ambient and increase a share of the low-grade indigenous coal in fuel balance.

For nearest future Minenergo also developing other high-priority projects to attract investments.

To complete erection of big 1000 MW units 418 mln USD for Rovno NPS and 384 mln USD for Khmelnitsk NPS is needed. Also for completion of 2300 MW of Dniestrovskaya Hydropower Pump Storage Project approximately 500 mln USD is needed and another 300mln USD is requested for completion of Tashlyk HPPS.

Proposals for rehabilitation of other coal firing power plants having high priority and included to Ukrainian National Program for Power Branch Development

LUGANSK TPP

Installed capacity – 1800 MW (2 units x 100 MW, 8 units x 200 MW).
Start of operation: 1957 – 1968.
Rehabilitation of 175 MW power unit No.13 by replacing the wearied parts and mechanisms and installation of the modern equipment.
Cost of the project – 150 mln USD.
Payback period – 7 years.
Emissions – at the level of European standards.

SLAVIANSK TPP

Installed capacity – 1700 MW.
Start of operation: 1954 – 1971.
Erection of three new 125 MW power units with CFB boilers. At the first stage only one 125 MW unit will be constructed to replace existing 100 MW unit.
Cost of the project (per one unit) – 110 mln USD.
Options for investment - ownership and operation, joint venture, stock company.
Payback period – 7 years.
Emissions – at the level of European standards.

KURAKHOVO TPP

Installed capacity – 1460 MW (1 unit x 200 MW, 6 units x 210 MW).
Start of operation: 1972 – 1975.
Rehabilitation of 200 MW and 210 MW units aiming improvement of technical and economic performance and reduction of harmful pollution.
Cost of the project (per one unit) – 25 mln USD.
Options for investment – acquisition of shares and joint management, joint venture, stock company.
Payback period – 5 years.

Emissions – reduction to the level of modern regulations.

BURSHTYN TPP

Installed capacity – 2400 MW (12 units x 200 MW).
Start of operation: 1965 – 1969.
Rehabilitation of all 12 units
First stage of the project: rehabilitation of units No. 8 – 12 as step by step reconstruction aiming improvement of technical and economic performance and reduction of harmful pollution.
Cost of the project (per one unit) – 30 mln USD.
Radical reconstruction of unit No.1.
Cost of the project for unit No.1 – 100 mln USD.
Participation in the distribution of the profits is regulated by the contract.
Payback period – 7 years.
Emissions – at the level of European standards.

To solve these difficult problems, which power sector is now facing, the Ukrainian National Program for Power Branch Development confirmed by the Parliament of Ukraine suggests the following measures:
Implementation of the market levers to regulate prices, distribution of electricity and purchase of the fuel. Special stipulations are made on restructuring, commercialization of the power enterprises, on introduction of private ownership and establishing market medium, favoring the development of private sector.

More astringent limitations and effective sanctions are applied toward consumers who delay payments for electricity. The role of municipal authorities, both as owners and consumers of heat, is in the process of establishing, in line with idea of reducing non-payments from the side of heat consumers.

The success of undertakings in the sphere of wide scale attraction of investments in great extent depends on favorable macroeconomic medium and the structure of the branch.

The Government actively supports investment into power sector, which has a high priority.

In recent time many companies realized that situation of investment possibilities to power sector has improved. Coming from this interest, EBRD decided to organize this May in Kiev a Meeting of the Board of Directors. It is planned that about 3000 bankers and businessmen will participate in this Meeting. Power industry will be of high interest to the participants of this Meeting.

Analyzing the situation in the whole it could be concluded that despite existing difficulties the interested investors together with Minenergo and our enterprises found possible options to expand investing process and that this process is becoming stronger.

STATE OF COAL PREPARATION INDUSTRY IN UKRAINE

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Coal, mined in Ukraine, due to special mining-geological conditions of its bedding has in the most cases high ash content (on average 37%). It does not allow to use effectively the coal without cleaning. 64 coal preparation plants with total capacity of 145.7 millions tons per year improve the coal quality up to level of customers demand. The average capacity of one plant is 2.28 millions tons per year under extreme values from 0.8 to 9.6 millions tons.

23 plants with total capacity of 46.1 millions tons per year prepare anthracite. 6 plants of above-mentioned plants have cleaning level of 0.5 mm, 16 plants have cleaning level of 6 mm and 1 plant has cleaning level of 13 mm.

In the most cases coal preparation plants have been in long-term operation: only 7 plants were constructed less than 25 years ago, the operation age of 53 plants is from 25 to 50 years and 4 plants have been more than 50 years in maintenance.

Approximately 70-75% of total volume of the coal mined in Ukraine is prepared. Modern technology applied in coal industry allows to produce commercial concentrates with ash content which meets the customers requirements:

- for using in coking process ash content amounts in average 8.2%;
- for using in power industry ash content amounts up to 17%.

Sulfur content in run-of-mine coal varies from 0.8 to 4.5%, in prepared product it varies from 0.8 to 3.9%. Only, if sulfur is mainly concentrated in mineral part of the coal, reducing the sulfur content and preparing the coal by reducing the ash content are cooperatively achieved.

At present, prices of imported liquid and gaseous fuels from Russia and other CIS countries have risen to world level. This change in the pricing of oil and gas in Ukraine came in time when the need for these fuels as support fuels was increasing. In this connection replacing the stoker furnaces by the furnaces designed for low quality coal combustion in fluidized bed at the low temperature have been carried out.

Now, the coal industry supplies the Ukrainian thermal power stations with concentrates, intermediate solid product of coal preparation, riddling (schtib), schlamm and run-of-mine coals of long-flame, long-flame-gaseous, gaseous, semi-anthracite and anthracite types (different ash content and calorific value).
Besides increasing the quality of prepared product, there is another priority problem in coal industry of Ukraine: increasing the commercial resources under constant mining volume.

The first way to settle this problem is to reduce the content of flammable matter in low quality coal products and coal preparation wastes.

The second way to increase fuel-energy resources is to develop the secondary fuel technological reserves by extracting it from schlamm, which are out of solid fuel balance and are contained in silt storage of coal preparation plants. 120 millions tons of silts are stored there, 40 millions tons of such silts have characteristics allowed its mining and preparing under technologically and economically admissible conditions.

Ukrainian scientists have worked out technology of producing the granulating matter from silts contained ash and moisture without adding the binder. Such technology will allow to effectively increase using the furnaces of above-mentioned type for combustion of schlamm products from silt storage. This strategy is the subject to mutual beneficial cooperation of coal industry and power industry of Ukraine and the USA.

System of bidding at Electricity Market, Collection of Payments. Payments to Generation Companies.

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1. Reorganization of power sector of Ukraine

Reorganization of power sector and establishing of wholesale market of electricity in Ukraine have entered the phase of practical realization, starting from the second half of 1995.

Main objectives of reorganization are:

- Minimization of COE on competitive basis for all consumers in Ukraine and formation of the cost for electricity according to objective economic conditions of power production;
- Optimization of the production and consumption of electricity;
- Establishing favorable financial conditions, providing normal functioning of power branch, its attractiveness for perpetual investments.

At present time, reorganization of power sector aiming the establishing of the market of electricity is practically finalized. Generating and distribution companies are founded and operate, conditions are created for free extension of Energomarket on account of independent suppliers and generators of electricity licensed at the National Commission on Regulation in Power Generation, incorporating financial and organizational mechanisms necessary for functioning of the wholesale market of electricity in Ukraine.

Mechanism of transactions at the wholesale market of electricity (WME) in Ukraine after extensive elaboration was introduced on March 13, 1997.

2. Structure of the state enterprise Energomarket, functions of its subdivisions

At this moment functions of the state enterprise Energomarket is performed by National Dispatch Center (NDC) of Ukraine.

Within NDC the Board of Executive Directors is created. The Board includes two main subdivisions:

- manager of accounting (MA)
- treasurer of WME;

These subdivisions are fully charged for financing and performing economic and monetary accountancy at WME according to WME Guidelines and Regulations on expenditures of WME.

Main responsibilities of MA are:

- acquisition, analysis and control of the data concerning buying and selling of electricity on the market;
- defining the hourly prices at the market of electricity;
- informing the members of WME on the final agreed data on the scope of purchased and sold electricity;
- supplying information to the treasurer of WME

Main functions of MA of WME:

- accounting of incoming payments by each item;
- daily distribution of acquired means;
- daily transactions to the accounts of generators and third parties;
- control on the collection of payments, the in-time payments to WME and advance payments from suppliers;
- reporting on transactions with each member of WME and cash flow on accounts.

3. Members of Energomarket

In 1997 in the wholesale market of electricity of Ukraine were acting
6 generating companies
5 atomic power stations,
6 thermal power stations,
13 operators - suppliers of the electricity on the market
as producers and sellers of electricity.

For the same period, 27 large energy-supplying companies and 106 independent suppliers acted as wholesale buyers of electricity.

4. Main provisions of the Agreement between members of Energomarket

The Agreement between members of the wholesale market made on November 16, 1996 is put in the basis of activities at the wholesale market.
The agreement regulates:

- rights and responsibilities of WME;
- structure of WME;
- management bodies of WME and their authority;
- functions, rights and responsibilities of the manager of accounting, treasurer;
- mechanism of commercial registration and financial accounting of WME
- mutual responsibility of the members of WME for omission of the adopted obligations
- Procedures of conflicts resolution at WME.

5. Calculations in conditions of non-payments. Temporary system of means distribution.

Not yet overcame the crisis of non-payment creates significant difficulties not only in activity of power companies, but also in application of principles of calculations in WME, stipulated by the constituent and regulating documents.
For minimum support of power industry operation, various schemes of barter transactions are applied.
In 1997 the share of barter transactions in total cash flow in WME reached 90%.
Following transactions were applied:

- Mutual recalculations
- By the bills of NDC
- By concession of the requirements on recovery of the debts
- By transferable commissions of the independent suppliers.

The adopted recently solutions are directed on a gradual decrease of the share of barter originally up to 65-70%.

6. System of the bank scores

To arrange motion flow of means in WME, the WME Banker - Prominvestbank of Ukraine, one of the most high-power banks of Ukraine is assigned, in which structure the special department of Energomarket is created.
System of the bank transit scores is created in the regions and areas, which provides within 2 working days accumulation of all payments, assembled in Ukraine, for the electricity and its distribution between members of WME.
All means assembled on clearing (transit) score of Ukrainian NDC up to their distribution are the property of all members. The executive management of WME in precise conformity with the authorized procedures executes the instruction by these means.

7. Payments to the generating companies, their debts to Energomarket for the purchased electricity

The total sum of the indebtedness of Energomarket to the producers of the electricity in 1997 unfortunately continued has increased and reached 2744.4 mln. UAH. at the end of a year (against 2032.1 mln UAH by the beginning of the year, growth 35.1 %).

The indebtedness to the generating companies has increased in a greater proportion - with 732.3 up to 1256.7 mln UAH, by 75.5 % and on 01.01.98 has exceeded the indebtedness of NPS. It is connected with anticipated debt servicing for NPS in 1997, owing to usual backlog calculations during preceding years, and also with initiated by NPS's in 1997 significant scope of barter transactions.

The level of payment by all kinds of payments in 1997 for electricity sold by genco's at Energomarket, has made 86.2 % of its cost, and bank payments - 8.7%.

It is necessary to admit the increase of absolute size of payments by bank means observed since autumn 1997. Latter is explained by taken measures. Full accomplishment of intended complex of measures will allow to raise payments at Oblenergoes and, accordingly, will increase collection of payments from Energomarket to generating companies.

A. Rogozin
Donbass Regional Dispatch Center

INFORMATION ASPECTS OF UKRAINIAN WHOLESALE ELECTRICITY MARKET FUNCTIONING

Energy Market information system, as any other system, must perform the functions of initial data collection and processing, providing their authenticity, custody and analysis, making decisions. Reflecting a hierarchical Energy Market structure, its information system is represented as a complex of tasks, having inner inter-level vertical ties and outer horizontal ties with other tasks on each level.

Any sub-task of any level can be formally described as a structure, which includes the above-mentioned functions. Depending on the technology of information processing some of the data base and functions can be absent on some levels, however, the following requirements are obligatory for each task:

1. Each function must be available at least on one level.
2. Data of any sub-task must be available for sub-tasks of other tasks of this level and for sub-tasks of the same task on adjacent levels.
3. Any data must be inserted into the information system once and on the level where they appear.
4. Data authenticity must be provided on the level, where the data are being inserted into the system.
5. With the increase of complicacy of information ties the sub-tasks of authenticity function and analysis must be getting deeper.
6. With the rise of sub-task level analysis functions must be getting deeper.

Considering the above-mentioned requirements the current state of Energy Market information system can be characterized as follows:

- in a number of tasks data exchange between sub-tasks of the same level and inter-level data exchange were replaced by documents transfer, by means of E-mail, which is in contradiction with item 3 (data are inserted repeatedly) and with item 1 (the function of data actuality is not automatized).
- in a number of tasks data bases on some, and even on all levels exist in not completed form (electronic tables, text files of not formalized structure), which is in contradiction with item 2.
- data authenticity, if provided, exists only on the upper levels, where not all the data and methods of their authenticity are available (violates requirements of item 4 and item 5)
- in a number of tasks data analysis is fragmentariness and not completed even on the upper levels.

It seems that the creation of information system, meeting the set requirements, is determined by solution of two main tasks:

- developing the existing in the industry technological network "Energy" to the point, providing safe and timely transfer of necessary scopes of data between all levels.

- elaborating the Energy Market information system architecture and the strategy of its development, reconsidering the existing technical and organizational solutions.

If the first task is mostly connected with technical and economical problems, but the second is a pure organizational one. It can be solved by creating a task force under the Energy Market Council, detailing the specified items with participation of the experts from NDC, RDC and the companies - members of the market. The above-mentioned task force must be permanent have as a result of it's activity concrete terms of references, standards and recommendations. As a minimum on the RDC level organizational solutions and software can and must be unified, that could help avoiding troubles, unnecessary labour costs, provide the proper quality of elaboration and their adaptiveness. However, if Energy Market is, how it was declared, the structure, functioning in the interests of all its members, so the market members themselves should be interested in the dissemination of unification to the levels of their companies, enterprises and units.

LUGANSK POWER STATION UPGRADE PROJECT

A. Efremov,

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At present, Lugansk Oblast Administration, Ukraine has investigated two main aspects of carrying out the betterment of Lugansk Thermal Power Station: upgrading performance and total increasing the output of low-price power at Lugansk Power Station on the basis of locally available fuel, and increasing the demand both for energy coal mined in Donbass region and for utilizable carbon component of the coal industry wastes.

Lugansk oblast is the large industrial complex in Donbass basin. The population of this oblast is 2.9 millions people, it occupies 26,700 square km.

Lugansk oblast is the forth highest on industrial output in Ukraine (in 1997 industrial production value was 4.5 billions UAH).

The main branches of industry are coal mining (28.5%), metal industry (16%), chemistry and oil chemistry (15%) and engineering industry (11%).

As stated above the power-intensive industrial plants preponderate in Lugansk industrial-economical complex.

In 1997 oblast energy consumption was 12,224 millions kWh, including 4,484.2 millions kWh (36.7%) of local generation energy.

So the deficit of generating capacities in Lugansk oblast is more than 60% of total consumption volume. We have to point out that this factor impedes the economy stabilization and building-up the production capacities.

Lugansk Oblast Administration has devised a strategy to settle this problem. It includes two lines of activity as follows:

the first way is general electric power saving in all spheres of human activities, first of all by introduction of advanced power saving technologies in industry and for domestic using. Oblast Administration sets itself a task to sharply increase the culture of power consumption, to reach the level with the highest world standards in specific consumption of power resources per unit of gross product;

the second way to solve the problem of providing oblast with power resources is building-up the power capacities, since necessary economical conditions just exist.

The feasibility of increasing generating capacities in Lugansk economic region by constructing additional electric power transmissions lines (e.g. from Pridniprovska Thermal Power Station) or movable power station with CFB boilers for burning out the coal preparation wastes were subjected to detailed studying . Analysis indicated that the costs of these both variants are significantly larger than costs of reconstruction of Lugansk power station.

Lugansk Power Station was constructed in the three stages and all capacity consists of pulverized coal (PC) boilers for which anthracite is the principal intended fuel. The design capacity is 2,300 MWe, but in service there are only 8 power utility units with pulverized coal boilers installed in the 1960s, other units are now obsolescent and no longer in service. At present due to deteriorating power plant equipment the station has only 1,500 MWe of installed capacity from the TP-100 boiler units initially.

Ministry of Energy of Ukraine (Minenergo), Federal Energy Technology Center, US Department of Energy, Pittsburgh, Babcock & Wilcox and Burns and Roe Enterprises, USA and Coal Energy Technology Center (CETC), Kyiv, a division of the Ukrainian National Academy of Sciences cooperatively devised the power plant upgrade project. Collecting data, inspection and evaluation of the plant equipment, engineering and financial analysis to determine optimal upgrading plans for different levels of capital investment that was performed during more than two years period have confirmed technical possibility and economic feasibility of reconstruction of Lugansk Power Station.

Implementation of this project allows not only to increase installed capacity but can be a model for further elaborating and using at the other power stations.

In Lugansk oblast there are enough energy resources needed for determine the optimal power station betterment under using the local raw materials. The large oil-refining plant is situated in Lugansk region, searching, prospecting and developing the natural gas deposit are intensively carried out, the project on utilizing the methane gas resources of coal deposit in fuel-energy balance and investigating the use of water-coal fuel are conducted.

There are a wide rate of different energy coals in Lugansk oblast. In 1997 18.8 millions tons of the coal were mined, including 81.4% of energy coal. 28 coal preparation plants with the capacity of 60 millions tons of the coal per year are situated in this oblast.

In accordance with Decree of the President of Ukraine the structural reorganization have been maid in coal industry. The development program of Lugansk oblast coal industry provides for the concentration of mining works by closing the unprofitable mines and production efficiency enhancement. By 2005 the program foresees achieving the region mining level of 25-27 millions tons of the coal per year.

The reserves of coal in Lugansk oblast amounts to tens of billions tons. So, with taking into consideration the stable mineral basis and wide highly developed network of the coal preparation plants we are able to supply Lugansk power station with hard fuel that answers to specified characteristics on the concrete combustion technology.

What is more, having such variety of energy resources and energy coal excess we are ready to examine any serious proposals applied to the long-term cooperation in Lugansk Power Station modernizing and also in the constructing the new thermal power stations.
One of upgrade approaches for Lugansk Power Station is using as a fuel the low quality coal and coal preparation wastes.

In Lugansk oblast and Donetsk oblast approximately 490 millions tons of dry wastes with 62-82% ash content have remained in dumps of anthracite mines, and 150 millions tons of dry wastes are in dumps of anthracite preparation plants. Extracted carbon from the dry coal wastes (average content of carbon is 12%) it is possible to obtain approximately 80 tons of commercial fuel with ash content up to 35% that is applicable for combustion in CFB boilers.

Resource basis of wet wastes of anthracite cleaning in Lugansk oblast and Donetsk oblast with taking into account balance schlamms makes a total of more than 11.5 millions tons.

To create the admissible conditions for potential investors Oblast Administration has carried out the program on corporatization and privatization of enterprises, including enterprises of fuel-energy complex.

8 state holding companies were formed on the basis of 9 industrial production associations mined the coal. They consist of 67 of 75 mines and 22 of 23 coal preparation plants in Lugansk oblast. On our initiative the state joint-stock generating company "Luganskoblenergo" were established. This company and Lugansk power station are just ready for privatization.

Lugansk Thermal Power Station is in need of wide modernization and new technology using. It will allow to increase electric power production and to extend the lifetime of Lugansk station on the basis of cheap locally available raw materials.

With that end in view, necessary preparatory work is already done. The state joint-stock generating company "Luganskoblenergo" and Lugansk Power Station have cooperatively worked out and have coordinated with Oblast Administration the Program on upgrading and technical rehabilitation of Lugansk Power Station for 1998-2000. The Program provides for reconstruction of 200 MWe units and replacement of generating capacities of the first stage.

At present Minenergo, Ministry of Finance of Ukraine, the State Joint-Stock Generating Company "Donbassenergo" are in direct search of financial resources for station reconstruction.

One of the possible ways of engaging the funds for realization of this project is establishing the open joint-stock company "Lugansk Thermal Power Station-2".

THE NEED OF THE POWER GENERATING COMPANY IN POWER PLANT MODERNIZATION AND RECONSTRUCTION ON THE BASIS OF NEW TECHNOLOGIES. BUSINESS OPPORTUNITIES AND INVESTMENT DEMAND.

(Presented at Ukrainian-American conference)

Ivanov S.A.

State-Owned Joint-Stock Power Generating Company "Donbassenergo"

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The state-owned joint-stock power generating company "Donbassenergo" (the "Donbassenergo") was founded in 1995 and is one of the largest power generating companies of Ukraine.

The company includes five thermal power plants (TPP) (the Zuevskaya TPP, Starobeshevskaya TPP, Luganskaya TPP, Slavianskaya TPP, Kurakhovskaya TPP) with total installed capacity of 7610 MW.

The electric power produced in 1997 accounted for 21.4 bln kWh, the heat produced was 702000 Gkal.

The company currently use both out-dated and relatively new power equipment including 3 turbogenerators of 80-100 MW, accumulating 218000-293000 operating hours, 25 boiler units of 175-210 MW (18 of boiler units have been in operation more than 200000 hours), 4 boiler units of 300 MW commissioned in 1982-1988, 2 boiler units of 800 MW (one of them was the largest one firstly commissioned in Europe in 1967).

Poor technical and economic performance of 100-200 MW boiler units is resulted from wear and low quality of coal used. There are no special NO_x and SO_x removal systems installed at the plants. The number of staff serving the power plants is about 13000.

The share of the company at the Energy Market in 1997 accounted for over 12%. The electric energy is sold to the Wholesale Market of the country.

The company has an opportunity to select a fuel supplier and to import the fuel concluding a long-term contract.

The company developed its own Program of Staged Reconstruction and Technical Modernization of the TPPs by the year 2002 complied with the "National Energy Program of Ukraine by the year 2010". The main program objectives are:

1. to provide reliable operation of the existing boilers and improve boiler technoeconomic performance which allows to compete efficiently at the Wholesale Energy Market and get maximum profit.

To provide reliable operation of the existing 200 MW boiler units is planned to realize by staged element-by-element reconstruction together with overhaul repair. The scope of the reconstruction will include boiler modernization with implementation of new solid fuel combustion technology, reconstruction of regenerative air-heater seals, reconstruction of turbines by low-pressure rotor replacement, reconstruction or replacement of electrostatic precipitators (ESP), implementation of SO_x and NO_x removal systems.

2. Replacement of non-effective and worn 100 MW turbogenerators by new power equipment using new coal combustion technologies.

It is considered to replace out-dated turbogenerators of 100 MW and some 200 MW boilers by using new equipment to be installed at the area of the I st-phase main building while keeping minimum reconstruction of civil-engineering structure. It will be possible to install at the vacated area a 100 MW fluidised bed boiler or a 350 MW combined cycle plant which use clean combustion technologies.

3. Improvement of ecological performance of the plants of the company.

It is planned to improve ecological performance by reconstruction or replacement of the ESPs with further implementation of advanced electronic-beam flue-gas cleaning system at the 200-300 MW boilers.

Of great importance for the company is to reconstruct the Slavianskaya TPP and the Luganskaya TPP, which is resulted from their critical technoeconomic conditions.

Slavianskaya TPP

The design capacity of the TPP was 2100 MW (I ST-phase building include 5 turbogenerator sets of 100 MW each, II-nd-phase building include 2 boiler units of 800 MW each). The plant was brought on stream in 1952-1971. At present the installed capacity of the TPP accounts for 1530 MW:

Ist-phase building - turbogenerator set No.3 of 80 MW

- turbogenerator set No.5 of 100 MW

IInd-phase building - boiler Unit No.6 of 720 MW

- boiler Unit No.7 of 800 MW

As a result of complete wear, three 100 MW turbogenerator sets were phased out in previous years. The rest turbogenerator sets accumulated more than 290000 operating hours.

The boiler Unit No.6 (720 MW) was commissioned in 1967. It consists of two-furnace TPP-200 boiler, made by "Krasny Khotelschik" Inc., and K-720-240-1 turbine which includes 2 turbogenerators of 500 and 300 MW. The boiler was designed to burn solid fuel (Donetsk anthracite, "ASh"-type). As a result of design and manufacturing mistakes, the boiler was not operational and was adopted to burn fuel oil in 1972. The boiler was out of operation since 1993 because of absence of fuel oil. The boiler unit No.6 has accumulated 155000 operating hours.

The boiler Unit No.7 (800 MW) is in operation and has accumulated over 170000 hours. Central coal production factory (CCPF) with annual capacity of 1.0 mln tons cannot provide coal for the boiler Unit No.7 and requires urgent reconstruction and replacement of drying facilities.

Wear of main production funds of the TPP accounts for over 60%.

Specific coal flowrate for the Ist-phase building is 893 g/kWh, for the boiler unit No.7 - 369 g/kWh.

The structure of fuel used at the TPP is as follows:

63% - solid fuel (anthracite culm, "ASh"-type)

31% - gas

6% - fuel oil

The economic analysis of the TPP shows ineffective operation which is resulted from the following:

- an decrease of electricity production by the boiler Unit No.7 as a result of insufficient coal production capacity of the CCPF;
- summer outage of the boiler Unit No.7 with the aim of accumulation fuel for autumn-winter.

The outages result in 35% electricity production losses.

For the TPP to work at the developing Wholesale Energy Market will be not possible, until the urgent repowering is undertaken even despite the location of the TPP in the coal mine site of Ukraine.

The Slavianskaya TPP Reconstruction and Repowering Program
for the period of 1998-2002.

1.It is assumed to build a 125 MW unit consisting of two fluidised bed steam generators of 260 t/h, KT-125 turbine, TA-120 generator in order to replace Ist-phase phased-out capacity.
Expected cost is 100 mln U$.
2. To prolong the operation time of the 800 MW boiler Unit No.7, the element-by-element reconstruction and replacement of out-dated parts of the turbine, boiler, and auxiliary equipment are necessary.
Expected cost is 0.5 mln U$.
3. To achieve design capacity of the Central Coal Production Factory, the replacement of dryers and CCPF's auxiliary equipment is necessary.
Expected cost is 4.5 mln U$.
4. It is planned to build the pilot-scale electron-beam flue gas cleaning facility (dust, NO_x, SO_x removal system) in order to gain experience in advanced flue gas cleaning technology.
Expected cost is 5.3 mln U$.
Total capital cost for the Slavianskaya TPP for the period of 1998-2002 is expected to be 110.3 mln U$.
The "Donbassenergo" does not have the above mentioned financial resourses to realize the program and the local or foreign investments, joint-stock company creation are necessary.

Luganskaya TPP

The design capacity of the TPP was 2300 MW (the Ist-phase includes 7 turbogenerator sets of 100 MW each, the IInd-phase has 8 boiler units of 200 MW each). At present the installed capacity of the TPP accounts for 1500 MW:

the Ist-phase	- one 100 MW turbogenerator set
the Iind-phase	- 8 boiler units of 175 MW each (commissioned in 1961-1968)

The replacement of out-dated Ist-phase main equipment, losses in installed capacity of the IInd-phase boilers (from 200 MW down to 175 MW) because of the wear and obsolescence of the main equipment as well as the use of non-design high ash coal result in installed capacity decrease. The 175 MW boilers have accumulated 200000 hours, which exceeds the design values. The capacity of the TPP is, in fact, only 500-800 MW because of frequent boiler shutdowns caused by repairs. The decrease in plant output and equipment deterioration are strongly connected with the use of non-design high ash coals. In addition, it is necessary to add gas or fuel oil (in amount of 30% of total heat) to support stable combustion of high ash coals.
The Luganskaya TPP is the only source of energy in the Lugansk region and there exists a continuos deficit in up to 1000 MW.
The main tasks for the Luganskaya TPP are:
1. The rehabilitation of the plant generating capacity up to 1670 MW.
2. Optimization of technical and economic power plant performance and profitable operation.
3. Decrease of harmful impact on the environment.

The Luganskaya TPP Reconstruction and Repowering Program
for the period of 1998-2002.

1. Element-by-element reconstruction of 175 MW boilers.

The main objectives of the reconstruction are to provide the following (while keeping unchanged the fuel resources):

- to increase a boiler capacity up to 200 MW;
- to improve boiler economics and operation reliability when burning anthracite ("ASh"-type);
- to increase electricity production;
- to decrease specific fuel flowrate, cost of electricity, and negative impact on the environment;
- to increase the TPP profit.

At present the technical and economic investment study being prepared by Donetsk "Teploelectroproect" Institute on the reconstruction of 175 MW boilers of the Luganskaya TPP is under way. The study includes development of the detailed work on reconstruction of the individual parts of the boiler unit such as turbine, boiler, and auxiliary equipment.

It is planned that the boiler reconstruction will be divided into several phases accounting the overhaul repair schedule.

Expected cost of reconstruction for a 175 MW boiler is 17 mln U$.

2. The construction of a new 100-350 MW boiler.

The TPP Ist-phase, which includes 100 MW turbines with cross-linking, was built in the 1950s and had design capacity of 700 MW. At present, there are 5 boilers (TP-7, TP-43) and one K-100-90-5 turbine in operation. The rest equipment was written off and phased out because of wear. The remaining equipment is also scheduled for phase-out in the nearest future.

The main objective of the construction is to replace worn and obsolete generating equipment with new advanced 100 MW boilers, to decrease the cost of the electricity produced, to improve economic performance.

The replacement of the generating capacity of the Ist-phase can follow one of the options available:

1. The construction of a new pressurized fluidised bed (PFB) boiler of 125 MW.

Expected cost is 100 mln U$.

2. The construction at the vacated area of a new 350 MW combined cycle plant.

Expected cost is 350 mln U$.

The "Teploelectroproect" Institute is responsible for the preparation of a plan to involve investment for the new boiler unit construction, the key point of the plan is to prepare a document for creation of a not-state-owned joint-stock company at the Luganskaya TPP.

Starobeshevskaya TPP.

The installed capacity of the plant is 1750 MW (10 boiler units of 175 MW each).

Because of the plant was built in 1961-1967 and operation time exceeds 190000-230000 hours, the reconstruction and modernization of the main power equipment are strongly needed.

The opportunity to use local low grade coals including coal preparation wastes (schlamms) as a result of reconstruction is important. To achieve the objective, the Credit and Guarantee Agreements on the Starobeshevskaya Power Plant Reconstruction Project was signed in December 1996 by the representatives from the European Bank for Reconstruction and Development (EBRD), the "Donbassenergo", the Ministry of Finance of Ukraine. The Verkhovnaya Rada of Ukraine approved the Guarantee Agreement (Starobeshevskaya TPP Reconstruction Project) between the Ukraine and the European Bank for Reconstruction and Development (the Law of Ukraine of 03.04.97 No.173/97-BP). In accordance with the Agreement, it is planned to reconstruct the boiler unit No.4 by means of installation of a new circulating fluidised bed boiler (CFB) capable of firing Donbass coal

preparation plant wastes, drier, and ESPs. The project funding will be provided by the long-term EBRD Credit of 113.22 mln U$ and own resources of the company (29 mln U$).
The construction and delivery of the equipment will be based on a tender. The boiler unit reconstruction should be completed in 2000.

Zuevskaya TPP

The installed capacity of the plant is 1200 MW (4 boiler units of 300 MW each). The boiler units were commissioned in 1982-1988 and are designed to burn high reactive solid fuel along with fuel oil or gas. The flue gas cleaning from dust is provided by ESPs with 98% efficiency. NO_x and SO_x removal systems are not installed. The operation of the Zuevskaya TPP is enough cost-effective and stable among the rest of the plants being in operation at the company.
It is planned for the nearest 5 years to improve operation efficiency and to decrease harmful emissions. The total cost of the reconstruction is 60 mln U$ including the reconstruction of water-cooling towers No.1 by replacing the obsolete water capturing facilities, sprayers, tubes (the replacement by new polyethylene ones) and reconstruction of concrete structure. The cost of water-cooling tower reconstruction is 20 mln U$.

Kurakhovskaya TPP

The installed capacity of the plant is 1460 MW (1 boiler unit of 200 MW and 6 boiler units of 210 MW each). The boiler units were commissioned in 1972-1975 and are designed to burn wastes of high reactive coals and schlamms along with fuel oil. The flue gas cleaning from dust is provided by ESPs with 97% efficiency. NO_x and SO_x removal systems are not installed. The conditions of the main power equipment, building of the plant are satisfactory.

The main prospects on the TPP reconstruction.

1. Element-by-element reconstruction of boilers, turbines, and auxiliary equipment.

For the 200 MW boiler unit to be operational, the first phase of reconstruction includes the replacement of worn boiler parts and elements, affected by corrosion and erosion processes, turbines and auxiliary equipment, live steam pipelines, reheat tubes, feed water tubes. The use of design coal to minimize or even exclude fuel oil addition is necessary.

2. Minimization of harmful emissions and ESP efficiency improvement.

It is planned to replace the ESPs of all boiler units.
Expected cost of ESP replacement for a boiler is 6.6 mln U$.
Total cost of replacement of the ESPs of all boiler units is 46.2 mln U$.

The realization of the Reconstruction and Modernization Program of the company is under way.
At the Starobeshevskaya TPP the works on the reconstruction of the 175 MW boiler unit No.4 has been started involving the EBRD credit. The project includes the construction of a new CFB boiler, drier, and ESPs. The existing TP-100 type boiler has been removed and tender to define a company-winner which will supply boiler is under way.
At the Slavianskaya TPP the construction of the pilot-scale facility on electron-beam flue gas cleaning from nitrogen and sulfur oxides with capacity of 100000 m^3/h has been started. The financial funding is provided by International Atomic Energy Agency in a free of charge way.
To execute the element-by-element reconstruction of the 175 MW boiler units of the Luganskaya TPP, the technical and economic investment study is being developed together with foreign companies. Once the study is agreed and approved, the detailed design for the modernization of individual element of a boiler will be provided.

The negotiation with the European Bank for Reconstruction and Development is under way to get a credit to replace the phased-out equipment of the Luganskaya TPP by new one.
The company has unlimited market for the implementation of advanced technologies and investment. To execute the measures, considered within the Program by the year 2002, a large capital cost is needed. It is impossible for the "Donbassenergo" to provide complete funding of the work in itself only. That is why the company now looks for a potential investor wishing, on the basis of mutual conditions, to invest the reconstruction of the "Donbassenergo" power plants. The company assumes that a partnership with foreign investors can be established in a different form of mutual cooperation such as, for example, creation of open joint-stock company at the plant and so on. It is necessary to note that the work in these directions is coming slowly.

The company hopes that the decisions approved by the conference may facilitate the involvement of the investment in the power industry of Ukraine.

The Program
of Reconstruction and Modernization of "Donbassenergo"'s Power Plants
by the year 2002

No	Plant, scope of work	Expected cost, mln U$	time scale, year	The objective of the reconstruction
1	**Slavianskaya TPP** Construction of a 125 MW boiler unit which includes two PFB boilers with steam production of 260 t/h, KT-125 turbine, TA-120 generator.	100.0	1999-2001	The replacement of the Ist-phase generating equipment, improvement plant economics and load following
2	Element-by-element reconstruction and replacement of phased-out elements of turbine, boiler, and auxiliary equipment of the 800 MW Unit 7	0.5	1998-2002	To extend operation time of the unit and to improve technoeconomic performance
3	Reconstruction of the central coal production factory (CCPF) with replacement of drying facilities	4.5	1998-2000	To achieve design capacity of the CCPF and to increase the electric output of the Unit 7
4	The construction of pilot-scale plant providing flue gas electron-beam cleaning from dust, SO_2, NO_x	5.3	1998-2000	To get experience on advanced flue gas cleaning technologies
	Sub-TOTAL A	**110.3**		
1	**Luganskaya TPP** Element-by-element reconstruction of 175 MW boilers including reconstruction of boilers, turbines, and auxiliary equipment	76.7	1998-2002	To increase boiler electric output, to improve plant economics and reliability, to increase electricity production and plant profit
2	The construction of a 125 MW fluidised bed boiler unit	100.0	1999-2001	Replacement of phased-out units of Ist-phase, decrease of cost of electricity, improvement of plant economics and ecological performance.
3	The construction of a new combined-cycle 350 MW unit at the area of the Ist phase building or at a new place beyond the Unit 15	350.0	1999-2002	To increase the installed capacity, replacement of old equipment, improvement of plant economics and ecological performance
	Sub-TOTAL B	**526.7**		

No	Plant, scope of work	Expected cost, mln U$	time scale, year	The objective of the reconstruction
1	**Starobeshevskaya TPP** Reconstruction of the 175 MW boiler Unit 4 by installation of a new CFB boiler, drier, ESPs.	113.22 (EBRD credit) 29.0 (own cost)	1998-2000	Increase of the boiler unit output up to 210 MW, improvement of plant economics, reliability, ecological performance
2	Element-by-element reconstruction of 175 MW boiler units including reconstruction of boilers, turbines, and auxiliary equipment	47.3	1998-2002	Increase of electric output, improvement of plant economics and reliability
	Sub-TOTAL C	**189.52**		
1	**Kurakhovskaya TPP** Element-by-element reconstruction of the boiler units including replacement of out-dated equipment of boilers, turbines, and auxiliary equipment.	25.0	1999-2002	To provide operational condition for the existing equipment
	Sub-TOTAL D	**25.0**		
	TOTAL (A+B+C+D)	**851.52**		

THE MAIN PROSPECTS OF REHABILITATION AND MODERNIZATION OF THE "DNEPROENERGO" THERMAL POWER PLANTS

Barkov G.P.

State-Owned Joint-Stock Power Generating Company "Dneproenergo"

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The "Dneproenergo" Company was founded in 1995 as a result of change in organization structure of the Ukraine power industry.

The installed capacity of "Dneproenergo"'s thermal power plants (TPP) accounts for 8160 MW including the Pridneprovskaya TPP of 1740 MW, Krivorozhskaya TPP of 2820 MW, Zaporozhskaya TPP of 3600 MW.

There are 25 boilers in operation at the "Dneproenergo" power plants, namely:

- the Pridneprovskaya TPP has 4 boilers of 150 MW each and 4 boilers of 285 MW each;
- the Krivorozhskaya TPP has 10 boilers of 282 MW each;
- the Zaporozhskaya TPP has 4 boilers of 300 MW each and 3 boilers of 800 MW each.

The boilers of 150 and 300 MW are designed to burn solid fuels, 800 MW boilers are designed to burn fuel oil and natural gas.

The main and auxiliary equipment of the Pridneprovskaya TPP was commissioned in 1957-1966, of the Krivorozhskaya TPP in 1966-1973, of the Zaporozhskaya TPP in 1972-1977.

Pulverized coal-fired (PC) boilers are wet-bottom boilers with reheat. The PC boilers have a closed pulverized-coal preparation system with a storage bin.

The flue gas cleaning for a 300 MW boiler is provided by electrostatic precipitator (ESP) (two ESPs per boiler) with ESP efficiency of 96-98%. The venturi scrubber ensures flue gas cleaning for a 150 MW boiler with 94-96% efficiency.

The flue gas cleaning from nitrogen oxides and sulfur oxides is provided by means of operation measures and by selection of proper quality fuel respectively.

The service water supply system is of a recirculating type.

The combustion of non-design low grade coals, being currently used at the boilers, with low heating value and high ash content results in boiler capacity losses, poor load regulation, deterioration of economic and ecological performance. For the low grade coals to be burnt efficiently, the addition of expensive fuel oil and natural gas as supplementary fuel is necessary.

The Krivorozhskaya TPP is designed to burn Donetsk semi-anthracite coal ("T"-type) with heating value of 6550 kcal/kg and ash content of 15%. However, the coal supplied is of much worse quality having heating value of 4400-4500 kcal/kg and ash content of 35%. The other power plants face the same situation with coal supply.

The low quality of the coal supplied to the power plants makes it difficult to use coal efficiently and requires improvement of coal combustion technologies, it also causes the necessity to replace the out-dated equipment of the existing power plants.

In addition, based on the results (as of 01.01.98) of technical inspections of metal, the power plants have a limited potential to prolong a operation time for the equipment being used.

Taking into account the limited financial resources and estimated low growth in electricity demand, of high priority for the future is to reconstruct and modernize the equipment of the existing TPP according to low cost variants which assume the replacement of some out-dated elements and parts, implementation of advanced fuel combustion technologies and modern control and automation system.

It is assumed within the above prospects of the TPP reconstruction to:

- prolong the operation of the existing TPP equipment;
- keep the rated boiler capacity;
- increase the operation reliability of the equipment;
- increase the efficiency of the fuel use and decrease the consumption of expensive imported fuel oil and gas;
- improve technical and economic performance;
- decrease harmful emissions up to required level.

It is considered that the combustion of coal in atmospheric circulating flüidised bed (CFB) boilers is a real way to reconstruct TPP for the nearest future.

Taking into consideration the developing of market-oriented relations, one of high priority directions is the realization in nearest future the following projects which comply the low-cost variants of the reconstruction:

At the Pridneprovskaya TPP:

1. Combustion of low grade coals such as anthracite culm ("ASh"-type) at 150 MW boilers on the basis of atmospheric CFB technology.

2. Combustion of anthracite culm ("ASh"-type) at 300 MW boilers on the basis of atmospheric CFB technology.

At the Krivorozhskaya TPP:

1. Adaptation of 300 MW boilers with the arch prefurnaces.

At the Zaporozhskaya TPP:

1. Adaptation of 800 MW boilers for PC combustion using dry-bottom removal.

2. Adaptation of 300 MW boilers to use dry-bottom removal and implementation of waste-free utilization technology of ash and slag.

For all power plants:

1. Modernization of the out-dated elements and parts of the equipment.

2. Implementation of whole-through separators.

3. Implementation of new modern control and automation systems.

4. Replacement of control instruments.

5. Replacement of circuit breakers with electric-gas circuit breakers.

6. Modernization of start-up boiler scheme by using recirculation with pumps located in the feed boiler circuit.

Estimated investment cost required for the reconstruction of the "Dneproenergo"'s thermal power plants is as follows (in mln UAH):

	1998-2000	2001-2005	2006-2010	2011-2015	Total 1998-2010	Total 1998-2015
1. Rehabilitation of thermo-mechanical equipment	364.34	1247.21	1491.15	196.58	3102.7	3299.28
2. Rehabilitation of electric equipment	89.08	233.98	179.98	5.0	503.04	508.04
3. New erection	-	1826.98	1198.0	3049.0	3024.98	6073.98
Total	**453.42**	**3308.37**	**2869.13**	**3250.58**	**6630.72**	**9881.3**

N. Syaber

SJSEC "Centrenergo"

SJSEC "CENTRENERGO" DEMANDS IN REFIRBRISHMENT AND RE-EQUIPMENT OF THE COAL-FIRED POWER PLANTS

As for 01.01.1998 the demand for the nearest 6 years in modernization and re-equipment of the coal-fired units with the purpose of their life time prolongation for 15-20 years, safety and ecomonical characteristics improvement for 5-6%, environmental pollution reduction is expected.

For Uglegorskaya TPP:

Replacement of two steam turbines K-300-240-2 by turbines K-325-23,5 - implementation term 1999-2002, approximate cost - 40 mln US dollars.

Replacement of two generators for the units 300 MW with excitation system - implementation term 1999-2003, approximate cost - 16,5 mln US dollars.

Replacement of boilers heating surfaces, live steam pipe-lines, intermediate superheating and bypass tubes of boilers #1-4 - implementation term 1999-2003, approximate cost - 3,2 mln US dollars.

Reconstruction of ADMTP at two 300 MW units - implementation term 1999-2003, approximate cost - 7,0 mln US dollars.

Including the basis of new technologies - turbine capacitors ball cleaning according to the technology of the company "Taprogge" - implementation term 1998-2003, approximate cost - for the unit 300 MW is 19,5 mln US dollars, for the unit 800 MW - 23,0 mln US dollars.

Construction of gas turbine topping with 200 MW capacity at one of the units 800 MW - implementation term 1999-2003, approximate cost - 120 mln US dollars.

The total costs for Uglegorskaya TPP modernization are 229,2 mln US dollars.

For Zmievskaya TPP:

Boiler #8 reconstruction with 300 MW capacity following the project of the company "Siemens" with the change of combuster's configuration for arched type - implementation term 1998-1999, approximate cost - 20 mln US dollars.

Replacement of boilers heating surfaces, LIVE steam pipe lines, the pipes of feed mains for boilers #1-6; 7,9, 10 - implementation term 1998-2003, approximate cost - 38,1 mln US dollars.

Including the basis of new technologies - turbine capacitors ball cleaning according to the technology of the company "Taprogge" - implementation term 1998-2003, approximate cost - 41 mln US dollars.

Replacement of bleeder air heater by baffle one, of the company "Balish-Dur" at the units #7-10, implementation term - 1998-2002, approximate cost - 28,0 mln US dollars.

The total costs for Zmievskaya TPP are 127,1 mln US dollars.

For Tripolskaya TPP:

Replacement of steam turbine K-300-240 of the unit 1 by turbine K-325-23,5 - implementation term - 2001, approximate cost - 20,5 mln US dollars.

Electric precipitators reconstruction for the units 1, 3, implementation term - 1998-2001, approximate cost - 9,8 mln US dollars.

Replacement of boilers heating surfaces, live steam pipe lines, the pipes of feed mains for boilers #3,4; - implementation term 1998-2003, approximate cost - 17,2 mln US dollars.

Including the basis of new technologies - turbine capacitors ball cleaning according to the technology of the company "Taprogge" - implementation term 1998-2003, approximate cost - 40 mln US dollars.

The total costs for Tripolskaya TPP are 87,5 mln US dollars.

The total costs for SJSEC 'Centrenergo" are 444,8 mln US dollars.

THE NEED OF THE "ZAKHIDENERGO" COMPANY IN POWER PLANT MODERNIZATION AND RECONSTRUCTION ON THE BASIS OF NEW TECHNOLOGIES. BUSINESS OPPORTUNITIES AND INVESTMENT DEMAND.

Volodymyr Pavliuk

State-Owned Joint-Stock Power Generating Company "Zakhidenergo"
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The state-owned joint-stock power generating company "Zakhidenergo" ("Zakhidenergo") was founded in 1995 as a result of change in the organization structure of the Ukraine power industry. The company includes three thermal power plants (TPP), namely: the Burshtynska TPP, Dobrotvirska TPP, Ladyzhynska TPP. Total number of boilers is 23 with installed capacity of 4700 MW. The company also has one hydro-power plant (HPP) with installed capacity of 7.5 MW which is a structural part of the Ladyzhynska TPP.

The **Burshtynska TPP** has 8 boilers of 195 MW each and 4 boilers of 185 MW each. The plant was built from 1962 to 1969. Total installed capacity of the plant is 2300 MW.

The **Dobrotvirska TPP** has 3 turbogenerators of 100 MW each and 2 boilers of 150 MW each. The plant was built from 1951 to 1965. Total installed capacity of the plant is 600 MW.

The **Ladyzhynska TPP** has 6 boilers of 300 MW each built from 1968 to 1978. Total installed capacity of the plant is 1800 MW. In addition, the 7.5 MW HPP constitutes a structural part of the Ladyzhynska TPP.
The "Zakhidenergo" also has 3 enterprises which provide operation and maintenance.

The "Zakhidenergo" is a public joint-stock company, it has been established and exists in accordance with the legislation of Ukraine. The company has its own balance, settlement account, currency account, and seal of the company. The property of the company includes fixed and current assets, material assets which value is declared in the "Zakhidenergo" balance. In accordance with the "Property Value Assessment Act", the capital fund of the company constitutes 127905410 UAH which accounts for 12790541 nominal shares 10 UAH each.

Wear of the technological equipment of the plants is more than 80%. All boilers and turbogenerators of the Dobrotvorska TPP and boilers numbered from No.1 to No.7 of the Burshtynska TPP have accumulated more than 200000 operating hours. Besides this, the thermal power plants, originally designed to burn high (medium) volatile bituminous coals with heating value of 5500-5700 kcal/kg of Lvov-Volyn region, now use coals with heating value of 3500-4500 kcal/kg instead. The wear and obsolescence of the equipment, the use of non-design coals result in poor technical and economic plant performance. The same reasons make the plants as dangerous pollution sources with flue gas cleaning equipment not working effectively and which requires new technologies to be applied. Thus, the urgent reconstruction of the power plants is strongly needed and resulted from significant wear and obsolescence of the equipment, poor technoeconomic performance, growth of negative impact on the environment, and estimated crucial role of the power plants in electricity export growth.

Technical repowering and reconstruction of the thermal power plants of the company comply with the "National Energy Program of Ukraine by the year 2010" approved by the Verkhovnaya Rada on May, 1996.

The main directions and scope of reconstruction of the Burshtynska TPP

It is planned to reconstruct the Burshtynska TPP in two phases.
The first phase (1997-2000, small-scale reconstruction) includes rehabilitation of nominal capacity and economical performance of the boilers numbered from No.8 to 12, preparation for electricity export activity as a part of the energy systems of the Central European countries, accumulation of resources necessary for large-scale reconstruction.

The second phase (1998-2005, large-scale reconstruction) includes complete rehabilitation of the boilers numbered from No.1 to 7 and possible upgrade of capacity up to 210 MW with replacement of the main and auxiliary out-dated boiler equipment while keeping unchanged the main civil-engineering structure of the plant main building, prolongation of the plant operation by 25-30 years.

<u>The first phase of reconstruction</u> (boiler No. 8-12).

The scope of work for each boiler includes:

- complete replacement of the existing electrostatic precipitators (ESP) of a boiler by homemade ESPs;
- replacement of ID fans of a boiler by fans made abroad, partial replacement of a boiler gas duct, firstly, at the premises in front of the ESPs;
- overhaul repair of the main and auxiliary boiler equipment with partial replacement of the boiler heating surfaces;
- partial replacement of control and automation system including implementation of automated frequency and capacity regulation system to comply with the energy systems of the Central European countries;
- overhaul repair and partial modernization of the coal crusher equipment for the boiler to use pulverized coal with further increase of the coal share in fuel balance up to 90%.

The reconstruction will allow to rehabilitate the capacity of each boilers by 15-16% (up to 180-185 MW) and to increase the capacity of five boilers by 125 MW totally, to decrease specific fuel flowrate by 1.6-2.1% (up to 373-375 g/kWh), to approach the European standards on load change (130-185 MW). It will also allow to take part in frequency and capacity regulation, which permits to increase tariffs on the electricity exported.

The expected reconstruction cost for a boiler is from 2.5 mln U$ (boiler No.12 for which the ESPs have been already purchased) to 5.5 mln U$ for other boilers. If the expenditure on auxiliary equipment and regulation systems is included, the reconstruction cost will be from 3.5 mln U$ (boiler No.12) to 7.3 mln U$. Total reconstruction cost for five boilers accounts for 36.7 mln U$ including 24.5 mln U$ for main equipment. The specific cost, calculated by our experts, accounts for about 40 U$/kW, including for a boiler - 27 U$/kW. Calculated period of cost return for the first phase of the reconstruction accounts for 1.5 year.

The second phase of reconstruction (boilers No. 1-7).

The scope of work for each boiler includes:

- development, production, and installation of a 210 MW pilot-scale facility capable of firing high (medium) volatile bituminous coal ("GSSh"-type) inside the area of the main building with steam generator of 670 t/h, pressure of 140 bar, steam temperature of 540/540^{0}C, exhaust gas temperature of 130^{0}C, 92% efficiency including ESP, gas ducts, steam pipes, and auxiliary equipment;
- replacement of K-200-130-1 steam turbine by advanced K-215-130-13/15 turbine together with condensers, regulation devices, and auxiliary equipment at the existing bearing support seating;
- replacement of generators of TGV-200 type by advanced ones with air cooling (TAP-220 series) and auxiliary equipment homemade;
- replacement of transformers of TDCG-240 type and auxiliary equipment by advanced ones;
- replacement of boiler control system and implementation of flow-diagram and computer-based monitoring of the operation readouts, complete replacement of cable equipment;
- repair of the main building including replacement of soft roof, fire-control systems, waste water sink, glazing etc.;
- installation of a new system for chemical water preparation in accordance with the standards on water supply of new boilers, reconstruction of the existing chemical water preparation system in accordance with characteristics of the plant heating systems and Burshtyn district heating, and the other heat consumers;
- expansion of the dry ash removal scheme, construction of ash dump with capacity of 25 mln tons of wet ash;

- partial reconstruction of fuel handling system by replacement of two side-discharge tipplers, rearrangement of coal yard applying the coal overhead loading crane.

The reconstruction will allow to rehabilitate the capacity of each boilers by 31-32% (up to 200-210 MW) and to increase the capacity of seven boilers by 350 MW totally, to decrease specific fuel flowrate by 5.2-6.5% (up to 355-360 g/kWh), to meet the European standards on load change (130-210 MW). It will allow to participate in frequency and capacity regulation, which permits to increase export tariffs on the electricity by 0.2-0.4 cent/kWh and to work for 25-30 years (the life time of the main building civil-engineering structures and stacks).

Own cost to be spent on reconstruction of a boiler accounts for 45-50 mln U$, if the cost for plant equipment is included, it rises up to 60 mln U$. Total reconstruction cost for seven boilers accounts for 418.5 mln U$ including 320 mln U$ on boiler reconstruction.

Because of the Minprirody's ban to commission a boiler after overhaul repair without the change of ESPs, it is planned to execute the first phase of the reconstruction of the boilers No.8-12 in 1998-2000. The second phase of the reconstruction of the boilers No.1-7 is scheduled on 1998-2005.

The main directions and scope of reconstruction of the Ladyzhynska TPP

Taking into account satisfactory condition of the technological equipment, the main objectives of the plant reconstruction are as follows: replacement of out-dated worn equipment, an increase of reliability, economic performance and operation safety by means of construction and reconstruction of ash-slag-dumps, reconstruction of control and operation system of the boiler, ESPs, boiler reconstruction by implementation of three-stage combustion (reburning). The total investment cost for reconstruction accounts for 74 mln U$.

A View of the Electricity Industry of Ukraine as seen from Kazakstan: The Experience of AES

By Paul Stinson, Vice President, The AES Corporation and Group Manager of the AES Silk Road

<u>The First Acquisition, Ekibastuz Gres-1</u>

AES first ventured into Kazakstan in February 1996, looking to see what opportunities might exist for power projects. During the visit, the Minister of Energy asked us to consider a number of possible projects. One of these was the purchase of Ekibastuz GRES-1.

During March, I led a small technical team to Ekibastuz to investigate the power station. There are eight 500 MW super-critical coal-fired blocks installed. Only six of them were operable, and of those only four in reasonable condition. The overall plant capacity factor was about 20%. The dreadfully poor condition of the plant was surprising, given that the units were all commissioned between 1980 and 1984.

We learned that since independence, lack of finance in Kazakstan had prevented proper maintenance.
Health and safety conditions were the worst we had ever seen. Initially we were reluctant.

Upon later reflection, we thought that if there was ever a place that AES could make a difference, it was at Ekibastuz. Talk about Social Responsibility! The people of AES could really get behind a project like this. Besides, we believed then and still do that Kazakstan will have a bright future.

One of the largest open pit coalmines in the world is about 22 kilometres from GRES-1. Ekibastuz GRES-1 was built to exploit this huge, low-cost reserve. Thus, it should remain a competitive generator in the long term.

For these reasons, we decided to purchase the plant's assets and took over in August. A thirty-five year Power Purchase Agreement (PPA) was signed with the national grid company of Kazakstan, National Electrical System, Kazenergo (NES-KE).

Our learning started right away and the honeymoon was short. Very soon NES-KE was unable or unwilling to fulfil its obligations under the PPA. AES very soon started selling power under direct contracts to industrial customers and Regional Electricity Companies (RECs).

A severe shortage of paying customers required a reduction in output down to a steady 250-300 MW from the available 600-700 MW. (Note: Because of the poor condition of plant, it required four units to keep two running (two in operation, one or two in maintenance, and one or none in reserve. Running capacity of the blocks is limited to about 350 MW to reduce the incidence of tube leaks.)

AES ran only one unit for most of the winter of 1996-1997, despite extreme pressure from government officials to produce more electricity.

By the middle of 1997 almost all electrical generation in Kazakstan was in control of private companies. Generators refusing to export power without at least some payment imposed discipline upon the system. Thus, the newly formed Kazakstan Grid Company (Kegoc) and the RECs, mostly under the control of Kegoc, had to act. Kegoc began to severely limit flow of power to non-paying RECs and industrials. Payment collection and grid frequency has improved, although much further improvement is necessary.

Ekibastuz Gres-1 now runs two blocks steadily, at times selling three blocks of capacity. Improved maintenance and some major outages of the blocks have resulted in the plant having a reliable capacity of 900-1000 MW. Average run length of the blocks between forced outages for has been extended dramatically, with new records regularly being set. Five blocks are maintained in the rotation and plans are well advanced for refurbishment of Block 8.

The Second Acquisition, AES Altai

In October of 1997, AES acquired the generation assets of the Altaienergo REC in East Kazakstan. Two hydroelectric dams with a combined capacity of 1030 MW were taken under a twenty-year concession. Four combined heat and power plant companies, with 360 MW electric and 2000 MW thermal capacity were purchased.

These assets came without any long-term sales contracts. The heat businesses are regulated monopoly utilities and the electric sales are subject to regulated tariffs but do not have a franchise.

AES is seeking, unsuccessfully thus far, to acquire the East Kazakstan and Semipalatinsk RECs, which consume a large portion of its electric generation. These RECs have yet to be privatised.

The Altai generation plants are in need of investment but were among the best-maintained assets in Kazakstan. This can be attributed to the quality of the management there and the relative strength of the economy in East Kazakstan.

AES acquired the heat distribution assets in Leninogorsk and Sogrinsk, where two of the combined heat and power plants are located. In Semipalatinsk, the main heat distribution lines are part of the acquisition. In Ust Kamenogorsk, which has the largest heat business, we recently took the entire district heating system under management due to payment problems with the existing management.

In Altai, like Ekibastuz, large amounts of working capital have been required to operate the businesses and pay back and current wages of staff. This has been a more significant investment than the purchase price. This was expected and is one cost of turning these assets into good businesses.

The Kazakstan Electricity Market

A very competitive market for base-load power has developed in Kazakstan. The contracts tend to be one year in length or less. We are starting to have negotiations for longer-term contracts.

The market does not yet cater for hot reserve or peaking power, at least as a pool. Each generator must arrange for it's own back up and there is no price differential for peak power. We believe these markets will develop over time. This may produce a phenomenon not expected, that legislation is not required to form a working electricity market.

We think that a mandatory electricity market, such as that implemented in England, Argentina or Ukraine, is not well suited for Kazakstan. Such markets are implemented to promote competition in electricity generation and supply. Kazakstan has some of the lowest wholesale-cost power in the world and very vigorous competition for credit-worthy customers. Thus the cost of implementing such a market cannot be justified.

Mandatory energy pools do little or nothing to reduce the cost of distribution and transmission. The huge profits of the UK's National Grid Company and the English RECs illustrate this. (This is also evidence of the inefficiency of the previous state ownership!) Of course this is a regulatory issue. The biggest obstacle to implementation In Kazakstan is that mandatory market has no way to compensate for either the collection problem or the use of barter transactions.

The current market in Kazakstan, despite its shortcomings, does provide for competition for customers. Customers that can pay fully in cash or barter can purchase power on the most favourable terms. This provides a strong incentive to improve collections. When the excess in available supply is reduced, the proportion of cash collections will increase, as Generators will be able to demand more favourable terms of sale.

AES View of the Ukraine Market

Like Kazakstan, we believe the major problem in the Ukraine is collection of money for power sold. We think the mandatory electricity market is not helpful in solving this problem, as it reduces the incentive for RECs to collect money. The market makes it more difficult for Generators to work directly with customers on payment issues.

We think problems will occur if the Generators are privatised with the current market arrangement because private companies will be far less willing to provide electricity without full payment. As long as the electricity market in its present from is mandatory, we think the Generators will be unattractive to strategic investors unless the collection problem is first resolved. This means that the prices to be realised for sale of the Generators will be low and mainly stock speculators will be attracted.

The Electricity Industry of Ukraine is in transition, and that can be a time for caution. The optimum economic solution for generation of electric power today, when collections for power sales are low, will not be optimal tomorrow, when full collections are made. Once consumers are paying the full cost of the power they consume, the generation equation will change. We foresee large numbers of combined cycle gas turbine plants being built both to reduce the cost of power and address environmental issues.

Much of the current generation plant will be obsolete or environmentally inappropriate. Generators needing much more than 2.5-3.0 US cents per kilowatt-hour to cover their total cost will likely not be able to compete in the market in the long term. This is the price level that can justify the construction of new combined cycle gas turbine plant. Also, we expect the price of gas in the Ukraine will drop as paying customers can demand better terms from gas suppliers.

If the Distribution Companies can be privatised with investor control, the payment problem will be resolved most expeditiously. Investors such as AES understand the magnitude of the effort required and the cost in working capital in the meantime. Successful privatisation will require sensible prices for the assets to attract strategic investors, control for the investors and tariff setting mechanisms that are reasonable and consistently applied. AES is maintaining a constructive dialogue with representatives of the Government about these and other related issues.

We are optimistic that we will be able to participate in the Electricity Industry of Ukraine in the near future.

In Conclusion

AES hopes to build upon its experience in Kazakstan by working in the Electricity Industry of Ukraine.

We believe there are some common characteristics of the electricity industries of the countries formerly in the Soviet Union. Collection for power and heat is the main problem that inhibits investment and proper maintenance of equipment. Development of markets must recognise this issue and provide incentives for improvement while allowing for flexibility between suppliers and consumers in working out payment.

Privatisation of the distribution companies is key to improving collections for power and heat expeditiously. Privatisation of generation companies should follow, or be concurrent with, but should not precede privatisation of distribution companies. Early privatisation of generating companies may be problematic with the Electricity Pool as it is presently structured in Ukraine.

We expect resolution of the payment collection problem to produce large changes in the modes of generation, as new equipment can be financed.

Ultimately, AES believes the people of Ukraine will compete well in the Global Market. The work force is well educated and professional in their approach to work. A huge amount of infrastructure is in place, some of which must be re-directed and re-organised. Like people all over the world, we believe the Ukrainians are thinking, creative, trustworthy individuals. Thus, AES will invest in Ukraine without hesitation if we can gain ownership of an enterprise so that we may unleash the creativity and individuality of the people there. We can do it when the Government will allow us.

For Presentation at the "Ukraine/U.S. Joint Conference on Ukraine Clean Coal Power Plant Upgrade Opportunities," April 21-24, 1998, Kiev.

Effects of Coal Quality on Operation of a PC-Combustor: Results of an Experimental Study with Ukrainian Anthracite

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Abstract

Workers at the Energy Departments of the United States and Ukraine have cooperatively devised a strategy for upgrading performance of a 200-MWe wet-bottom pulverized-coal boiler in eastern Ukraine at the Lugansk GRES power station. The plant currently burns poor quality anthracite (approx. 30% ash versus 18% ash design coal, as-received basis) and is in need of maintenance. Oil or gas support fuel in the amount of 30% (calorific basis) is required to stabilize the flame and supplement the calorific value of the coal feed. No NO_x or SO_2 controls are used at present, and unburned carbon content in the fly ash is high. An experimental program was carried out at the Federal Energy Technology Center (FETC) to estimate the improvement in plant performance that could be expected if the unit is supplied with design coal and is refurbished. High-ash Ukrainian anthracite was cleaned to design specifications. Raw and cleaned coal were fed to a 490-MJ/h coal feed combustion unit at a number of conditions of support fuel use and ingress air leakage designed to simulate current and improved operations at the power plant. The results indicate the improvement in performance in terms of flame stability, reduction in support fuel requirement, improved carbon burnout, reduced fouling tendency, and reduction in SO_2 emissions that can be expected as a result of the planned upgrade and conversion to use of cleaned coal.

Introduction

In 1994, the U.S. Agency for International Development agreed to sponsor a cooperative U.S./Ukrainian coal-fired power plant upgrade project. Principal participants in the project are the U.S. Department of Energy (Office of Fossil Energy), the Ukrainian Ministry of Power and Electrification ("Minenergo"), and the Ukrainian National Academy of Sciences. Ukraine has ample reserves of anthracite and bituminous coals but modest production of oil or gas. Before the breakup of the Soviet Union, commodities were passed among the constituent countries at concessionary prices. Oil and gas were used extensively for power generation at facilities designed for coal due to the availability and convenience of these other fuels.

Following the declaration of independence of Ukraine in 1991, however, prices of imported fuels from Russia and other former Soviet countries have risen to world levels. This change in the pricing of oil and gas in Ukraine came at a time when the need for these fuels as support fuels was increasing. Increased support fuel requirements are due to deteriorating coal quality and deteriorating power plant equipment. Support fuels both stabilize burner flames and provide thermal input when calorific content from coal is low.

An overview of how electricity generation has changed in Ukraine in recent years is shown in Table 1. Total power output decreased substantially in the period 1993-95 reflecting the general contraction of the Ukrainian economy.[1] Most of the reduction in output occurred at the thermal generating stations. Within the thermal power sector, coal consumption fluctuated and showed a small decrease, but oil and gas use experienced larger decreases. Average coal quality as indicated both by calorific content and ash content is poor by international coal trade standards.

The joint US/Ukrainian project team decided to make an anthracite burning power station in the Donbass region of eastern Ukraine the subject of its work. The station, Lugansk GRES, is the only utility power producer in the oblast, or state, of Lugansk, and belongs to the newly privatized generating company "Donbassenergo." The station was constructed in three stages, and all capacity consists of pulverized coal (PC) boilers for which anthracite is the principal intended fuel. The first stage was installed in the 1950s and is made up of units consisting of twin 50-MWe boilers connected to a single 100 MWe steam turbine. Seven of these units, delivering a total of 700 MWe, were installed, but are now obsolescent and no longer in service. The second stage consisted of four 200-MWe boiler/ turbine units installed in the early 1960s. They employ TP-100 type, wall-fired, wet-bottom boilers, and each boiler is paired with a steam turbine. Design steam pressure is 139 bar, and design superheated steam temperature is 570 °C. The third stage was installed in the late 1960s and was a repeat of stage two. Thus, the station had 1600 MWe of capacity from the TP-100 boilers initially. The stage two and three units are fitted with electrostatic precipitators (ESP) or venturi scrubbers but have no provision for control of SO_2 or NO_x emissions.

The TP-100 boilers were designed to be fed with anthracite having ash content in the range 18-20% (as-received) and calorific content in the vicinity of 5,800 kcal/kg (as-received, LHV). They were designed as base-load units, and when operated at full capacity were designed to require no more than 5% oil or gas support fuel. In the intervening years since the TP-100 boilers were installed, nuclear capacity has assumed the role of base-load generator. Coal-fired generators follow load. Additionally, both coal quality and boiler condition have deteriorated. The average ash content of coal consumed at Lugansk GRES in 1993 was 37% and the coal had a calorific content of 4,202 kcal/kg. More recently, coal quality has improved. In 1997 average ash content was 29%. Typical support fuel requirement for a TP-100 boiler currently is about 30% of total calorific feed, the value depending on coal quality and boiler load. The boilers have been derated to 145-MWe capacity.

Organization of the Plant Upgrade Project

The purpose of the joint US/Ukrainian power plant upgrade project was to define an upgrade approach for Lugansk GRES and assemble the necessary engineering and financial information to secure financing from an international funding source. The upgraded plant was to achieve the following goals:

- reduce cofiring fuel requirements to less than 5% of heat input
- increase plant output from present derated condition to 15% above original nameplate capacity
- extend power plant life by at least 15 years
- improve heat rate
- meet Ukrainian environmental requirements

The project was organized into the following parts:

Initial Scoping Studies

Process modeling and cost estimation software were used to identify promising approaches for an upgrade project. Coal cleaning for use in the existing TP-100 boilers, plant refurbishment, and introduction of circulating fluidized bed (CFB) boilers for use with low-grade coal were identified as having promise and worth detailed evaluation.

Experimental Investigation

An experimental program was undertaken to collect data concerning several possible approaches to upgrading Lugansk GRES. To conduct the test program 160 tonnes of uncleaned schtib were shipped to FETC, although part of the test program was also carried out at the Kiev laboratory of the Coal Energy Technology Centre (CETC), a division of the Ukrainian National Academy of Sciences. Float/sink measurements were made on the most extensively used anthracite feedstock for the TP-100 boilers, a sieved fraction called *schtib*. Schtib is prepared by sieving run-of-mine (ROM) anthracite with a screen having 6x13 mm openings. The schtib may be cleaned to reduce its ash content but is usually consumed by power stations without upgrading. Float/sink testing of schtib was done to determine ease of preparation of a feed with ash content for which the TP-100 boilers were designed, the Btu recovery that could be expected, and the extent of sulfur reduction that would result.[2] A second part of the experimental program consisted of preparing schtib having varying reduced ash contents in sufficient quantity for use in the pilot-scale Combustion and Environmental Research Facility (CERF) at FETC. The results of this PC combustion testing are described below. In addition, uncleaned schtib having an ash content of 36% was used to investigate CFB performance in a pilot-scale test burn employing a 2.5-MWt combustor. The CFB combustion test was successful and has been reported.[3,4]

Engineering Design Studies

An engineering services firm, Burns and Roe Enterprises (BRE), sent a technical team to Lugansk GRES to evaluate the plant equipment and to develop technical requirements and cost estimates for a number of approaches to plant betterment. Among alternatives they evaluated were the use of cleaned and uncleaned coal; conversion of the TP-100 boilers to a double arch-fired, dry-bottom design; conversion of the boilers to a membrane wall design; or retaining the existing boiler design with equipment refurbishment. Various approaches to reducing particulate, SO_2, and NO_x emissions from refurbished TP-100 boilers were evaluated, as was repowering one of the 2x50 MWe boiler/turbine units with CFB.

The inspection of two TP-100 boilers by the team of BRE engineers revealed the following deficiencies which affect performance of the boilers and the need for oil or gas supplementary fuel.

- A major problem is the excessive ambient air ingress through refractory insulation, lagging, and casing. These leaks must be repaired as the air leakage lowers combustion efficiency and increases the need for continuous supplementary fuel. Seals in the regenerative air preheaters are worn, resulting in excessive air ingress. Ukrainian engineers estimate the leakage of the air preheaters to be 35% on average for all eight TP-100 boilers at Lugansk GRES.

- The firing system of each boiler was found to have abrasion and erosion damage. The liner of each ball mill requires replacement. The existing static classifiers should be replaced with modern dynamic classifiers to increase pulverized coal fineness and produce a more stable flame with less supplementary fuel. The burners of both boilers inspected are worn and distended, requiring replacement.

- The design value for unburned carbon in fly ash with the TP-100 boilers is high by modern standards, being 18%. Because of boiler deterioration and poorer than design coal, the actual carbon in flyash is higher still, in the range 22-25% or higher (see below).

Expected cost and performance of the most promising approaches to upgrading were subjected to financial analysis to determine optimal upgrading plans for different levels of capital investment. Conventional financial measures were computed, including capital cost per kW of new or refurbished capacity, lifetime cost of power, net present value, and return on investment.

Experimental Investigation

The purpose of the experimental program of PC combustion testing described below was to examine the improvement in boiler operation that could be expected if the boiler deficiencies noted were corrected and a better grade of coal was used. The pilot-scale combustion tests were performed to examine the impact of clean schtib on

- supplementary fuel requirement for flame stability
- combustion efficiency and reactivity of schtib
- emissions
- slagging and fouling

Description of CERF

The CERF at FETC is a state-of-the-art facility to evaluate solid, liquid, and gaseous fuels in typical pulverized/suspension-fired systems. Commissioned in 1989, the basic design criterion for the 500,000 Btu/hr CERF was to achieve similarity with full-scale utility and industrial boilers. Using past experience with pilot-scale combustion rigs, the CERF was designed to closely duplicate typical full-scale specifications for solid fuel fineness, burner fuel/air velocities, furnace temperature distributions, radiant furnace residence time, and convective section gas velocity. Although it is difficult to exactly duplicate full-scale unit conditions, such as heat release rates and surface-to-volume ratios, information on the integrated effects of a number of interdependent design and operating variables can be obtained. Fuel quality is assessed by comparing pilot-scale results with baseline fuels for which full-scale performance is known. A significant portion of the CERF testing involves work with outside parties who bring their fuels, concepts, equipment, and/or materials for evaluation.

Figure 1 presents an isometric layout of the CERF. The facility is highly automated and equipped with a state-of-the-art personal-computer-based data acquisition and process control system. The CERF is equipped to evaluate the following parameters that depend on fuel characteristics: (1) transport, handling, and storage, (2) combustibility, including flame stability and carbon conversion efficiency, (3) ash deposition rates, deposit heat transfer properties, such as emissivity and thermal conductivity, and deposit removal characteristics, (4) flue gas emissions, such as SO_2, NO_x, CO_2, CO, and total hydrocarbons.

Prior CERF testing consisted of about twenty coals, including run-of-mine, conventionally-washed, and deep-cleaned coals, along with various coal blends. The CERF has also been used to evaluate co-firing of various fuels including wood wastes (e.g., sawdust) and energy crops (e.g., switchgrass). In addition, the flexible design of the CERF allows the development and testing of various concepts for improving combustion and reducing pollution, such as (1) in-furnace low-NO_x combustion, (2) post-combustion cleanup technologies to reduce NO_x and SO_2, (3) advanced diagnostic instrumentation for combustion processes, and (4) high-temperature ceramics and alloys for heat transfer applications.

Schtib Preparation

The raw schtib was processed through FETC's Process Research Facility (PRF). The PRF consists of a
1 t/hr pilot-scale coal cleaning circuit with conventional equipment for processing 1/4" by 0 coal, and a 100-500 lb/hr circuit for the study of advanced fine coal preparation processes and equipment. Before processing schtib in the PRF, standard laboratory washability tests were performed at various specific gravities to determine the cleanability of the schtib. Table 2 summarizes these washability results for a 1/2-inch by zero sample of the raw schtib.

Table 2 indicates that the raw schtib is easily cleanable, and has substantial opportunity for ash reductions at high energy recovery. For example, at a moderate specific gravity (s.g.) of 1.7-1.9, a product of about 8 wt% ash is achievable at about 80% energy recovery. Cleaned schtib in the desired 15-20 wt% ash range is achievable at excellent energy recoveries above 90%, however, such a process would require a separation at a very high specific gravity above 2.2. An alternative approach might be to clean only the coarse portion of the schtib and then add back the raw fines or raw coal to achieve the 15-20% clean coal target. This approach was simulated in Figure 2, which illustrates the processing scheme that was used in the PRF to prepare the cleaned schtib for the CERF combustion tests. In this flowsheet, the fines (minus 28 mesh) were first screened out and discarded for the sake of simplicity in handling and logistics. The coarser fraction (1/4" by 28 mesh) was cleaned in a dense-medium (DM) cyclone at a specific gravity of about 1.8 to produce a 9% ash clean coal. This clean coal was then blended with enough of the 36% ash raw coal to produce a final blended product with the target ash of about 19%. A commercial coal preparation plant design may use an alternative flowsheet to produce a specification fuel, depending on the schtib characteristics, the desired product properties, equipment preference, and the process economics. The final blended product was then ground in the PRF hammer mill to various size consists for CERF testing.

Analyses of Raw and Cleaned Schtib Samples

Table 3 presents the standard proximate and ultimate analyses of the raw and cleaned schtib burned during the CERF tests. A 30 wt% reduction in SO_2 is observed on an energy basis as a result of coal cleaning. Both the raw and cleaned schtib exhibit low fuel nitrogen content, which is less than half that for many coals.

Schtib contains substantial amounts of carbonates that decompose during the ASTM volatile matter (inert gas heating at 950 °C) test. In the Ukrainian convention for volatile matter determination, the schtib is first cleaned to about 10 wt% ash content to remove carbonate materials. Consequently, the useful ("combustible") volatile matter contribution is really only about 3 wt%. This volatile matter contributes less than 10% of the total schtib heating value.

Combustion Test Results and Discussion

The combustion test program evaluated the effects of using cleaned schtib on the following: supplementary fuel requirement for flame stability, combustion efficiency and schtib reactivity, pollutant emissions, and slagging and fouling. The results are as follows.

Supplementary Fuel Requirement for Flame Stability

The combustion tests demonstrated that flame stability is the key issue with the raw schtib. The raw schtib flame did not provide sufficient radiant heat back to the burner, and flameouts eventually occurred. As expected, flame stability was achieved when co-firing natural gas as a support fuel.

CERF combustion was greatly improved with a cleaned schtib below 20 wt% ash. Flame stability was not an issue and long term operations were established without natural gas support. CERF operations were improved with the cleaned schtib because of increased combustion efficiency and reduced ash variability.

Combustion Efficiency and Schtib Reactivity

CERF tests with raw schtib suggested that while the natural gas greatly assists flame stability, it does not significantly improve schtib combustion efficiency. This observation is consistent with Ukrainian experience. When unstable, unsupported combustion was achieved with raw schtib, the combustion efficiencies were not significantly different than the gas-supported cases. Apparently, the natural gas being injected around the primary air/raw schtib mixture preferentially reacts with the available oxygen in the near burner region and does not appreciably increase the raw schtib particle heat transfer and ignition.

Because of the poor combustion efficiency of the TP-100 boilers, substantial quantities of schtib are in effect thrown away. Reported residual carbon contents are greater than 20 wt% for the TP-100 fly ash when burning the design coal. Ukrainian engineers believe fly ash carbon is about 30 wt% when co-firing 30% natural gas with a high ash (38 wt%) schtib. Combustion efficiencies are well below 90%, and even approaching 80% for a 38% ash schtib. These observations are summarized in Figure 3, which is derived from a mass balance relating schtib ash content, fly ash loss-on-ignition (LOI), and combustion efficiency.

Some CERF tests were conducted to reproduce the low combustion efficiencies associated with the existing TP-100 boilers. As requested by Ukrainian engineers, a gas injection system was designed to rapidly cool the flue gas by about 200°C in the lower furnace and decrease the available residence times. This was thought to more closely simulate the actual TP-100 boiler environment given its design and excessive air in-leakage near the water walls which would reduce radiant heat transfer contributions to combustion. Under these conditions, combustion efficiencies were much lower (85-90% range) and near the TP-100 performance.

The low reactivity of raw schtib was confirmed in several CERF tests. For example, low excess air operation in the near burner zone (to simulate excessive furnace air in-leakage) was problematic. Unlike most coals, low excess air operation was difficult with the schtib. Frequent flameouts occurred unless high levels of gas support were provided. Low combustion efficiencies resulted in the formation of "reactive" still-smoldering ash deposits that were visually observed. An analysis of flue gas at the entrance to the convective section indicated that ash deposits continued to burn at a rate equivalent to 1-3% of the normal firing rate even after shut down of schtib feed to the CERF. Such burning at the convective section, which was not observed in previous tests with other coals, impacts control of air/fuel stoichiometry.

It has been suggested that the high-ash nature of the raw schtib could pose mass transfer limitations, where combustible portions of particles become essentially encapsulated by an ash layer, thereby limiting carbon burnout. This phenomenon has been reported for certain high-ash Spanish anthracites whose physical/chemical characteristics appear similar to the Ukrainian schtib.[5,6] Another theory is that the higher ash acts as a heat sink, where combustion of some carbonaceous fraction of particles could be delayed beyond the flame region where cooling begins to occur. This theory has been proposed by Ukrainian combustion researchers.

The CERF tests indicated that the inherent reactivity of the schtib does improve as the ash content is reduced to less than 20 wt%. Combustion efficiencies exceeding 95% were obtained in CERF tests with cleaned schtib. This is attributable to improved particle heat transfer and ignition behavior in the near burner zone, and the more well-anchored nature of the flame for the cleaned schtib based on measured flame root positions inside the burner quarl.

Emissions

NO_x emissions of raw schtib are significantly lower than most other coals that have been tested in the CERF. CERF operations with raw schtib resulted in NO_x emissions in the range of about 0.4-0.5 lb/10^6 Btu over a wide range of burner and furnace operating conditions. Using the Ukrainian reporting methodology (dry basis, corrected to 6% O_2), the raw schtib NO_x emissions were in the 350-500 mg/Nm^3 range, while the cleaned schtib NO_x emissions were somewhat higher in the 500-800 mg/Nm^3 range. When co-firing natural gas with raw schtib, NO_x emissions reductions are generally proportional to the percent thermal input of natural gas with a few exceptions when flame behavior (e.g., flame root position) changes significantly.

The cleaned schtib NO_x levels are consistent with other coals that have been burned in the CERF. The apparent increase in cleaned schtib NO_x emissions could likely be suppressed with adjustment of burner design/operation. With proposed Ukrainian NO_x emission goals near 500 mg/Nm^3, this should not be difficult to achieve, and the addition of post-combustion control strategies (e.g., selective noncatalytic reduction, SNCR) would reduce NO_x to levels well below proposed regulations.

Observed SO_2 emissions in CERF tests tracked fuel composition. Cleaned schtib exhibited about 30% lower SO_2 emissions on an energy basis than the raw schtib. In engineering design studies, furnace sorbent injection and use of a dry scrubber were evaluated to reduce SO_2 emissions to a target value of 1,200 mg/Nm^3.

Particulate emissions are approximately three times lower with cleaned schtib relative to raw schtib because of the reduced ash loading. This factor would be reduced proportionally by the percent natural gas support fuel. Most of the ash was recovered as fly ash (collected in the baghouse), similar to the TP-100 boiler data, where 20% of the total ash is recovered as bottom ash. The CERF bottom ash consisted of a mixture of both sintered-type and molten/fused deposits.

The Ukrainian methodology for reporting and regulating emissions corrects to 6% O_2 or 40% excess air, the implication being that the two calculations are nearly equivalent. Because excess air (not measured O_2) essentially determines the flue gas volume, and thus ppm and mg/Nm^3, 40% excess air and 6% O_2 (dry basis) are only equivalent at complete combustion. Thus, any O_2 correction errors roughly correspond to measured combustion inefficiency differences. A second consideration is that normalized flue gas volume varies among fuels (e.g., when comparing a cleaned schtib versus a gas-supported raw schtib). For these reasons, environmental decisions should be made based on an energy equivalent basis (e.g., g pollutant per kcal). It is also preferable to take into account the net thermal efficiency of the plant when normalizing emissions.

Slagging and Fouling

The CERF slagging and fouling behavior of the cleaned schtib was not significantly different from the raw schtib. A critical furnace exit gas temperature (FEGT) was determined to be about 1,150 °C (2,100 °F) before fouling became severe. This FEGT is higher than that actually employed for the TP-100 boilers to suppress fouling tendencies. Boiler slagging/fouling results were consistent with expectations based on the ash compositions and ash fusion temperatures shown in Table 4.

Some of the literature correlations have been reviewed for predicting general slagging and fouling behavior of the raw and cleaned schtib. The high ash loading of the schtib, coupled with its moderate fusion temperatures, makes it a fuel of concern in terms of matching furnace design and operating conditions (keeping the FEGT down) to ensure that heavy fouling would not occur in a PC boiler.

Other Observations

The CERF results suggest that a rehabilitated TP-100 boiler is needed to improve flame stability and combustion efficiency with the raw schtib. High levels of reported air ingress into the TP-100 boilers has led to several major problems. The air ingress has a cooling effect on the walls, reducing the radiant heat transfer to burning schtib particles. This contributes to increased flame instability and reduced combustion efficiency, as evidenced by major increases in the unburned carbon content of the fly ash. The localized excess air in the TP-100 burner zone and inner boiler is probably much lower than that near the walls. While air ingress does contribute to combustion, it is not nearly as effective as the air that is injected (at high velocity and swirl) through the burners. For this reason, the TP-100 boiler cross-section is likely not homogeneous in terms of oxygen-availability, velocity profile, temperature, and combustion.

Because of the high-fouling nature of the schtib, burner air flow must be carefully controlled to keep FEGT below 1,100 °C. Consequently, TP-100 operators do not increase burner air flow to compensate for poor combustion and air ingress. This air ingress may also contribute to derating of the TP-100 boiler, from the standpoint of heat absorption and control of FEGT. Because measured O_2 values are in the usual 4-5% range, the TP-100 boilers are likely oxygen-deficient in the burner region. Future plant assessments should include in-furnace traverses of temperature, particulate characteristics, and flue gas composition.

The CERF results show that the cleaned schtib is a much more intrinsically reactive fuel than the raw schtib, principally due a reduction in ash content as large as three fold on an energy basis. Cleaned schtib was shown to burn without the need for natural gas support fuel under normal combustion conditions.

Summary

An experimental test program conducted at the FETC's CERF examined the impacts of using a design specification coal at Lugansk GRES in Ukraine. The raw schtib containing 38% ash content was processed to give clean coal containing less than 20% ash. The test program was successful in identifying the improvements in boiler operation that could be expected if the boiler deficiencies noted were corrected and a better grade of coal was used. The highlights of the study are as follows:

- The combustion tests demonstrated that flame stability could be achieved with raw schtib only when co-firing natural gas as a support fuel.

- Combustion stability of schtib in these tests greatly improved when coal cleaned to below 20 wt% ash content was used. Long-term operations could be established using the cleaned coal without natural gas support because of increased combustion efficiency and reduced ash variability. Overall, cleaned coal is much more reactive than raw schtib.

- The increased combustion efficiencies with cleaned coal will more than offset small energy losses associated with coal cleaning. Thus, coal cleaning improves net utilization of raw schtib.

- Tests conducted to simulate the TP-100 boiler environment indicated that excessive air ingress into the boiler leads to reduced combustion efficiency and flame instability.

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Table 1. Trends in electricity production in Ukraine.[1]

	1993	1994	1995
Electricity Production (billion kWh)			
Hydro	11.2	12.3	10.1
Nuclear	75.2	68.8	70.5
Thermal	143.8	122.1	113.2
Total	230.2	203.2	193.8
Fuel Use for Heat and Power Production			
Coal: -- million tonne energy equiv.*	26.2	21.6	24.3
-- %	31.1	28.9	34.0
Fuel oil: -- million tonne energy equiv.*	6.5	4.1	3.3
-- %	7.7	5.5	4.6
Nat. gas: -- billion m^3	23.1	22.2	16.5
-- %	27.4	29.7	23.1
Quality of Coal Consumed at Power Stations			
Heat of Combustion (LHV), kcal/kg	4,353	4,251	4,282
Btu/lb	7,835	7,652	7,708
Ash content (dry), %	32.0	33.3	33.4
Moisture content (as-received), %	10.0	9.9	9.7

*tonnes of fuel that would have been consumed if fuel had a standard calorific value of 7,000 kcal/kg (LHV)

Table 2. Laboratory washability results for raw schtib

Specific Gravity	**Cumulative Product**				**Incremental Product**
	% Material Recovery	% Energy Recovery	wt% Ash	wt% Sulfur	wt% Ash for Each Specific Gravity
1.60 Float	12.8	19.9	3.3	1.59	3.3
1.60-1.70	44.3	67.3	5.4	2.01	6.2
1.70-1.90	55.7	82.5	7.7	2.57	16.5
1.90-2.10	61.6	88.6	10.4	2.73	36.5
2.10-2.40	69.0	93.3	15.8	2.73	60.5
2.40-2.60	75.6	95.5	21.3	2.67	78.0
2.60 Sink	100.0	100.0	37.7	3.03	88.4

Table 3. Typical analyses of raw schtib and cleaned coal

	Raw Schtib	Cleaned Coal
Proximate (wt%)		
Moisture	4.15	2.16
Volatile Matter	6.27	5.41
Fixed Carbon	53.01	77.37
Ash	36.57	15.06
Ultimate (dry wt%)		
Hydrogen	1.08	1.51
Carbon	56.35	79.29
Nitrogen	0.38	0.53
Sulfur	2.83	2.83
Oxygen	1.20	0.45
Ash	38.16	15.39
Heating Value (Btu/lb, as-received)	8,327	12,082
Heating Value (Btu/lb, dry)	8,687	12,349
lb SO_2/million Btu, equivalent	6.52	4.58
lb NO_x/million Btu, equivalent	1.44	1.41

Table 4. Ash fusion temperature behavior and ash composition of raw schtib and cleaned coal

	Raw Schtib	Cleaned Coal
Ash Fusion Profile, °F (Reducing Conditions)		
Initial Deformation Temperature	2,220	2,070
Softening Temperature	2,290	2,150
Hemispherical (H=1/2W) Temperature	2,390	2,170
Fluid Temperature	2,520	2,310
Ash Fusion Profile, °F (Oxidizing Conditions)		
Initial Deformation Temperature	2,370	2,370
Softening Temperature	2,420	2,390
Hemispherical Temperature	2,470	2,400
Fluid Temperature	2,570	2,480
Ash Composition, wt%		
SiO_2	50.14	43.54
Al_2O_3	25.63	23.00
Fe_2O_3	10.08	20.71
TiO_2	1.34	1.28
CaO	4.59	4.10
MgO	1.24	1.10
Na_2O	1.82	1.70
K_2O	3.68	2.86
SO_3	1.41	1.63
P_2O_5	0.07	0.08

THE NEED FOR POWER PLANT MODERNIZATION AND RECONSTRUCTION ON THE BASIS OF NEW TECHNOLOGIES. BUSINESS OPPORTUNITIES AND INVESTMENT DEMAND.

Mikhail Mikhailov

The Luganskaya Thermal Power Plant
348903, Schastie-2, Lugansk region

Current Situation Analysis

The Luganskaya Thermal Power Plant (TPP) is located in the city of Schastie of Lugansk region near the city of Lugansk. The climatic conditions of the region are as follows:

- dry hot summer and relatively warm winter;

- annual average amount of precipitation is 476 mm, in rainy years - from 600 to 750 mm;

- height above sea level - 224 m;

The plant is located in non-seismic zone.

The Lugansk TPP with design capacity of 2300 MW was completed in 1969 and consisted of two phase buildings:

- the Ist-phase building has 7 turbogenerators of 100 MW each;
- the IInd-phase building has 8 boilers of 200 MW each.

The first 100 MW turbogenerator was commissioned in 1956, the last boiler of 200 MW was commissioned in 1969.

Currently the installed capacity of the Lugansk TPP is 1500 MW.

As of 01.01.98, each 100 MW turbogenerator has accumulated 279000 operating hours, each 175 MW boiler has accumulated from 192000 to 235000 operating hours (maximum allowable operation time is 200000 hours).

Wear of basic production funds of the TPP is more than 70%.

The Lugansk TPP was not equipped with NO_x or SO_x removal systems. The fly ash removal system is highly worn and obsolete as well as it does not operate effectively.

Collaboration of Minenergo of Ukraine and US Department of Energy

As a result of more than two year work of the experts from Minenergo of Ukraine, Pittsburgh Energy Technology Center of the US Department of Energy, Burns and Rhoe (USA), Babcock&Wilcox (USA), and Department of High Temperature Energy Conversion (National Academy of Sciences of Ukraine), the Lugansk TPP reconstruction project was developed including three closely tied cases. The project includes:

1. Reconstruction and modernization of an existing 175 MW boiler.

The project cost of that case accounts for 75.2 mln U$ approximately.

2. It is planned to install two CFB boilers of 62.5 MW each, a 125 MW turbogenerator equipped with automation system, auxiliary equipment, control and automation system etc. instead of Ist-phase removed equipment.

The preliminary cost of that case accounts for 100 mln U$.

3. The application of modern equipment with high requirements on water treatment, the need to separately feed fuel of different quality, significant wear and obsolescence of water treatment and fuel feeding systems cause the necessity to reconstruct the above out-dated equipment.

The project includes:

3.1. Reconstruction of water treatment system of 350 t/h capacity.

3.2. Replacement of the overhead loading cranes with rotary facilities.

The preliminary cost of that case accounts for 15.4 mln U$.

The realization of the project allows to employ people and extend operation time of the plant by 15-20 years.

The required project funding that includes unexpected expenses and loan interest during construction was calculated by the US Department of Energy experts and accounts for 271.9 mln U$. It is assumed that the project funding will be provided within a World Bank credit. The above mentioned project is supported by Minenergo of Ukraine, region municipal administration body, Board of Administration of the State-Owned Joint-Stock Power Generating Company "Donbassenergo".

For the “Donbassenergo” to build a new 125 MW boiler is expensive and cannot be provided in itself. That is why the first step of the project realization is to find a partner and to call for investment on the basis of mutual conditions. To do so, it is necessary to evaluate all factors, choose a certain boiler and create a new structure (Stock-Company, Joint-Stock Company etc.) capable to coordinate the reconstruction project.

As a rule, a partwise (element-by-element) reconstruction of a boiler should be accompanied with overhaul repair. Such the boiler reconstruction includes:

- reconstruction of TP-100 boiler;
- reconstruction of K-175-130-1 turbine;
- reconstruction of fly ash removal system;
- reconstruction of auxiliary equipment;
- service heating of the TPP and the city of Schastie while boiler shutdown or reduced number of boilers in operation.

The overall duration of the partwise reconstruction for one boiler should not exceed 12 months.

The cost for the reconstruction of one 175 MW boiler should be within the 17 mln U$.

US / UKRAINE JOINT STUDY OF REHABILITATION OF LUGANSK GRES

To be Presented at

UKRAINE / U.S. JOINT CONFERENCE
ON
UKRAINE CLEAN COAL
POWER PLANT UPGRADE OPPORTUNITIES

Kiev, Ukraine
April 21 - 24, 1998

BURNS AND ROE ENTERPRISES, INC.
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US / UKRAINE JOINT STUDY OF REHABILITATION OF LUGANSK GRES

Introduction

Burns and Roe, a Technical Support Contractor to the U.S. Department of Energy,s Federal Energy Technology Center in Pittsburgh, was assigned the task of performing an engineering analysis for rehabilitating three generating units at Lugansk GRES in order to improve generation and efficiency, and reduce environmental impact. The results of the Burns and Roe analysis are summarized in this presentation. The detailed results of the study were analyzed by Parsons Power to determine the economic feasibility of the various options developed, and Mr. Rubow will describe that effort next.

1.0 Description of Lugansk GRES Power Station

The Lugansk GRES Power Station, when it was completed in 1969, had a generating capacity of 2300 MW. The station name at that time was Voroshilovgrad GRES. The name was changed to Lugansk GRES at the breakup of the Soviet Union. The station was constructed in three phases. Phase 1 consisted of 14 boilers feeding steam to seven 100 MW turbine generators through a common steam header system. Phase 1 went operational between 1956 and 1958. Phase 2 included four separate 200 MW units, each with its own boiler and turbine generator, completed between 1961 and 1963. Four more 200 MW units, as Phase 3, were completed between 1967 and 1969.

All of the units were originally fueled by Ukraine anthracite coal which had 15-18 % ash, 4 % volatiles and a heating value of about 6010 kcal/kg (10,820 Btu/lb). Over the past 20 years, or so, the quality of the coal available to the plant has deteriated to the present 34-36% ash, 4% volatiles, and a heating value between 3800 and 4500 kcal/kg (6800 - 8100 Btu/lb). The use of this lower quality fuel, combined with the aging of the plant, have caused much deterioration.

As a result of this deterioration, the 200 MW generating units have been derated to between 145 and 175 MW. The units now operate at capacity factors below 45 %. It is necessary to cofire with natural gas or mazut to maintain flame stability in the boilers. The gas and mazut must be imported from Russia which worsens the national debt.

There is no control of sulfur dioxide and nitrous oxide emissions in the units, which is typical of plants from that era. Also, control of particulate emissions is inadequate, by todays standards.

All of the Phase 1 equipment has been decommissioned and most is in various stages of disassembly and removal.

The scope of our study was to develop conceptual designs, and estimates of performance, capital costs and operating costs for the rehabilitation of one 200 MW unit from the Phase 2 section (Unit 10) and another 200 MW unit from the Phase 3 section (Unit 13). In the Phase 1 area, we were to investigate replacing one of the 100 MW turbine generators and two of the small boilers with a unit which will include a new 125 MW turbine generator supplied with steam from two new circulating fluidized bed boilers.

We were also to investigate the need to rehabilitate common plant equipment and systems which would affect the performance of these units. We identified the need for a new makeup water treatment system. We understand that after we completed our investigation, the need to rehabilitate some of the coal handling equipment in the yard was identified.

2.0 Scope of Study

The following options were investigated for the 200 MW Units Nos. 10 and 13:

Option 1. Minimal refurbishment, minimal emission control

Option 2. Minimal refurbishment, extensive emission control

Option 3. Conversion to arch firing, extensive emission control

Option 4. Extensive refurbishment, extensive emission control

For each of these options we considered the burning of either the coal presently fired (36% ash) or a beneficiated coal with an 18% ash content.

Minimal Refurbishment is the minimum required to achieve longer life, increased generation, improved efficiency and reduced use of supplementary fuel.

Minimal Emission Control is achieving the required limitation of particulate emissions only; while Extensive Emission Control is meeting the current emission limitations for SO_2 and NO_x, as well as particulates.

Arch Firing refers to a double arch furnace configuration, with downward firing burners, which is an arrangement found to be more suitable for burning this high ash, low volatile anthracite.

Extensive refurbishment is to achieve the maximum generation that is practical with these units.

The replacement of two boilers and one turbine in the Phase 1 Area with a single unit consisting of a 125 MW turbine generator and two circulating fluidized bed boilers was investigated. The rating of the new turbine generator was selected because it is the largest size that could be accomodated on the existing pedestal.

Study objectives

Extended life

Our goal was to extend the lives of the refurbished 200 MW units by at least 15 years. The 125 MW replacement unit was to be designed for a life of at least 30 years.

Increased power generation

Generation from the derated condition of the 200 MW units will be increased.

Improved efficiency

Heat rate will be improved with each item of modification or replacement, except for those items which are for life extension only.

Reduced use of supplementary fuel

The rehabilitated boilers will require no more than the original designed quantity of supplementary fuel, unless required for control of NOx emissions.

Reduced flue gas emissions

Flue gas emissions, consisting of particulate matter, sulfur dioxide and nitrogen oxides will be controlled to levels established by Ukrainian environmental officials and World Bank.

3.0 Approach to Study

Burns and Roe reviewed existing reports and documents pertaining to the Ukraine power system in general, and to Lugansk GRES in particular. A Ukraine engineering firm, Kharkov Central Design Office, which had detailed knowledge of the design and operation of Lugansk GRES, was retained to obtain additional data needed for the investigation. This was accomplished through the use of questionnaires prepared by the project and transmitted to this firm. There were several questionnaires during the course of the project.

A team of Burns and Roe engineers inspected the plant, accompanied by engineers from Kharkov Central Design Office. Many details were obtained from discussions with plant personnel and from reviewing the available engineering documents and drawings. The collected data were analyzed and the various alternatives for refurbishment or replacement were considered and evaluated. The availability of commodities and equipment in Ukraine and in other CIS countries was established by Kharkov Central Design office and budget costs obtained. Budget pricing for western-supplied equipment and services was obtained from vendors, and from data from Burns and Roe files for similar installations.

4.0 Rehabilitation of 200 MW Units 10 & 13

Recommendations for rehabilitation of the boilers were developed for each of the options, considering the alternatives of using both cleaned coal and uncleaned coal. These are reheat units, with main steam conditions of 130 ata pressure and 540C temperature. The turbine thermal cycle includes seven feedwater heaters and a deaerator.

4.1 Summary of Recommendations

(Refer to Figure 4-1)

Boiler

The boilers of the two units are nearly identical. Each is a natural circulation, drum type with a balanced draft, wet bottom furnace. The boilers originally had sixteen circular swirl type burners in the furnace front and rear walls, but Unit 10's burners have since been replaced with eight burners of the fuel/combustion air ejector type.

The boiler recommendations listed in Figure 4-1 are based on the following problems found:

Major ambient air leakage into the furnace and flue gas passages
High temperature corrosion and wall thinning in furnace wall tubes
Low cycle fatigue, corrosion and creep damage in tube banks
Worn attemperator systems
Excessive air preheater leakage
Erosion damage in induced draft fan housing and impeller
Abrasion and erosion damage in the firing systems
Existing static type coal classifiers not adequate

The Repair/Refurbishment items apply to all options in various degrees, except that the furnace and roof tubing is to be repaired only in the Minimum Refurbishment Options 1 and 2, and is to be replaced with membrane walls in Options 3 and 4. Also, the ball mills are to be repaired in all options, except replacement is required for the uncleaned coal alternative in Options 3 and 4, in order to obtain maximum possible generation. The existing burners are to be repaired only for Minimum Emission Controls Option 1; while for all other options, the burners are replaced with low NOx burners. Replacing the existing static type mill classifiers with the dynamic type is recommended for all options.

Emission Controls

Unit 10 has a wet ash collection scrubbing system in which water is sprayed into the flue gas in scrubbing vessels. Unit 13 has an electrostatic precipitator. Both provide insufficient ash removal efficiency to meet todays required emission limitations. Replacing the existing collection equipment with higher efficiency equipment and installing new continuous monitoring systems are recommended for all options. New equipment for controlling sulfur dioxide and NOx is needed for the options requiring Improved Emission Controls.

For sulfur dioxide control, we considered the Dry Process (furnace and duct injection), the Wet Process and the Semi-dry Process. The Semi-dry Process is recommended, with a spray drying vessel located upstream of the precipitator. The flue gas entering the vessel is sprayed with an alkaline slurry, while the heat dries the atomized droplets as they absorb the sulfur dioxide. The solids with the flyash are then collected by the ash handling system. Lime is used for the reagent. The advantages of this Process over the Wet Process are lower cost, less space required, less gas side pressure drop and less complexity of operation. The dry processes were rejected as they did not provide sufficient SO_2 removal.

For NOx removal, a combination of low-NOx burners followed by selective non-catalytic reduction of the remaining NOx is recommended. The non-calalytic reduction is by reaction with ammonia, without the use of a catalyst.

Turbine

The turbine is a reheat unit with seven stages of feedwater heating extractions. It is a single shaft machine with separate high pressure, intermediate pressure and low pressure sections. We determined that the turbine governor parts had experienced significant wear and the casings had previously developed cracks, which had been repaired. There were signs of metal fatigue in many components and, in some cases, deformation and erosion wear in the turbine steam path. Last stage blading of the low pressure turbine is to be replaced, which is a normal precaution for life extension, since it is subject to severe erosion. The Extensive Refurbishment Option includes a new 225 MW modern turbine generator with all its accessories.

Balance of Plant

To obtain reliable operation, replacement of much of the turbine system balance of plant equipment is necessary for all options. Replacement of more of the piping and valves is needed for the Extensive Refurbishment Option than for the others, as the increased capacity requires larger sizes. The recommended bypass around L.P. Feedwater Heater No. 1 will provide improved protection against water induction into the turbine. Repair of condenser air leakage is recommended for all options except the Extensive Refurbishment Option, which requires replacement with a larger condenser.

Electrical Equipment

We found that major replacement of electrical equipment and systems is required, as indicated in Figure 4-1. This is due to deteriorated condition, obsolescence and worn components. A larger generator with its excitation system are required for the Extensive Refurbishment Option.

Instruments & Controls

We found that the existing plant control systems are inaccurate and obsolete; supervisory and protection systems are minimal; event recording and operator information systems are unreliable.

Installation of a new distributed control system (DCS) and a new burner management system are recommended for all options. Also, all plant controls and control valves are past their useful lives and must be replaced.

4.2 Summary of Performance and Capital Cost - Unit 10

(Refer to Figure 4-2)

4.3 Summary of Performance and Capital Cost - Unit 13

(Refer to Figure 4-3)

FIGURE 4 - 1
SUMMARY OF RECOMMENDATIONS
REHABILITATION OF 200 MW UNITS 10 & 13

OPTION NO.	1	2	3	4
REFURBISHMENT	Min	Min	Arch Firing	Exten
EMISSION CONTROL	Min	Impr	Impr	Impr
BOILER				
REPAIR/REFURB				
REFRACTORY,INSUL, LAGGING & CASING)				
SH, RH & ECON TUBE BANKS)				
ATTEMPERATOR PIPING, VALVING, ETC.)	X	X	X	X
FLUE GAS DUCTWORK & EXPANSION JOINTS)				
SOOT CLEANING SYSTEMS)				
BOILER SUPPORTS, PLATFORMS & STAIRS)				
GRINDING CIRCUITS)				
BALL MILLS)				
MILL CONTROL SYSTEM)				
AIR PREHEATERS)				
INDUCED DRAFT FANS)				
FURNACE & ROOF TUBING	X	X		
BURNERS	X			
REPLACE				
FURNACE CONFIGURATION (TO DOUBLE ARCH)			X	
FURNACE WALLS (MEMBRANE WALL CONSTR)			X	X
MILL CLASSIFIERS	X	X	X	X
BALL MILLS (FOR UNCLEANED COAL ONLY)			X	X
EMISSION CONTROL				
REPLACE				
ELECTROSTATIC PRECIPITATORS	X	X	X	X
INSTALL NEW				
CONTINUOUS MONITORING SYSTEM	X	X	X	X
SO2 CONTROL EQUIPMENT		X	X	X
NOX CONTROL EQUIPMENT		X	X	X
TURBINE				
REPLACE				
H.P. & I.P. CYLINDERS)				
L.P. TURBINE LAST STAGE LP BLADING)				
TURBINE GOVERNING SYSTEM)	X	X	X	
GOVERNOR VAVES & INTERCEPT VALVES)				
FRONT STANDARD & FLANGE HEATING SYSTEM)				
OIL COOLER)				

OPTION NO.	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
REFURBISHMENT	Min	Min	Arch Firing	Exten
EMISSION CONTROL	<u>Min</u>	<u>Impr</u>	<u>Impr</u>	<u>Impr</u>
TURBINE (CONT.)				
UPGRADE				
GLAND SEAL EXHAUSTER SYSTEM)				
DRAINAGE/BLOWDOWN EQUIPMENT)	X	X	X	
H2 SEALING SYSTEM)				
INSTALL NEW				
225 MW TURBINE & AUXILIARIES				X
BALANCE OF PLANT				
REPLACE				
FEEDWATER PUMPS & CONDENSATE PUMPS)				
CONDENSER TUBE CLEANING SYSTEM)	X	X	X	X
H.P. & L.P. FEEDWATER HEATERS)				
PIPING & VALVES (AS NECESSARY))				
INSTALL NEW				
L.P. HEATER BY-PASS	X	X	X	
STEAM SAMPLING SYSTEM	X	X	X	X
CONDENSER				X
HEATER DRAIN PUMPS				X
REPAIR				
CONDENSER AIR INLEAKAGE	X	X	X	
ELECTRICAL EQUIPMENT				
REPLACE				
220 KV SWITCHYARD EQUIPMENT)				
6 KV SWITCHGEAR & BUS)				
400 V SWITCHGEAR & TRANSFORMERS)				
MOTOR CONTROL CENTERS)				
BATTERIES & CHARGERS)				
PROTECTIVE RELAYS, MAIN &AUX. PANALS)	X	X	X	X
UPS SYSTEM)				
POWER/CONTROL/INSTRUMENT WIRING)				
CONDUIT & CABLE TRAY)				
LIGHTING, GROUNDING, CATHODIC PROT.)				
COMMUNICATIONS & FIRE PROTECTION)				
INSTALL NEW				
225 MW GENERATOR)				X
EXCITATION SYSTEM)				
INSTRUMENTS & CONTROLS				
INSTALL NEW				
DISTRIBUTED CONTROL SYSTEM)	X	X	X	X
BURNER MANAGEMENT SYSTEM)				
REPLACE				
CONROLS & CONTROL VALVES	X	X	X	X

FIGURE 4-2

SUMMARY OF PERFORMANCE & TOTAL CAPITAL COST - UNIT 10

		OPTION 1		OPTION 2		OPTION 3		OPTION 4	
		MINIMUM REFURB		MINIMUM REFURB		ARCH FIRED BOILER		EXTENSIVE REFURB	
		MINIMUM EMISSION CONTROL		IMPROVED EMISSION CONTROL		IMPROVED EMISSION CONTROL		IMPROVED EMISSION CONTROL	
	CURRENT CONDITION	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
TURBINE GROSS OUTPUT, MW	144.5	144.5	200.0	144.5	200.0	200.0	200.0	225.0	225.0
TURBINE GROSS HEAT RATE, kcal/kWh	2042	2012	1960	2012	1960	1960	1960	1889	1889
UNIT NET OUTPUT, MW	126.5	131.5	186.2	130.7	185.1	182.8	184.7	206.8	208.9
NET UNIT HEAT RATE, kcal/kWh	2805	2797	2567	2814	2583	2382	2358	2283	2261
SUPPLEMENTARY FUEL USAGE, %	35	30	15	30	15	5	0	15	5
SO2 EMISSIONS, mg/Nm^3	6600	6600	5206	1200	1200	1200	1200	1200	1200
NOx EMISSIONS, mg/Nm^3	1600	1600	1300	800	800	800	800	800	800
PARTICULATE EMISSIONS, mg/Nm^3	2000	150	150	150	150	150	150	150	150
TOTAL COST ESTIMATE (U.S. DOLLARS)		51,664,400	51,644,400	61,695,300	63,840,000	78,513,000	78,006,000	83,862,900	83,472,400
COST/NET KW (U.S. DOLLARS)		393	277	472	345	430	422	406	400

FIGURE 4-3

SUMMARY OF PERFORMANCE & TOTAL CAPITAL COST - UNIT 13

		OPTION 1		OPTION 2		OPTION 3		OPTION 4	
		MINIMUM REFURB		MINIMUM REFURB		ARCH FIRED BOILER		EXTENSIVE REFURB	
		MINIMUM EMISSION CONTROL		IMPROVED EMISSION CONTROL		IMPROVED EMISSION CONTROL		IMPROVED EMISSION CONTROL	
	CURRENT CONDITION	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
TURBINE GROSS OUTPUT, MW	145.5	148.0	200.0	148.0	200.0	200.0	200.0	225.0	225.0
TURBINE GROSS HEAT RATE, kcal/kWh	2032	2018	197.2	2018	1972	1970	1970	1889	1889
UNIT NET OUTPUT, MW	132.6	134.8	186.2	134.0	185.1	182.8	184.7	206.8	208.9
NET UNIT HEAT RATE, kcal/kWh	2852	2804	2584	2821	2599	2395	2370	2283	2261
SUPPLEMENTARY FUEL USAGE, %	35	30	15	30	15	5	0	15	5
SO2 EMISSIONS, mg/Nm³	6600	6600	6600	1200	1200	1200	1200	1200	1200
NOx EMISSIONS, mg/Nm³	1600	1600	1300	800	800	800	800	800	800
PARTICULATE EMISSIONS, mg/Nm³	1300	150	150	150	150	150	150	150	150
TOTAL COST ESTIMATE (U.S. DOLLARS)		45,690,300	45,690,300	56,342,900	58,486,100	72,302,700	71,719,500	84,750,500	84,266,500
COST/NET KW (U.S. DOLLARS)		339	245	420	316	396	388	410	403

5.0 Replacement of Phase 1 Boilers and Turbine

5.1 Recommendations

(Refer to Figure 5-1)

In the Phase 1 area, the equipment was in the process of being dismantled and removed, when we visited the plant. Our study addresses the removal of what was left of one of the old 100 MW turbines, the two boilers and their auxiliaries, and their replacement with a new unit consisting of a 125 MW turbine generator, two half size circulating fluidized bed (CFB) type boilers, and all the auxiliaries. Two half-capacity CFB boilers were selected over one full capacity as the operating advantages they offered were considered to more than offset the additional cost. The boilers are to be suitable for burning Ukrainian anthracite culm (schtib), with limestone injected as the sorbent. All boiler auxiliary equipment will be new except those sections of the ash handling and coal handling systems which can be salvaged, will be refurbished.

Most of the existing structures and foundations are in reasonably good condition and could be reused and modified as necessary to suit the new equipment. The main building is still usable except that the roof in the area of the CFB boilers must be modified to suit the new equipment.

A fabric filter (baghouse) system will control particulate emissions which will consist of ash, sulfated limestone, excess lime and a small amount of unburned carbon. Fabric filters are normally used with CFB boilers, rather than electrostatic precipitators. They provide a higher collection efficiency and can accomodate changes in fuel quality better. No other emission controls are required, as both SO_2 and NOx emissions can be held within the prescribed limits by controlling the limestone feed rate

Turbines designed and manufactured by Ukraine's Kharkov Turbine Works were investigated for this application. The 125 MW turbine size was selected because it was the largest that would fit on the existing pedestal without major modifications. We obtained details of the turbine equipment and thermal cycle through Kharkov Central Design Officeand developed the balance-of-plant design. The thermal cycle is none-reheat, with six stages of feedwater heating extractions. Steam is provided to the turbine at 130 ata pressure and 555C temperature.

With the increased capacity of the new equipment and the generally poor condition of the existing equipment, we determined that the existing balance of plant systems all had to be replaced, except for sections of the circulating water system, which could be refurbished.

We determined that all existing electrical, instrumentation and control equipment needed to be replaced with modern equipment. A state-of-the-art digital distributed type control system is recommended.

5.2 Performance and Cost of Replacement

(Refer to Figure 5-2)

FIGURE 5 - 1
SUMMARY OF RECOMMENDATIONS
REPLACEMENT OF PHASE 1 BOILERS AND TURBINE

BOILER
INSTALL NEW
- 2 HALF SIZE CFB BOILER SYSTEMS & ACCESSORIES
- INDUCED DRAFT FANS & F.D. BLOWERS
- COAL CONVEYORS & COAL BUNKERS
- COAL CRUSHING SYSTEM
- LIME PREPARATION & FEED SYSTEM

REFURBISH
- ASH HANDLING AND COAL HANDLING SYSTEMS

EMISSION CONTROL
INSTALL NEW
- FABRIC FILTER ASH COLLECTION SYSTEM
- CONTINUOUS EMISSIONS MONITORING SYSTEM

TURBINE
INSTALL NEW
- 125 MW TURBINE GENERATOR AND ACCESSORIES

BALANCE OF PLANT
INSTALL NEW
- FEEDWATER/CONDENSATE/CONDENSATE BOOSTER PUMPS
- SURFACE CONDENSER & TUBE CLEANING SYSTEM
- CIRCULATING WATER PUMPS
- AIR COMPRESSORS
- FEEDWATER HEATERS & DEAERATOR
- HEATER DRAIN PUMPS
- PIPING & VALVES

ELECTRICAL EQUIPMENT
INSTALL NEW
- 220 KV SWITCHYARD EQUIPMENT
- MAIN & AUXILIARY TRANSFORMERS
- SWITCHGEAR & BUS
- GENERATOR CIRCUIT BREAKER
- MOTOR CONTROL CENTERS
- BATTERIES & CHARGERS
- UPS SYSTEM
- MAIN &AUXILIARY PANELS
- POWER/CONTROL/INSTRUMENT WIRING
- CONDUIT & CABLE TRAY
- GROUNDING SYSTEM/CATHODIC PROTECTION
- COMMUNICATIONS/FIRE PROTECTION

INSTRUMENTS & CONTROLS
INSTALL NEW
- DCS SYSTEM
- INSTRUMENTS & CONTROLS

FIGURE 5 - 2
PERFORMANCE AND COST
REPLACEMENT OF PHASE 1 TURBINE AND BOILERS

<u>Performance</u>	
Turbine gross output, MW	125
Turbine gross heat rate, Kcal/kWh	2,042
Unit net output, MW	114.4
Unit net heat rate, Kcal/kWh	2595
Particulate emissions, mg/Nm3	50
SO2 emissions, mg/Nm3	600
NOx emissions, mg/Nm3	200
<u>Capital Cost</u>	
Estimate of Total Capital Cost	$108,839,600
Cost/Net kW	$951

6.0 Makeup Water Treatment System

(Refer to Figure 6-1)

We found that upgrading the plant makeup water system would greatly improve the availability of these units. The present system gets water from the Donets River. The river water is fairly brackish and contains a significant amount of hardness and alkalinity. The present system treats the water in clarifiers, filters it, passes it through two stages of softening and a degasifier and the pumps it to the evaporator of each unit. (Each 200 MW unit has an evaporator in its cycle.) The distillate from each unit's evaporator is supplied as makeup to that unit.

The new system will receive the raw water, after it is clarified and filtered, and pass it first through a reverse osmosis exchange, then through mixed bed demineralizers. The demineralized water will be supplied to the units as makeup. The quality of the demineralized water will result in far less boiler blowdown.

The new water treatment system is expected to consume more electrical power than the existing system, because of new high pressure reverse osmosis pumps. However, the old evaporators will be blanked off, which will eliminate their maintenance problems and result in increased electric power output.

Our report addressed a makeup water treating system suitable for only the units being investigated. After completing our report, we understand that a decision was made to upgrade the entire plant makeup water system for supplying the needs of all units. Mr. Rubow of Parsons Power will tell you more about that.

FIGURE 6 - 1
MAKEUP WATER TREATMENT SYSTEM

Present System

Clarifiers
Pressure filters
Two stages of softening with degasification
Evaporator distillate is makeup

New System

Upgrade existing soda ash feed system
Two 50% reverse osmosis trains
Thre 50% mixed bed demineralizer trains
Demineralized water makeup to units

Comparison of Performance

	Existing Evap. Effluent	New Demin. Effluent
Hardness, ppb	50	0.0
Iron, ppb	25	0.0
Silica, ppm	1.35	0.01

Estimate of Total Capital Cost **$2,690,400**

LUGANSK GRES REHABILITATION PROGRAM ECONOMIC AND FINANCIAL ANALYSIS

Ukraine / U.S. Joint Conference on Ukraine Clean Coal Power Plant Upgrade Opportunities

by
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The World Bank is considering a loan to the government of Ukraine for the rehabilitation of Lugansk GRES. All eight operating 200 MWe units were originally fueled by Ukraine anthracite coal, which has significantly deteriorated in quality over the last 15 to 20 years, resulting in unit derating, high required quantities of imported gas support fuel, and high maintenance requirements.

The recommended project includes extensive rehabilitation to one 200 MWe TP-100 unit burning cleaned coal; a new 125 MWe Circulating Fluidized Bed (CFB) plant, consisting of two 62.5 MWe CFB boilers and one 125 MWe steam turbine; and rehabilitation of selected common plant facilities. Total investment cost is US$243.8 million, including interest during construction, fees, escalation, and inflation.

Details of the recommended project and other alternatives were selected by a team consisting of Minenergo, Donbassenergo, and the U.S. Department of Energy.

Economic and Financial Analysis Objectives

The purpose of the Analysis is to define a project which will upgrade the performance of Lugansk GRES. The project is intended to satisfy the following criteria:

1. It will extend the life of the upgraded portions by at least 15 years;
2. Upgraded units will restore capacity, improve efficiency, lower imported gas usage, improve environmental performance, improve operating flexibility (fuel), and lower life cycle cost, when compared against a "Without Project" scenario;
3. Donbassenergo has the ability to support the financing for Lugansk GRES.

The objective of the Financial Analysis is to determine the financial viability of the recommended Lugansk GRES project suggested by the Economic Analysis, and also to assess the impact of the project on Donbassenergo operations.

Project Fuels

Study fuels include schtib, cleaned schtib, schlam, cleaned culm, and natural gas.

"Schtib" refers to as-mined anthracite coal with a top size of 6 millimeters. Natural gas is required as support fuel to stabilize/enhance combustion of schtib.

"Cleaned" schtib is a product having a sulfur content, heating value, and an ash content consistent with the original fuel specification for the TP-100 unit. Both "cleaned" and "uncleaned" schtib were considered for Unit Options.

"Schlam" is anthracite washery waste, consisting of fine particles, which is routinely dried and delivered to plants for combustion or alternatively stored in waste areas. Recent studies in Ukraine have characterized the performance of varying grades of schlam in a CFB, and also verified their availability to Lugansk GRES.

"Culm" refers to a currently unused anthracite waste resulting from mechanical separation processes, and has been stored in many waste piles over the last 100 years. "Cleaned culm" is anthracite waste which has been cleaned to an ash level comparable to an unwashed schtib. The combustion characteristics of culm fuels have also been determined in recent Ukraine tests.

Development of Unit Options and Project Scenarios

Unit Options and Project Scenarios (structured from the options) were analyzed. The following Unit Options were considered:

Unit Option 1	Minimal rehabilitation to extend service life to 15 years, increase power generation above its present derated capacity, and improve efficiency. Includes particulate control, but no SO_2 or NOx control.
Unit Option 2	Basic rehabilitation including membrane boiler wall construction to increase power generation above its present derated capacity, improve efficiency, and control SO_2, NOx and particulate emissions.
Unit Option 3	Boiler furnace converted to double arch firing with membrane wall construction. Otherwise similar to Option 2.
Unit Option 4	Extensive rehabilitation to increase generation to above the original rating (200 to 225 MWe), improve efficiency, and control emissions.
Unit Option: New CFB:	Replace existing retired units with 2x62.5 MWe CFB Boilers burning cleaned anthracite culm or a schtib/schlam mix, a new 125 MWe steam turbine, and emissions controlled to stringent new plant limits.
Unit Option New Arch-Fired PC	Replace existing retired units with 2x62.5 MWe Arch-Fired PC Units burning schtib, a new 125 MWe steam turbine, and emissions controlled to stringent new plant limits.

Unit Option 1 was eliminated early from further consideration due to the lack of acceptable emissions control.

Key Advantages and Disadvantages of remaining Rehabilitation Unit Options:

Unit Option	Advantages	Disadvantages
Basic Rehabilitation (Unit Option 2)	1. Restores the plant to acceptable operating condition, reducing maintenance, increasing availability. 2. With cleaned coal, support fuel is reduced from 35% (current) to 5% 3. With cleaned coal, design capacity is restored.	1. Does not benefit from heat rate and capacity benefits of new steam turbine. 2. Additional capacity beyond original design is not realized.
Arch-Fired Rehabilitation (Unit Option 3)	1. Restores the plant to acceptable operating condition. 2. Reduces support fuel requirement to 5%, even when burning uncleaned coal.	1. No precedent for conversion of an existing unit. 2. Full capacity may not be achieved. 3. Most costly rehabilitation. 4. May be subject to stricter "new plant" environmental standards.
Extensive Rehabilitation (Unit Option 4)	1. Restores the plant to acceptable operating condition, reducing maintenance, increasing availability. 2. Significantly improves heat rate. 3. Restores capacity to original design with uncleaned coal, but even further with cleaned coal. 4. With cleaned coal, support fuel is reduced from 35% (current) to 5%.	1. More costly than basic rehabilitation.

In addition to the rehabilitation options, two "new" Unit Options were included. A new CFB unit is designed to fit into the space presently occupied by the retired Phase 1 Boilers 15 and 16. The project includes a new 125 MWe steam turbine, replacing the retired 100 MWe steam turbine. Two 62.5 MWe CFB units are planned to occupy the space of the two retired boilers. The selection of two units vs. a single 125 MWe unit was carefully considered by the U.S. and Ukraine team, and it was agreed that two units offered operating advantages which outweighed the increased capital requirement. The CFB would be capable of burning cleaned culm or an 30/70 mixture of uncleaned schtib/schlam.

For comparative purposes, a new arch-fired pulverized coal (PC)-fired Unit Option of a like size was also analyzed.

The new CFB power plant will serve the multiple purposes of:

- utilizing large existing stores of waste fuel,
- providing the environmental benefits (lower emissions) of this new technology, and
- providing Ukraine with CFB technology, making it available for application elsewhere in their extensive coal based power industry.

The Lugansk plant is currently operating at very low capacity factors (below 45 percent), and may continue in this trend if the plant is not rehabilitated. Following project implementation, rehabilitated units should be dispatched more frequently, due to lower heat rates, lower operating costs, and higher unit reliability/availability. While accurate projections cannot be made without a detailed system analysis, the following conservative assumptions were made for projected unit capacity factors:

Rehabilitation burning uncleaned coal:	65 percent
Rehabilitation burning cleaned coal:	70 percent
New PC-Fired and New CFB Plants:	70 percent

The selection of 70 percent capacity factor is supported by consideration of U.S. operating experience as an upper bound, tempered by consideration of the Ukraine generation mix, and Ukraine experience of lower availabilities.

Using the Unit Options as a basis, Project Scenarios (combinations of unit options) were developed which resulted in project costs (capital, AFUDC, fees, escalation, and inflation) within the World Bank proposed budget of $250 million. The "Without Project" Scenario assumes continued degradation of existing units, including increases in support fuel, deterioration of heat rate, additional unit derating, increased maintenance, and eventual replacement of the unit with operation beginning in 2014.

Common Facility Improvements

Two major facility improvements whose benefits extend beyond the selected rehabilitated/new unit(s), are included in the Project Scenarios: (1) a new water treatment system for the entire plant, and (2) coal yard modifications.

The new water treatment system is required to inhibit the continued deterioration of operating units, and to improve unit heat rate and availability. Coal yard modifications, required to modernize the plant consistent with other plant rehabilitations, will also improve unit availability. The economic justification of both improvements was determined together with, and independently from, Project Scenarios.

Economic Analysis

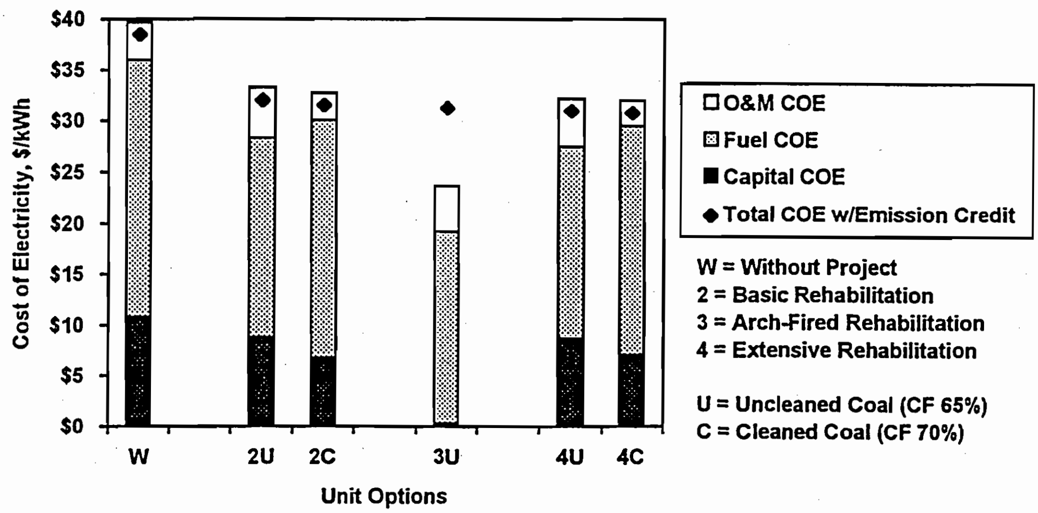
Four figures-of-merit are employed to measure the relative economic value of Unit Options and Project Scenarios:

- Levelized Cost of Electricity (COE),
- Economic Internal Rate of Return (EIRR),
- Cumulative Net Present Value (NPV), and
- Cost of Rehabilitated or New Capacity.

Environmental costs/benefits based on emissions quantities, relative to the "Without Project" scenario, represent an improvement in air quality and human health, and are included in the economic COE.

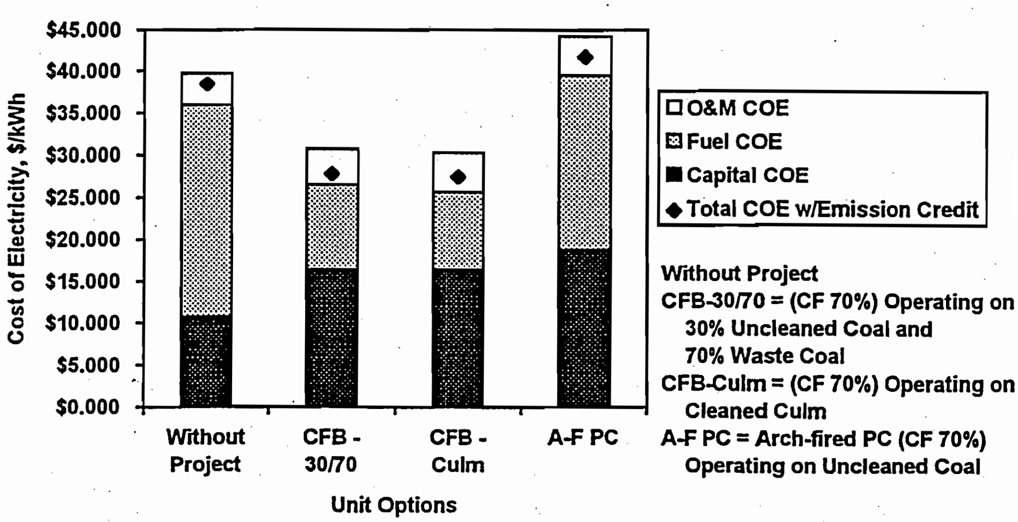
The following exhibit demonstrates that the Extensive Rehabilitation Unit Option, operating on cleaned coal, results in the lowest levelized COE.

Levelized Cost of Electricity for Rehabilitation Unit Options



The COE comparison for New Plant Unit Options is presented below. It is clear that if a new plant is considered, the CFB is the preferred Unit Option.

Levelized Cost of Electricity for New Plant Unit Options



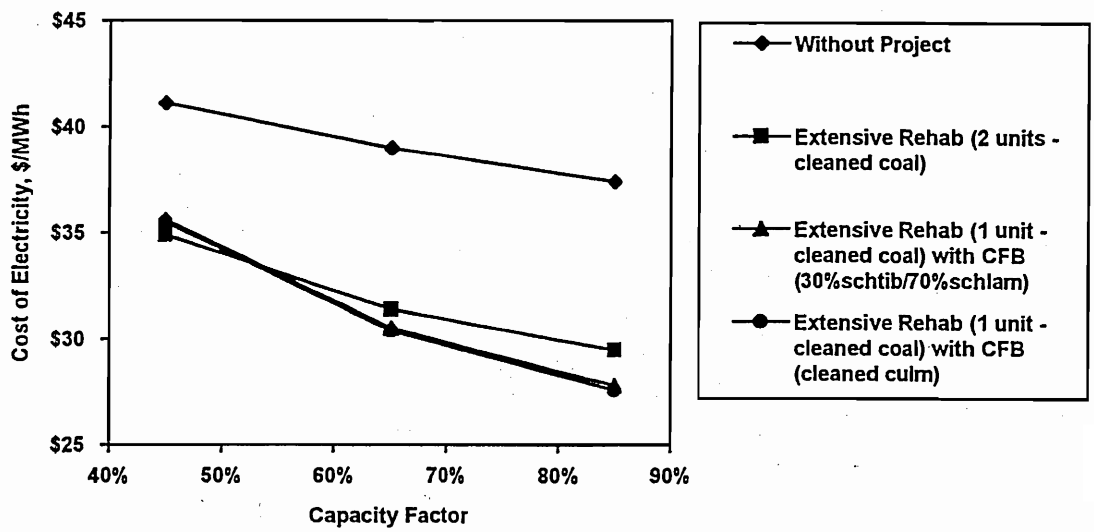
"Combined project" scenarios consisting of Extensive Rehabilitation and new CFB Unit Options, considering available funding, were investigated. Their characteristics are:

Project Scenario	Upgraded/New Capacity	Capital Need, US$ million[a]	Comment/Justification
Extensive Rehabilitation of two existing units	450 MWe	$216.9	Least cost rehabilitation option.
Extensive Rehabilitation of one existing unit and 2x62.5 MWe CFB with new 125 MWe steam turbine	350 MWe	$243.8	Combined options which reduce risk and provide development opportunity.

Note: a. This cost includes capital, and an estimate of interest during construction, fees, escalation, and inflation. The economic analysis uses this cost, less fees and interest. It is presented here only as a limit to select Project Scenario components.

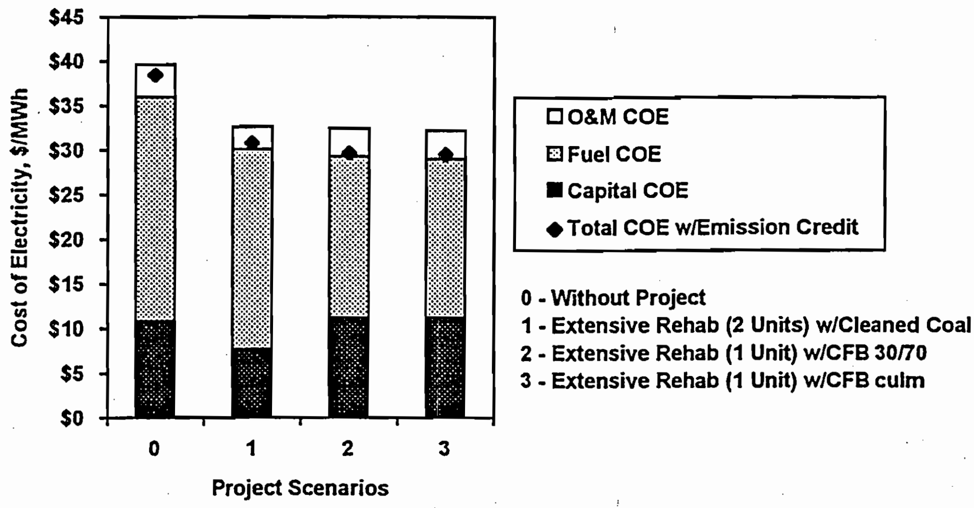
The Extensive Rehabilitation using cleaned coal provides the lowest COE at capacity factors below 55 percent, but a COE that is higher than a CFB burning culm for higher capacity factors, as shown in the exhibit below.

Levelized Cost of Electricity vs. Capacity Factor for Project Scenarios



The next exhibit shows the COE details for the same project scenarios at assumed capacity factor of 70 percent. These Project Scenarios are relatively close in total COE; however, since projected future capacity factors are not known with a high degree of certainty, risk is considerably reduced by selecting a combined Project Scenario: Extensive Rehabilitation and New CFB.

Levelized Cost of Electricity for Project Scenarios



Economic Analysis of the four Project Scenarios resulted in the following key values and figures-of-merit:

Project Scenario	Project Cost, million US$[a]	COE US$/MWh	EIRR[b]	NPV[b] US$1000	Capacity Cost, US$/kWe
"Without Project"	NA	$38.5	0	0	$1,113[c]
Extensive Rehab (2 Units) using Cleaned Coal	$216.9	$30.8	14.88%	$56,973	$386
Extensive Rehab (1 Unit) using Cleaned Coal with CFB using 30%schtib/70%schlam	$243.8	$29.7	14.71%	$64,200	$570
Extensive Rehab (1 Unit) using Cleaned Coal with CFB using cleaned culm	$243.8	$29.5	14.81%	$65,758	$570

Notes: a. This cost includes capital, and an estimate of interest during construction, fees, escalation, and inflation. The economic analysis uses this cost, less fees and interest. It is presented here only as a limit to select Project Scenario components.

b. The Economic Rate of Return and Net Present Value for the project scenarios are based on the incremental differences between the with project and without project scenarios, therefore these values are zero by definition for the without project scenario.

c. The Without Project Scenario assumes a replacement unit installed in 2011.

Economic figures-of-merit of the combined scenario are competitive with both rehabilitation and new plant scenarios. The goal is to select a project that comes closest to economically meeting the project objectives, including the probability that each performance target will be achieved. The matrix below contains performance measures (upon which achievement of objectives depend) arrayed for each Project Scenario. Each element displays a value (ten is the best, while one represents a less attractive, or more risky assessment) that reflects the collective judgment of the team participants, of the degree to which that measure can be achieved by the scenario.

Project Scenario	Performance Measures				
	Restore/ Provide New Capacity	Reduce Gas Support Fuel Requirements	Improve Heat Rate	Improve Fuel Flexibility[a]	Achieve Cost and Schedule
Baseline ("Without Project")	1	1	1	1	NA
Extensive Rehabilitation (2 units)	7	7	9	5	6
Extensive Rehabilitation (1 unit) and CFB	7	9	8	8	8

Note: a. Includes the ability to handle low quality or inconsistent fuel supply.

Rehabilitation and new plant Project Scenarios are clearly advantageous when compared to the "Without Project" scenario. A project scenario which depends solely on rehabilitation does not adequately cover the risk of fuel supply of adequate and consistent quality. Improved heat rates and reduced support fuel requirements of rehabilitated plants depend upon the use of cleaned coal. Conversely, use of project capital to install only new CFB capacity provides a plant that is robust to low/variable fuel quality; however, new capacity is more expensive than rehabilitated capacity on a $/kW basis. Project Scenarios which depend solely on new technology would provide inadequate quantities of reliable generating capacity in a country where it is badly needed.

Therefore, the strongest scenario combines rehabilitation with a CFB unit. This approach offers low cost of electricity and a relatively high probability of meeting project objectives, and provides a reasonable balance in selecting the best technical and economic alternative for electricity production. The combined scenario increases operational flexibility, considering the prospect of poor fuel quality. While reducing fuel supply and construction risks, the combined scenario is also superior to rehabilitation alone in environmental performance. The combined scenario also improves the power stations ability to respond to changing load. With the recommended CFB system, turndown to 25 percent of nameplate capacity can be achieved without use of natural gas or oil support fuel. The selected Project Scenario of Extensive Rehabilitation and New CFB, combined with selected common facility improvements, is accommodated within the constraint of US$250 million project cost.

Several sensitivity analyses were conducted to address identified risk areas. The results were used in assessing the risks, ranking the Project Scenarios, and selecting the recommended project.

Economic Evaluation of Common Facility Improvements

An independent evaluation of the proposed new water treatment and coal yard improvements demonstrated that these improvements are justified on their own economic merits. The heat rate improvement of all Lugansk GRES units, derived from improved water quality, results in an NPV of US$ 8.2 million and EIRR of 20.3 percent.

A very conservative increase of two percent capacity factor is assumed for all Lugansk GRES units, as a result of improved coal handling system availability. An NPV of US$4.1 million and EIRR of 17.3 percent justify the inclusion of this improvement in the project.

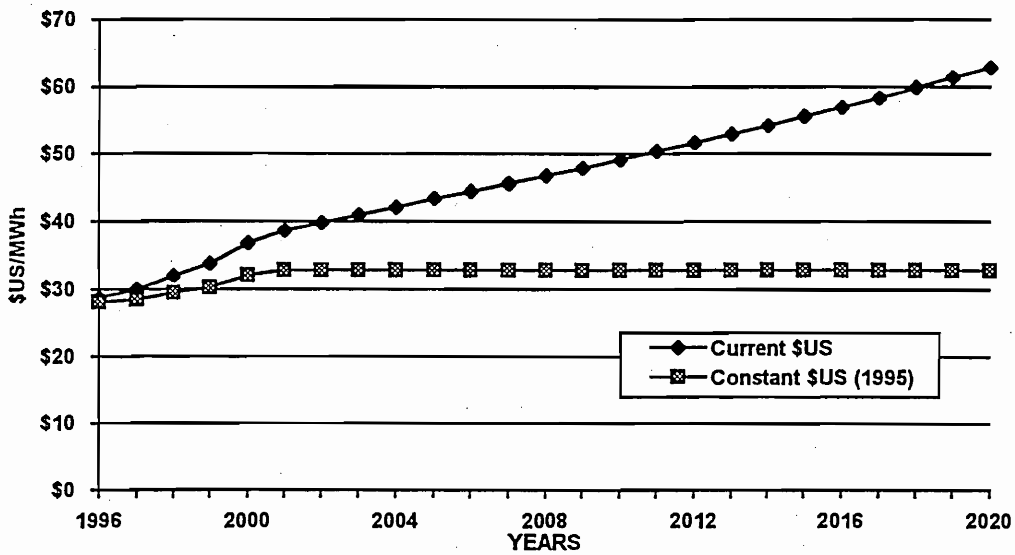
Financial Analysis

The financial model focuses primarily on the project, assuming that other Lugansk GRES operations will be independent and will not directly affect the project's financial viability. Two exceptions are the new water treatment facility and coal yard modifications, whose benefits extend beyond the boundary of the "project." Further, the project financial analysis does not include required facilities outside the boundary of Lugansk GRES, including coal processing facilities to provide cleaned coal or infrastructure requirements to provide waste fuel to the new CFB units.

The project capital cost estimate is US$ 184.2 million in real terms (1995 US$). Sixty percent of the project cost has been designated for the World Bank loan with a resulting loan amount, considering only capital costs, of approximately US$ 109.9 million (1995 US$). When fees, interest during construction, and escalation in project costs are included, the total project amount is US$ 243.8 million, and the amount of World Bank financing is approximately US$ 157.8 million.

Construction is estimated to last 5 years (1998 through 2002). Construction will begin with the rehabilitation of Unit 13. The common facilities portion will be completed in 2000, and the CFB construction will be completed in 2002. Output from rehabilitated Unit 13 and the CFB will begin in 2001 and 2003 respectively.

Projected electric tariffs utilize World Bank-supplied values through 2001. The assumed tariff projections are shown below:



The financial viability of the proposed project is measured by the Net Present Value (NPV) and Financial Internal Rate of Return (FIRR). The NPV and FIRR, using a discount rate of 10 percent, are calculated on an incremental basis relative to the "Without Project" case.

Revenue and financial measures are derived from Operation of Unit 13 and the new CFB, as well as the incremental efficiency improvement of all Lugansk units resulting from a new water treatment facility and increased availability resulting from coal yard improvements. All cash expenditures have been captured on an incremental basis, meaning that taxes and other expenses are those directly related to the project itself.

A summary of the project financial results follows:

Project	Net Present Value	Financial Internal Rate of Return
Rehabilitated Unit 13, New CFB Unit, New Water Treatment Facility, and Coal Yard Improvements	US$ 59.4 million	14.3%

Impact of the Lugansk Project on Donbassenergo Operations

The Lugansk GRES power station is one of five plants currently operated by the generation company, Donbassenergo. The 35 percent equity required to fund this rehabilitation and upgrade project is assumed to be provided by Donbassenergo. In order to evaluate the financial effects of this project on the generation company, two sets of Donbassenergo's financial statements (Income Statement, Sources and Uses, and Balance Sheet) were created. The first set states the long-term projections of the company assuming that the Lugansk GRES rehabilitation and upgrade project does not go forward. The second set restates the company's long-term financial position including the project's equity and debt funding and the incremental increased revenue and decreased cost structure.

The goal of this analysis was to evaluate the company's financial position during the construction and rehabilitation period. In order for this project to be financially viable for Donbassenergo, the company needs to have sufficient cash available during this period to fund the equity portion of the capital investment. The comparison between equity required and Donbassenergo's cash position reveals that the company will have sufficient cash to invest in this project. Therefore this project should not prevent the company from funding the Starobeshevo project in the next four years.

Conclusions and Recommendations

The selected Project Scenario of Extensive Rehabilitation and New CFB, combined with selected common facility improvements, represents the strongest approach to Lugansk GRES rehabilitation, and is accommodated within the guideline of US$ 250 million total project cost.

The financial viability of the proposed project is very dependent on the level of tariffs that the Lugansk GRES is able to obtain for electricity supplied to the National Dispatch Center. The Financial analysis has shown that a modest increase in tariff levels, consistent with World Bank projections, would achieve 14.3 percent return on the total investment. Factors that could help offset the need for higher tariffs include tax reform, particularly in the allowable deductions for income tax calculations.

An analysis of the project's impact on Donbassenergo operations demonstrated that the Lugansk GRES project has a minor impact during the construction period and during the subsequent operating period.

The proposed Lugansk GRES project is recommended for funding by the World Bank.

ABSTRACT

"Fuel supply variants for Ukrainian anthracite-using power plants"

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The application of circulating fluidized bed (CFB) boilers, which are less sensitive to fuel quality, to Ukrainian power plants allows to widen the fuel base of power plants at the expense of coal mining and preparation waste. It's reasonable to use coal waste at CFB boilers due to the following reasons:

- decreasing of electric power basic costs and of the terms of the credits repayment for power plant reconstruction;
- partial discharge of coal deficit in Ukraine;
- continuous liberation and rehabilitation of the waste storage places.

The report is devoted to the waste accumulated resources and quality (basing on the data of UkrNIIUgleobogaschenie Institute and the samples of CETC) and the possibility of the waste CFB combustion after suitable fuel preparation (basing on the results of test combustion at CETC 20 kg/h CFB plant).

<u>Dry waste of coal mining and preparation</u> contains 10-30% of residual carbon, but in the waste piles this level remains continuously only for anthracite waste. For CFB combustion, dry waste must be re-enriched. It's practicably to produce fuel with ash content 30-40% of dry waste, extracting up to 70% of residual carbon. If dry waste contains carbon above 15%, the fuel-of-waste cost would not be higher of 30-40% cost of the anthracite with the same ash content. Dry anthracite waste resources of the marked quality are accumulated:

- in Shakhtersk-Torez region — 90 mln.t (eq. 18-20 mln.t of CFB fuel);
- in Krasny Luch-Anthracite region — 75 mln.t (eq. 14 mln.t of CFB fuel);
- in Rovenky region — 25 mln.t (eq. 4,4 mln.t of CFB fuel);
- in Sverdlovsk region — 35 mln.t (eq. 8 mln.t of CFB fuel).

The railway distance from these regions to Lugansk Power Plant is 100-170 km. Combustion tests have shown, that fuel produced of anthracite waste is similar to the anthracite of the same ash content, and it can be considered as the alternative fuel for CFB-boiler of Lugansk Power Plant for a long period.

<u>Wet coal wastes</u> are presented by the limited resources of slime with ash content below 40%, slurry resources with ash content above 55% (not very suitable for combustion), and by slime-slurry waste resources with ash content 40-55%

(suitable for CFB combustion without any re-enrichment). The last-mentioned are accumulated in amount of 50-60 mln.t in Lugansk and Donetsk regions, and above 10 mln.t of them is anthracite wet waste.

High moisture and small individual particle sizes are typical for slime-slurry waste. At the same time, when thermal drying, thus in rotary furnaces, particles agglomeration happens due to the natural clay content. The drying & crushing procedure optimization can bring the slime-slurry fuel particle size distribution to the CFB requirements. Test CFB combustion was held in CETC of dried dust-like anthracite slime (together with anthracite), and of slime-slurry agglomerates. The possibility was demonstrated of the addition to the anthracite CFB fuel 50-85% of dried slime-slurry waste of Yanovskaya, Nagolchanskaya, Komendantskaya, Sverdlovskaya Coal Preparation Plants (distance 100-170 km from Lugansk Power Plant). Good results were obtained when Cherkasskaya CPP bituminous slime CFB combustion (distance less 50 km), but the possibility of its joint combustion with anthracite needs an additional study.

It can be concluded that using of dry anthracite waste (after re-enrichment) and of slime-slurry wet waste (after thermal drying) would provide CFB-boilers, being applicated at Lugansk and another Ukrainian power plants, with substantial part of fuel supply for a long perspective.

The Variant of Enriched Anthracite Culm Supply to Lugansk Power Station

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The "Ukrniiugleobogaschenie" Institute has developed a variant of supplying Lugansk TPS with enriched anthracite culms.

According to this variant, firstly power unit No.13 and later on another two units of Lugansk TPS will operate with enriched anthracite culm (AC) coming from local mines in Lugansk area.

Coal industry of Ukraine has at its disposal abundant deposites of anthracite coal to cover the needs of fossil power plants for next 225 – 250 years.

Major anthracite deposites and mining equipment in Ukraine are allocated in Lugansk region.

Anthracite mines in Lugansk region have direct railway access to Lugansk TPS.

Analysis of the results of investigations on quality, sieving, fractional, elementary and chemical contents of mined anthracite coals has shown that coals coming from practically all mines could be transformed to enriched anthracite culm product in full comply with claims of customer, i.e. having not more than 20% ash and sulfur content less than 1.5%.

Operating facilities of coal washing plants of Ukraine allow to process up to 50 mln tons of anthracite anually. However, sixty per cent of coal washing plants do not enrich fine fraction of 0…6 mm and this coal is shipped directly to customer with average ash content of 29%.

Supply to Lugansk TPS of culm with ash content less than 20% in needed quantity could be arranged by means of establishing new compleces for 0…6 mm class enrichment at two or three existing coal washing plants which already have the depth of coal enrichment up to 6 mm.

By means of comparative analysis and generalized estimation of different enterprises, study was performed on the feasibility of equipping such compleces to enrich fine anthracite classes at the existing Miusinskaya, Vakhrushevskaya and Krasnopartisanskaya coal washeries having projection for total capacity of 4700 thousand tons by processed matter, which is equivalent to 1115 thousand tons of enriched culm.

For these coal washing plants, suppliers of material were selected basing on perspective of leaving in operation and developing in future the mines with technologically matching characteristics of the raw anthracite coal and most economically attractive conditions of material transportation to the coal washing plants.

Selection of mines for raw anthracite supply to each washery was performed on the basis of the following considerations:

- abundance of raw anthracite to satisfy demand in concentrated culm to the period from year 2000 until year 2030;

- possibility to obtain enriched culm, maximum in comply with customer's claims regarding coal quality;
- avoiding counterflows of materials, with least transportation costs of the raw material to coal washeries and enriched anthracite to Lugansk TPS.

Finally, following mines were selected to supply raw material to the coal washing plants:

Coal washing plant	Mine
Miusinskaya	Miusinskaya
	Krasnoluchskaya
	Kniagininskaya
Vakhrushevskaya	Vakhrushevskaya
	b.n. Frunze
Krasnopartizanskaya	Krasnopartizanskaya
	Maiskaya

This variant is characterised by reduced amount of sludge formation, reduced consumption of electric power for retention and processing of sludge and drying the final product.

Potential resourses of the culm enrichable to 20% ash at the disposal of the above mentioned suppliers are estimated at 1115 thousand tons annualy during the period until year 2030, while the ordered per year amount is 675 thousand tons, i.e. sparing coefficient is 1.65.

Preliminary calculations on the balance of products confirm possibility of providing TPS with fuel of the needed quality, under condition that the three above mentioned coal washing plants are modernized basing of detailed study of the characteristics of incoming raw material.

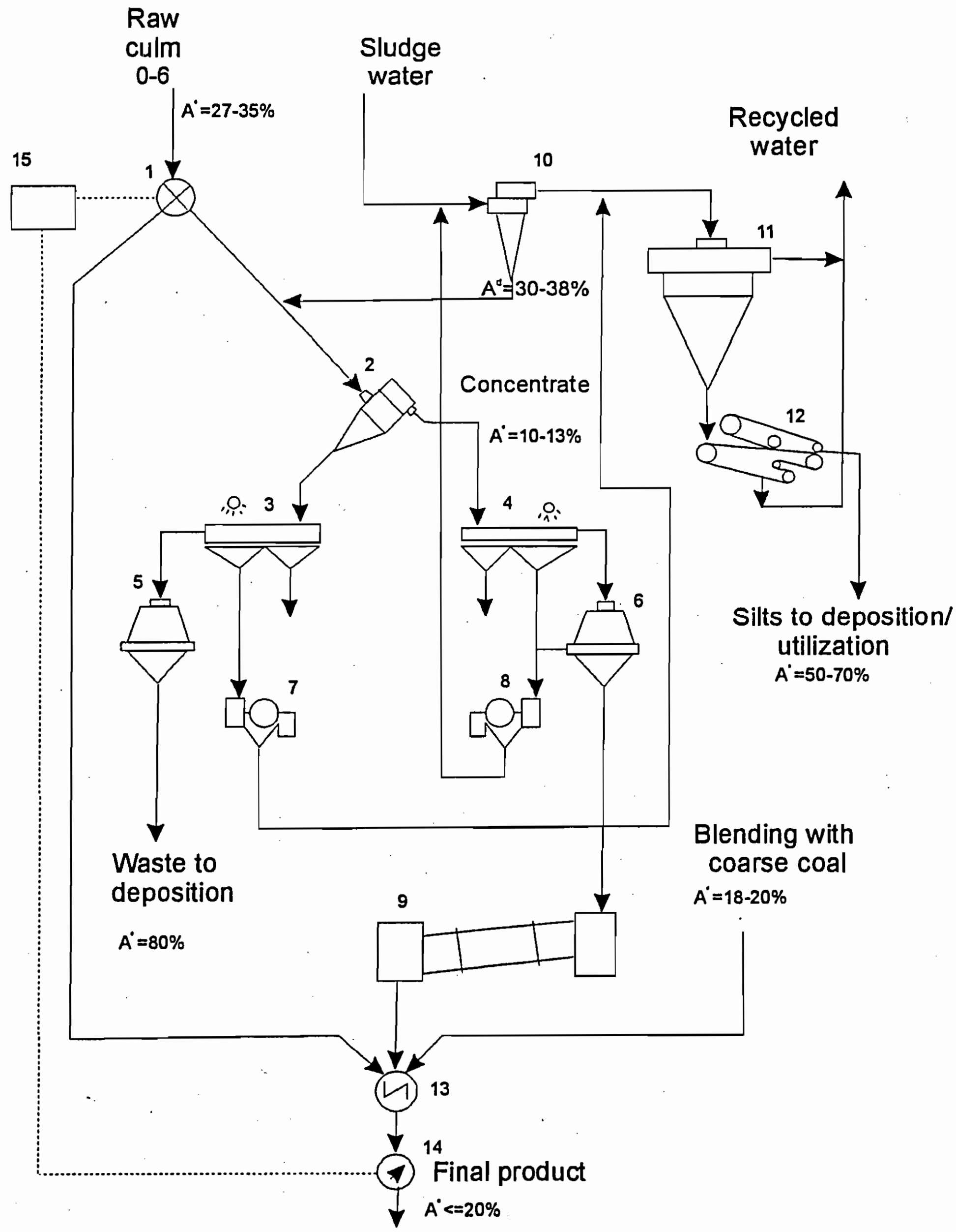
Taking into account scheme of the process at Miusinskaya, Vakhrushevskaya and Krasnopartisanskaya coal washeries, it is necessary to:

- apply culm enrichment process at above-medium size cyclones;
- improve the process scheme and equipment for sludge products treatment and retention;
- apply thermal drying of wet components in culm product;
- increase accumulating capacities to guarantee stable regime of equipment operation.

Preliminary study and assessment of options for technological schemes of each of the mentioned coal washeries allowed to make the following conclusions:

1. Processes and equipment for preparation, enrichment and sorting coarse and medium classes (bigger than 6 mm) at all three coal washeries are up-to-date and could be left in operation for further use after replacement of worn parts and repair of air and power supply installation of setting machines and tuning the regimes of optimum operation.
   Bolting machines for primary classification, dewatering and sorting are need to be equipped with modern wear-proof sieves.
2. Increase of separation efficiency of above-medium separators and setting machines could be simultaneously attained both by means of stabilizing regime of enrichment process feeding and by decreasing contents of pollutions in recycled water. The latter requires radical modernization of the systems of sludge product treatment and retention.

3. Production of the marketable culm 0…6 mm with 20% ash and 80% ash in the waste (minimum losses) necessitates an application of the special enrichment process for this class.
   Basing on characteristics of concentrating ability and fractional composition of the culm entering coal washing plants it seems adherent to apply for this purpose the hydrocyclone with magnetic suspension.
4. Resulting from the performed studies, it is recommended to apply at all three coal washeries the same type of the process of anthracite culm treatment and enrichment (See Figure), which will yield maximum concentrated AC output, conditioned with respect to ash content and humidity (by means of thermal drying).



Flow diagram of culm enriching process

1 – splitting of culm flow; 2 – medium size hydrocyclone; 3 and 4 – bolting machines; 5, 6 – centrifuges;

7 and 8 – magnetic separators; 9 – drier; 10 – hydrocyclone; 11 – hardener; 12 – press filter; 13 – mixer; 14 – metering device to measure ash contents in the mix; 15 – programmable automation device.
For maximum economic efficiency, option is recommended with partial enrichment of 0…6 mm class at above-medium cyclones, separate regeneration of suspension (while keeping the sludge feeding to cyclones), treatment of fine sludge without flotation.

The amount of raw culm extracted from general flow for further blending with concentrate will be determined on the base of continuos control of ash content in final product 0…6 mm using a signal transmitted to programmable logic controller for optimum operation of mechanical devider.

Fine silts will be extracted from the sludge after classifying hydrocyclone after thickening in conical condenser and dewatering at the belt press filter.

Optimum variant of the process was determined using a criterion of maximum output of 0…6 mm concentrate with 20% ash and not less than 80% ash in waste.

For each coal washing factory three variants of the process were considered:
1. Concentrating of 0…6 mm class is done together with class 0…13 mm, and further extraction of AC from enriched concentrate.
2. Concentrating of entire 0…6 mm class extracted from raw anthracite, yielding the concentrate of the given ash contents.
3. Concentrating of the part of 0…6 mm class extracted from raw anthracite and further mixing with raw culm to obtain marketable blend with the given ash contents.

In all variants, real efficiency of bolting machines and guidelines for intermixing of concentrated products were assumed.

For maximum yield of concentrate with the given ash content, rated demarkation density of separation was determined.

Comparison of the data for different variants allows to conclude that the most preferable is the third option. The latter has minimum losses of combustibles leaving with waste, while amount of culm subjected for treatment (compared to Option 1 and 2) and costs are reduced. Hence:
If suggested variant of the process is accepted, following amount of marketable culm could be produced at the factories:

Miusinskaya	311 thousand tons	19.9% ash
Vakhrushevskaya	370 thousand tons	20% ash
Krasnopartizanskaya	434 thousand tons	20% ash

Profits

Miusinskaya	1279.7 thousand USD	Investment pay-back period 3.68 years
Vakhrushevskaya	915.8 thousand USD	Investment pay-back period 3.42 years
Krasnopartizanskaya	1952.5 thousand USD	Investment pay-back period 2.57 years

Operation of the power plant using concentrated culm will contribute not only to efficiency increase of fuel firing process, but also to improvement of ecological situation.

REPORT ON PULVERISED COMBUSTION OF UKRAINIAN ANTHRACITE

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1. Introduction

One of the main parts of joint US/Ukrainian power plant upgrade project for Lugansk Power Station, Ukraine, is testing the pulverised combustion of Ukrainian anthracite. Such testing conducted in USA simultaneously with testing the combustion of the same coal in fluidized bed at the pilot-scale industrial facility manufactured by Babcock & Wilcox, Alliance Enterprise, Ohio.

On the ground of such testing, the final choice of optimal technical upgrade approach for reconstruction of Lugansk power station was maid.

2. Investigation Purposes

The matter of great importance of the investigation performance was to study the reasons of the low combustion efficiency, to estimate the effect of obvious difficulties of the combustion of the high ash coal with low volatile content as well as structural features of the boiler and its operational characteristics on the combustion efficiency and to develop technical requirements.

3. Experimental Facility

Investigations was carried out at the state-of-the-art Combustion and Environmental Research Facility (CERF) at the Federal Energy Technology Center (FETC) of the Department of Energy of USA.

Research facility is a pilot-scale installation and its structural features allow to examine different systems and to elaborate the concepts for upgrading fuel combustion and reducing the pollutant emission. Such facility provides the wide range of adjusting burner load and sufficient radiation volume residence time which is comparable with the boiler residence time.

Furnace chamber of the research facility is capable to achieve similarity with full-scale utility and industrial boilers but does not exactly duplicate the operating conditions of full-scale units, such as heat release rates and surface-to-volume ratios. Nevertheless, facility furnace chamber is useful for obtaining data on integrated effects of a number of interdependent design and operating variables on the characteristics of burning out and environment.

Nominal thermal load is approximately equal 500.000 kJ/hour, fuel consumption is 2 kg/hour, and the temperature of secondary air is 540^0 C. Thermal consumption in coolers is 140.000 kJ/hour. Furnace nominal residence time (full load) is 2.5 sec.

Characteristics of the fuel burned at the facility is shown in Tables 1, 2, 3.

27 tons of this fuel is the part of a large batch of anthracite schtib (160 tons) shipped from the 50 years of Soviet Ukraine mine, Donetsk coal basin. This mine was chosen as an official supplier for Lugansk power station because its coal meets requirements for the coal quality and also satisfies methodology of batch choosing, which is stipulated in the joint US/American agreement.

4. Fuel Cleaning and Testing Carrying out

At the Process Research Facility (PRF) of Federal Technology Center, Pittsburgh, the anthracite schtib was cleaned in the of heavy matter separator up to $A^i < 10\%$ and was milled in such way that 40-95% of the coal particles were less than 200 mesh.

Hereby, three sorts of the fuel were prepared for combustion at the CERF:
coal with ash content 10, 18 and 38% respectively, coal milling fineness varied in such way that 40-95% of the coal particles were passed through 200 mesh sieve.

5. Testing Results

Raw Schtib

Testing the raw schtib through FETC's Combustion and Environment Research Facility demonstrated that the key problem of the high ash anthracite combustion is the flame stability. Therefore, during carrying out testing, the flame root location is a matter of great importance because it is necessary to heat coal particles in full, sufficiently and quickly.

We have to point out that burning out characteristics were good enough even if reactor zone residence time was up to 1 sec. This observation is consistent with testing results obtained at VGP-100V facility, Coal Energy Technology Center, a division of the Ukrainian National Academy of Sciences.

One of the main conditions of carrying out CERF testing was to simulate the operation of the existing TP-100 boiler as closely as possible. The low air excess in the burner reproduced in some operating regimes has resulted on the efficiency of burning out. So, because to powerful effect of uncontrolled air suction in the furnace, oxygen content in the flue gas is not a control factor of the fullness of coal burning out, because the fullness of coal burning out decreases due to air deficiency in ignition belt zone.

Joint combustion of the natural gas and raw schtib did not lead to improvement of its burning out. The natural gas being injected around the primary air/raw schtib mixture preferentially reacts with the available oxygen in the near burner region and so stabilises the flame, but does not appreciably increase the raw schtib particle heat transfer and ignition. Particularly we have to point to the series of tests on the injection of cooled air being the mixture of nitrogen and oxygen. Such mixture was injected in the furnace at the temperature of ambient air and the gas composition was chosen in such way that the oxygen concentration (4%) in the furnace has not changed essentially.

Such additive was necessary because some facility structural characteristics (30 % heat removal from the reactor chamber walls, high temperature of the flue gas, the effect of lining of the high temperature reemission on the coal at the temperature 1,000^0 C and higher) favoured the creation of the muffle over all residence time of the coal dust in the facility reactor volume. The cooled gas injection into the facility reduced the temperature to 1,050-1,100^0 in the furnace at the moment corresponding to the real residence time of the coal particles in boiler furnace.

After above-mentioned reducing the temperature of the flue gas and reducing the temperature of the secondary air up to 340^0 C, for raw schtib the flame stabilisation was not achieved even at 25-30% additional combustion of the natural gas. Load reducing to 80% at the furnace top under such temperature level also led to the quick flame-out.

Furthermore, the tests at the regime with the cooled natural gas continued less than 4 hours was carried out. Such tests demonstrated that at the 30% gas additive the acceptable long-term tests could be performed, and if the gas additive was less than 20% the numerous flame-out were observed.

Summarised the above-mentioned we have to point out that the regime parameters as well as physical-chemical characteristics of the solid fuel is the possible reason of the poor high ash anthracite burning out.

Increased quantity of the mineral component produces an effect on decreasing the surface of the anthracite particles and simultaneously with the moisture it draws some heat quantity of the burned coal particles for its heating up.

The large-scale experimental program on wide rate of the anthracite and hard coal being carried out by Combustion Engineering company and Foster Weeler company has allowed to show up the effect of forming the slag film on the surface of the most analysed coal and also to determine the physical-chemical characteristics of the anthracite on which this slag film can be formed . The high ash content (>35%), uniformity of the mineral component distribution on the total particle volume, the low Hardgrow index and oxygen content, average diameter of the particle (<150%) relates to such characteristics.

Moreover, the tests demonstrated that the particles (which were less than 200 mesh) did not covered by slag firm. However, we have to advance the guess that the ash component effects on the change of the porous structure of such particles.

Experimental program, conducted at the laboratory facility, Coal Energy Technology Center, a division of the Ukrainian National Academy of Sciences, exhibited (see Table 4) the following: the surface of the anthracite micropores, defined by the adsorption of the water vapour, was reduced as a result of pyrolysis anthracite process.

Destruction and blocking the micropore orifices by melted mineral component can be the reason of decreasing the surface of the anthracite micropores and as a result, micropores become inaccessible for adsorbing gas. Some of the reasons for decreasing the fullness of coal burning out at the furnace output can be staging of combustion process and decreasing the reaction surface.

Cleaned Schtib

Analyses of the cleaned schtib (18% of the ash) during caring out the tests demonstrated that it can be burned without injecting the natural gas. The characteristics of the coal burning out fullness are the best if the milling is more fine (90% is less than 200 mesh), but such characteristics can be good enough even if the milling is more coarse (66% is less than 200 mesh) and make 98%.

Slagging and Fouling

Slagging and fouling behaviour of the cleaned schtib was not significantly different from the raw schtib. A critical furnace exit gas temperature (FEGT) was determined to be 1,135^0 C before fouling became severe.

NO_x Emissions

NO_x emissions of raw schtib are significantly lower than the most other coals that have been tested in the CERF. It can be explained by not high nitrogen content in such coals. Using the Ukrainian reporting methodology (dry basis, corrected to 6% O_2), the raw schtib NO_x emissions were in the 350-500 mg/Nm^3 range, while the cleaned schtib NO_x emissions were somewhat higher in the 500- 800 mg/ Nm^3 range. When co-firing natural gas with the raw schtib, NO_x emissions reductions are generally proportional to the percent thermal input of natural gas with a few exceptions when flame behaviour (e.g. flame root position) changes significantly.

SO_2 Emissions

Observed SO_2 emissions tests tracked fuel composition. Cleaned schtib exhibited about 30% lower SO_2 emissions on an energy basis than the raw schtib, although emissions absolute value is significant (up to 5,500 mg/Nm^3 at 6% O_2) because of high sulphur content ($\approx$ 3%) of the anthracite.

We have to make the following conclusions from conducted experimental program:

1. There were no regimes of stable high ash anthracite schtib without the need for the natural gas support even at 100% load. The enrichment value by the natural gas at the

stable regime was not less than 20% and increased up to 30% under reducing the facility load or under coarsening the milling from R_{90} = 3-5% to R_{90} = 8-10%.

2. The improvement in the anthracite schtib torch combustion could be achieved by coal grinding up to R_{90} = 3-5%, but in majority of cases the natural gas was needed as a support fuel for the enrichment in quantity of 20%.

3. Stability of the torch combustion without co-firing the natural gas as a support fuel could be achieved only by cleaned schtib (up to 18% ash).

4. The tests demonstrated that ignition and combustion of the raw anthracite schtib were much worse than ignition and combustion of cleaned schtib. Most likely the ash bed is formed at the micropore orifices and as a result blocks it.

As stated above we have to mention the following: if anthracite contains more than 20% ash, its usual torch combustion without natural gas and fuel oil support is a problematic. To maintain the anthracite torch combustion with 20-30% ash content we propose to carry out some procedures which are to improve the conditions of its ignition, to raise up the combustion zone temperature and increase the fuel particles residence time in the furnace volume. Such results can be achieved by installation of cyclone furnaces, muffle burners and arc-firer furnaces. In practice for burning the anthracite containing more than 30% ash the technology of combustion in fluidized bed is to be used.

Table 1. Technical and elemental analysis of raw anthracite schtib

Technical analysis, % weight	Raw schtib
Moisture	4.15
Volatile	6.27
Fixed carbon	53.01
Ash	36.57
Elemental analysis, % (dry)	
Hydrogen (H)	1.08
Carbon (C)	56.35
Nitrogen (N)	0.38
Sulphur (S)	2.83
Oxygen (O)	1.20
Ash	38.16
Low heat value, kcal/kg	4626
High heat value, kcal/kg	4826

Table 2. Ash composition of the raw anthracite

Ash composition ,% weight	Raw anthracite
SiO_2	50.14
Al_2O_3	25.63
F_2O_3	10.08
TiO_2	1.34

CaO	4.59
MGO	1.24
Na_2O	1.82
K_2O	3.68
SO_3	1.41
P_2O_5	0.07

Table 3. Results of raw schtib separation in hard liquids

Liquid density, ton/m^3	According to accumulation			
	% output	% energy recovery	% weight, ash	% weight, sulphur
-1.60	12.8	19.9	3.3	1.59
1.60-1.70	44.3	67.3	5.4	2.01
1.70-1.90	55.7	82.5	7.7	2.57
1.90-2.10	61.6	8.6	10.4	2.73
2.10-2.40	69.0	93.3	15.8	2.73
2.40-2.60	75.6	95	21.3	2.67
+2.60	100.0	100.0	3.7	3.03

Table 4 Change of the anthracite schtib porous structure as a result of pyrolysis (δ = 0.4-0.6 mm) at the fluidized bed facility

Ash content of initial coal A^d, %	S_{H2O}, m^2/g of initial coal	S_{H2O}, m^2/g after pyrolysis (T_p = 1123 K)
4.6	74	48
12.8	158	128
20.8	159	89
28.4	119	82
32.8	155	76
39.6	99	49

CFB Combustion of High-Ash Ukrainian Anthracite — Test Results and Design Implications

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Power Plant Upgrade Opportunities
April 21-24, 1998
Kiev, Ukraine

Abstract

High-ash anthracite is the most important indigenous fuel used for power generation in Ukraine. The power plant upgrade program, developed jointly by U.S. Department of Energy (DOE) and Ukrainian Ministry of Energy, anticipates applying the CFB technology for efficient and environmentally clean utilization of this hard-to-burn fuel. Testing of high-ash anthracite sponsored by DOE was conducted at CFB test facilities at the Division of High Temperature Energy Conversion (DHTEC) of Ukrainian Academy of Science in Kiev and at the Babcock & Wilcox Research Center in Alliance, Ohio, U.S.A. (ARC).

Testing at DHTEC included kinetics studies and combustion tests on a small-scale (100 mm diameter) CFB combustor. The test results were used to select the fuel sizing and limestone type for pilot testing at ARC and to evaluate the effects of operating parameters on fuel combustion. Testing at the ARC 2.5 MW_t CFB pilot facility (700 x 700 mm cross section, 23 m high) provided combustion and emission performance data applicable for designing of commercial-scale CFB boilers. Stable combustion without supplemental fuel and with the unburned carbon loss of less than 3% was achieved over a 55 to 100% load range. About 90% of sulfur was removed by adding limestone at a Ca/S ratio of 1.85: nitrogen oxide and carbon monoxide emissions were below 340 mg/Nm^3 and 260 mg/Nm^3, respectively.

The CFB boiler design recommendations for high-ash anthracite, developed based on the test results, are described in the paper. The designs of typical 250 ton/hr and 670 ton/hr CFB boilers for repowering of Ukrainian power plants were jointly developed by Babcock & Wilcox and Kharkov Central Design Bureau of Ukrainian Ministry of Energy. The design features of these boilers are presented.

Introduction

High-ash anthracite is the major energy resource for power plants in Ukraine. The anthracite size fraction minus 6 mm (about 1/4 in.) called anthracite schtib is the fuel for which most of the utility boilers were designed. The quality of anthracite schtib has deteriorated over the years. While the pulverized coal fired boilers were designed to burn a 15-20% ash anthracite schtib. ash content of this fuel is currently about 30-34%. with the maximum reaching 45%. As a result of the decreasing heating value and accompanying lower reactivity of anthracite schtib. the boilers have to operate with supplemental firing of fuel oil or natural gas (up to 20-25% of heat input), even though most of the coal fired units have been derated. Import of natural gas and oil present a huge economic burden for Ukraine. Another problem with the existing boilers is uncontrolled SO_x and NO_x emissions. Ukraine does not produce equipment for SO_x and NO_x control. In addition. the arrangement of existing power plants makes it very difficult or impossible to install such equipment.

New fossil power plants will not be constructed in the Ukraine in the foreseeable future due to the considerable under-utilized generating capacity. The main emphasis in increasing the coal-based generating capacity is on repowering and rehabilitation of existing power plants. CFB technology has been selected by the Ukrainian utility industry as the most important long-term direction in upgrading of Ukrainian power plants. The main reasons for using CFB boilers are: a) ability to efficiently utilize high-ash and high-sulfur fuels including coal wastes, b) control of SO_x and NO_x emissions within stringent limits without the use of backend scrubbing equipment, and c) poor condition of many aged coal-fired boilers makes their rehabilitation economically unfeasible.

The U.S. and Ukraine Governments' cooperative effort, directed by the U.S./Ukraine Clean Coal Task Force, supported a study on evaluation of Ukrainian high-ash anthracite as a fuel for CFB boilers. This study was funded through U.S. Department of Energy, Pittsburgh Energy Technology Center and conducted by Babcock & Wilcox with participation of the Department of High-Temperature Energy Conversion (DHTEC) of the National Academy of Sciences of Ukraine. The experimental work was performed at test facilities of DHTEC in Kiev, Ukraine and B&W's Alliance Research Center (ARC) in Alliance, Ohio. General technical direction of the study and interpretation of test results for CFB boiler design was provided by B&W's Power Generation Group.

Test Program

Objectives

The objectives of the study of CFB combustion of anthracite schtib were as follows:

- Determine kinetic characteristics of anthracite schtib to be used in combustion modeling.
- Select operating parameters of a CFB combustor for optimal combustion performance on anthracite schtib.
- Determine possibility of CFB combustion of anthracite schtib without the use of supplemental fuel in the 50 to 100% MCR load range.
- Evaluate expected combustion and emission performance of a commercial-scale CFB boiler burning anthracite schtib.
- Evaluate performance of Ukrainian limestones as a sorbent in a CFB process.
- Based on test results, develop design recommendations for a CFB boiler utilizing anthracite schtib.

Tests at DHTEC

Kinetic Characteristics of Anthracite Schtib. Kinetic characteristics of anthracite schtib were studied in comparison with other low-reactivity fuels previously tested at B&W. The study was performed with chars generated from three coals: anthracite schtib, Pennsylvania (Centralia) anthracite, and coal waste from medium-volatile bituminous coal from Ebensburg, Pennsylvania. The chars were generated by heating coal samples to 1123K (1561F) in an inert gas flow. Kinetic investigations with the chars reacting with oxygen from air were then carried out in a pulse reactor test rig.

Combustion Tests at Small-Scale CFB Combustor. The purpose of the tests was to determine optimal combustion system parameters for testing at a large-scale pilot CFB facility at ARC:

- combustor temperature and excess air
- fuel sizing
- temperature of solids recirculated from the secondary particle separator

The small-scale 0.05 MW_t CFB combustor is shown schematically in Figure 1.

The combustor is a 100 mm (4 in.) diameter, 2.6 m (8.5 ft) tall CFB reactor. The unit has a two-stage solids separation/recycle system, imitating that in B&W's CFB boilers. A water-cooled heat exchanger and an electric heater were installed at the recirculation pipe from the secondary separator to control the temperature of recirculated solids. During testing only the electric heater was used due to the high radiation/convection heat loss by the pipe and cyclone.

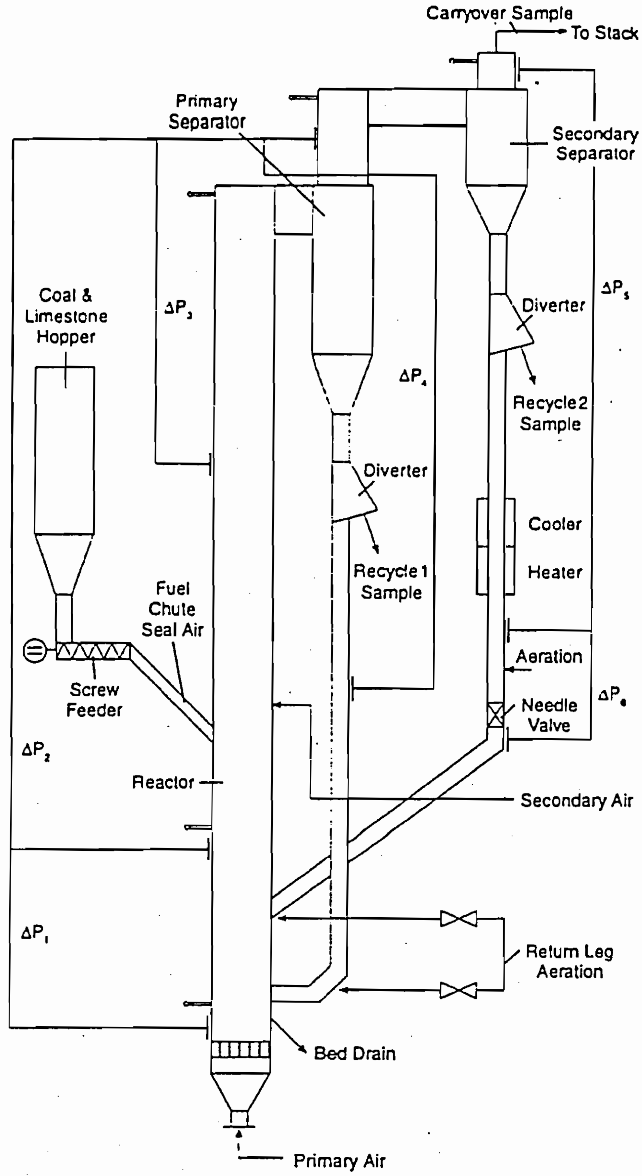

Figure 1 DHTEC small-scale (0.05 MW_t) CFB combustor.

Test measurement included all parameters required for heat and material balance calculations, determination of temperature and pressure distribution, and evaluation of bed material flows and sizing as shown in Figure 1. The test unit was equipped with a computerized data acquisition and performance analysis system.

Comparative Evaluation of Ukrainian Limestones. Three Ukrainian limestones (Komsomolsk, Novotroitsk and Dokuchayevsk) were tested during test burns at the small-scale CFB combustor to evaluate their comparative performance as sorbents for a CFB process and to select limestones for further testing at ARC. This was done by comparing the percent of sulfur capture for a constant molar Ca/S ratio maintained during testing of different limestones.

Tests at ARC

Bench-Scale Limestone Characterization. Two Ukrainian

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limestones selected by testing at DHTEC were evaluated using B&W's bench-scale (6-inch diameter) limestone test apparatus to determine their reactivity for sulfur capture and attrition properties under fluidized bed conditions. Information from the tests was used to rank the two Ukrainian limestones against B&W's data base of U.S. domestic limestones and to select a domestic limestone with performance characteristics similar to the Ukrainian limestones for the use in the pilot-scale .CFB test of anthracite schtib.

A 6-inch diameter atmospheric fluidized bed combustion test unit (6-inch AFBC unit) was designed to measure limestone reactivity and attrition – two fundamental properties that determine sorbent performance in a fluidized bed combustor.

Particles that elutriate from the bed are caught by the particulate filter train including two fiber filters with average pore size of 0.5 microns. Flue gas samples drawn from the bed are analyzed for O_2, CO_2, and SO_2.

Samples of each Ukrainian limestone (Komsolmolsk and Novotroitsk) were crushed and screened to a particle size of minus No. 8 sieve (-2360 microns) to plus No. 30 sieve (+600 microns). In addition, a sample of Lowellville limestone (a U.S. domestic limestone used as a calibration standard) was prepared in a similar way.

The test procedures used on the 6-inch AFBC unit allowed for simultaneous collection of both attrition and reactivity data. The bed section of the test unit was preheated to a temperature of approximately 1144K (1600F) using a gas that contained 9% O_2 and 2500 ppm SO_2, and then a sample of the limestone was added to the bed section. The test unit was operated at constant inlet conditions for 2 hours after addition of the limestone sample while the outlet SO_2 concentration was continuously recorded. During the same period, the elutriated material (attrition products) was collected by the alternating filters and measured every 10 to 30 minutes to determine the rate of fines being generated.

The limestone attrition was characterized by the attrition index that was calculated by comparing the percent cumulative attrition (related to the weight of the initial limestone sample) of each limestone to the percent cumulative attrition of Lowellville limestone.

The limestone reactivity was characterized by the reactivity index that was calculated by comparing the percent calcium utilization of each limestone to the percent calcium utilization of Lowellville limestone. The percent calcium utilization was computed by integrating the measured outlet SO_2 concentration curve and knowing the amount of calcium feed to the bed.

Pilot-Scale CFB Testing of Anthracite Schtib. A test burn of anthracite schtib at the targeted full-load and 50%-load conditions was conducted on B&W's pilot-scale (2.5 MW_t) CFB test facility.

The scope of testing included evaluation of ignition properties, combustion performance, furnace operating parameters, flue gas emissions, sulfur retention, and distribution of the ash.

The pilot-scale (2.5 MW_t) CFB test facility is designed to simulate the combustion, sulfur capture, and solids distribution of B&W's commercial circulating fluidized bed boilers. The previous work has demonstrated that the 2.5 MW_t CFB facility provides results closely approximating performance of commercial size CFB boilers. The 2.5 MW_t CFB facility is shown schematically in Figure 2. It is equipped with a computerized data acquisition system.

Furnace. The furnace inside dimensions are 0.7 meters by 0.7 meters by 23 meters tall. The furnace height is close to that

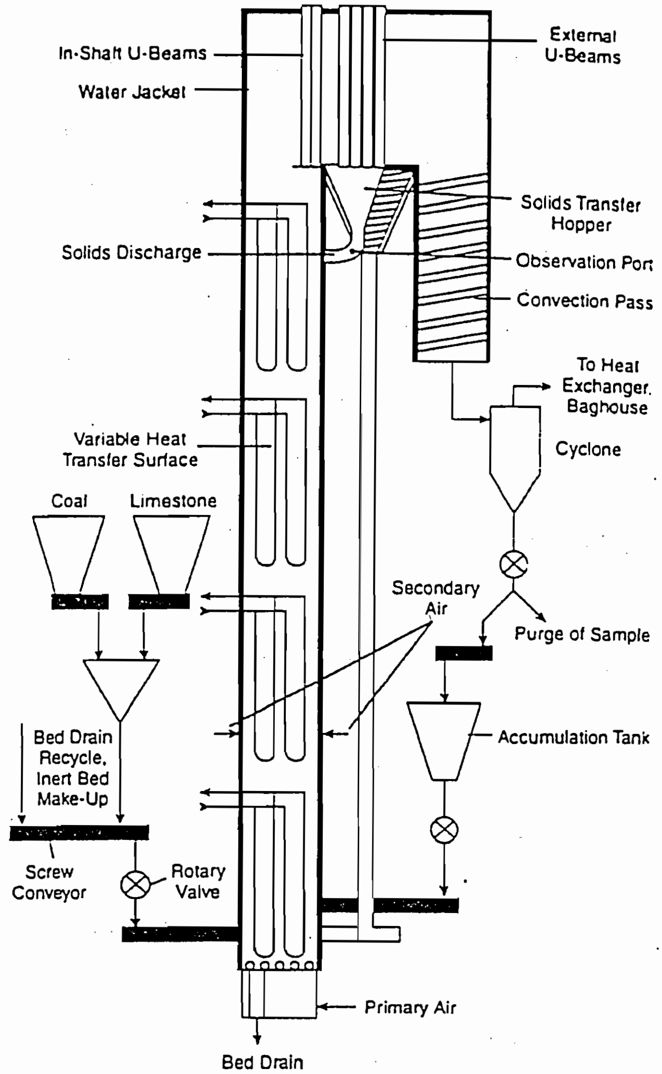

Figure 2 ARC pilot-scale (2.5 MW_t) CFB facility.

of commercial CFB boilers. The walls in the lower 3.3 meters of the furnace are tapered to 75% of the upper furnace area to promote better mixing. The furnace is refractory lined to control heat loss to water-cooled enclosure walls. Furnace temperature distribution is controlled by water-cooled tubes (U-tubes) distributed throughout the furnace to emulate the heat absorption of a commercial CFB furnace.

Air supplied by the forced-draft (FD) fan can enter the furnace at multiple locations: through the air distributor plate at the floor of the furnace; the lower secondary air ports at either 1.2 or 1.5 meters (48 or 60 inches) above the furnace floor; and the upper secondary air ports at either 2.5 or 3.2 meters (100 or 124 inches) above the furnace floor.

Primary Collector and Recycle System. The primary particle separator consists of a labyrinth of vertical "U"-shaped channels (U-beams) arranged in two banks at the top of the furnace. A schematic view of the U-beam separator is shown in Figure 3. The first U-beam bank called in-furnace U-beams (IFUB) collects particles and returns them to the furnace along the rear wall. Particles passing through the IFUB are further separated from the gases by the external U-beam bank (EXUB). Particles captured by the EXUB fall to a small hopper underneath and then are discharged by gravity to the furnace where they fall along the rear wall together with particles collected by the IFUB. More details on the patented internal-recirculation CFB combustor are provided by Belin et al (1995).

Convection Pass. Flue gases and solids leaving the U-beam separator are cooled by a convection pass tube bank. Outlet temperatures from the convection pass are controlled by varying the fraction of hot gas bypassing the tube bank.

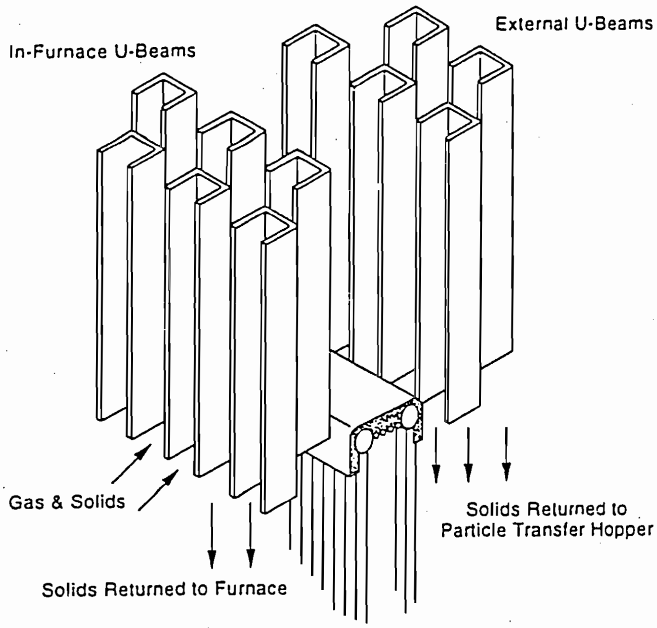

Figure 3 U-Beam separator.

Secondary Particle Collector and Recycle. A single cyclone directly follows the convection pass. Solids collected by this secondary collector can be recirculated to the furnace or discharged from the system. The recycle system includes an accumulation tank that allows part of the solids to be withdrawn from the circulation through the furnace, by changing the speed of the rotary valve downstream of the tank. This provides a patented means of furnace temperature control. The tank is supported by load cells thus enabling changes in inventory to be measured.

Material Handling. Fuel and sorbent flow rates are each metered by gravimetric feeders and injected to the furnace by a screw feeder. Hot solids are removed through a drain port in the floor of the furnace by the water-cooled screw. Bed material can be screened and recycled if this is needed for solids inventory control. Solids passing the cyclone separator are collected by the baghouse.

Results and Discussion

Kinetic Characteristics of Coal

The reactivity of the coals tested was characterized by comparing the char reaction rates with oxygen of air. The dependence of reaction rate on temperature for the three coals is shown in Figure 4 (Arrhenius-type plot). The results from the kinetics tests indicate that the anthracite schtib (curve No. 1) and Pennsylvania anthracite (curve No. 2) have similar low reactivity and almost equal activation energies (slope of lines). The Ebensburg coal (curve No. 3) is the most reactive of the three coals tested.

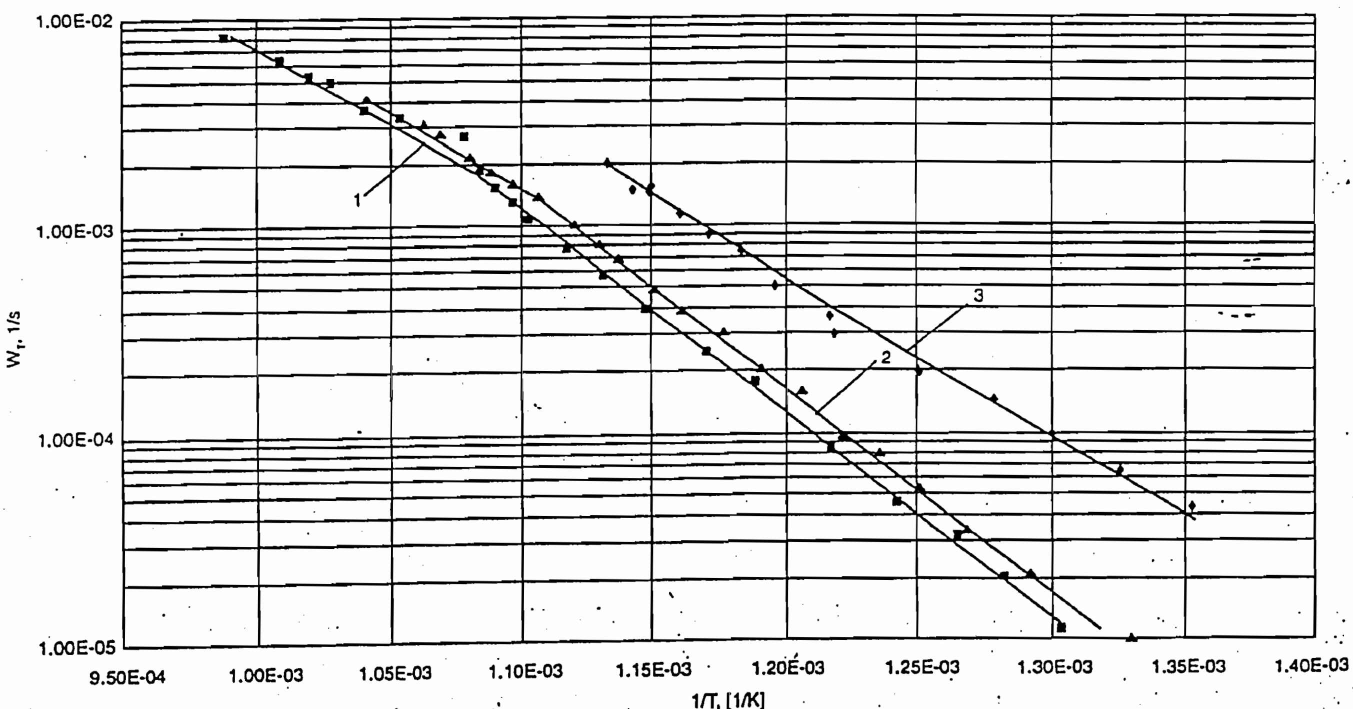

Figure 4 Dependence of char reaction rates with oxygen of air on temperature. 1 – Ukrainian high-ash anthracite / 2 – Pennsylvania centralia anthracite / 3 – Pennsylvania medium-volatile bituminous coal.

Testing at the Small Scale CFB Combustor

Furnace Operating Parameters. The optimal range of furnace operating parameters determined in the previous DHTEC testing of anthracite schtib, as described by Korchevoy et al (1994), was verified during this testing. The following was recommended for operation of the ARC 2.5 MW_t CFB facility:

- Minimum bed temperature for beginning of fuel feed – 1088K (1500F)
- Average furnace temperature during full load operation – 1173-1193K (1650-1690F)
- Excess Air – 25-30%
- Primary-to-total air ratio – 0.65

Coal Particle Size Distribution. Two particle size distributions of anthracite schtib were examined, finer (0 to 2.5 mm) and coarser (0 to 5.0 mm). Two tests were performed with each of the finer and coarser anthracite schtib distributions. The test conditions included a gas velocity in the upper furnace of about 5.2 meters/second (17.1 feet/second), average temperature of about 1173 K (1651 F), and primary/secondary air ratio of 75%/25%.

The results of the testing indicated that the fraction of the total ash discharged as bottom ash was 70% for tests with the coarse schtib compared to 46% for tests with the fine schtib. Analysis of ash size distribution showed a comparatively low attrition of anthracite schtib ash in the CFB combustor. While operating with coarse schtib compared to fine schtib, the solids flow in the primary circulation path and solids inventory in the upper region of the furnace decreased. The carbon burnout was similar for both coals. Based on these results, it was concluded that for the size distribution of 0-5 mm, the amount of solids in the size fraction corresponding to the material circulating in commercial-size CFBs is not sufficient to provide the required solids circulation through the furnace. A schtib size distribution with a top size of 3 mm was recommended for pilot-scale testing at B&W.

Effect of Recycle Cooling. For each coal particle size distribution, tests were performed with and without external electrical heating of the solids in the secondary recirculation path. The temperature of the solids ranged from 673-723K (751-841F) without heating and 923-943K (1202-1237F) with external heating. The average temperature in the combustor was about 1173K (1651F).

In the tests for both the finer and coarser schtib, the change of the temperature of solids recirculated from the secondary separator did not have a substantial effect on the combustion performance. From previous test work (Korchevoy et al, ibid), cooling of solids recirculated from the hot cyclone separator below 923K (1202F) resulted in increased unburned carbon loss, with combustion becoming unstable when the temperature decreased below 873K (1112F). The difference of these test results with the previous work is most probably explained by much smaller mean particle size of solids recirculated from the secondary separator and their comparatively low flow rate. The tests showed that B&W's CFB technology with two-stage particle separation can be used for efficient anthracite schtib utilization.

Evaluation of Ukrainian Limestones. Results from the sulfur retention tests on the small-scale CFB showed that, for tests performed at a calcium-to-sulfur molar ratio of about 2.5, sulfur retention was the highest for Novotroitsk limestone (85.6%) followed by Komsomolsk (83.6%) and Dokuchayevsk (82.0%). The Dokuchayevsk limestone may have had lower reaction due to greater attrition losses. Novotroitsk and Komsomolsk limestones were recommended for further experimental testing and characterization by B&W.

Limestone Characterization

The results of the limestone characterization tests are shown in Table 1. The two Ukrainian limestones show more attrition than the reference Lowellville limestone. With respect to each other, the Komsolmolsk limestone displays a slightly higher attrition tendency than the Novotroitsk limestone. The two Ukrainian limestones exhibit similar reactivity indexes and are significantly more reactive than the referenced Lowellville limestone.

The bench-scale performance results of the two Ukrainian limestones were compared to B&W's database of previously tested domestic limestones. Mississippi limestone from the Mississippi Lime Company in Alton, Illinois, was found to have very similar attrition and reactivity performance, as can be seen from Table 1. Mississippi limestone was chosen, therefore, for use in the 2.5 MW_t pilot-scale CFB tests.

Combustion Performance of Anthracite Schtib

The Ukrainian anthracite schtib was tested in the 2.5 MW CFB facility at both full-load and part-load conditions. For each test, the unit was held at steady-state conditions (80 hours and 9 hours for full and part load, respectively) while performance data, gaseous emissions data, and solids samples were collected. Anthracite schtib used during the test presented the worst quality end for this fuel. The ash content was varying from 37 to 46%. A typical coal analysis and size distribution are shown in Table 2. Sorbent used during the test was Mississippi Limestone with typical composition and size distribution shown in Table 3. A summary of test results for the full-load and part-load tests is given in Table 4. Based on heat inputs from schtib at steady-state conditions, the part-load test was performed at about 55% of the full-load heat input.

Vertical temperature profiles in the furnace are shown in Figure 5 for both the full-load and part-load tests. The full-load test showed an increase in temperature from the bottom of the furnace to the 6-meter (20-foot) elevation. The temperature remains fairly constant between the 6 and 24-meter (20 and 74-foot) elevation. The furnace temperature profile for the part load test showed a decrease in temperature with furnace height. Furnace modeling, based on the observed temperature distribution, has shown that during schtib firing at full load a considerable part of the fuel burns in the upper furnace.

The solids inventory (pressure differential) in the furnace and its distribution between the primary zone (lower 2.6 meters

Table 1
Results of Limestone Characterization

Limestone	Attrition Index	Reactivity Index
Lowellville	1.0	1.0
Komsomolsk	3.86	2.13
Novotroitsk	4.14	2.21
Mississippi	4.04	2.39

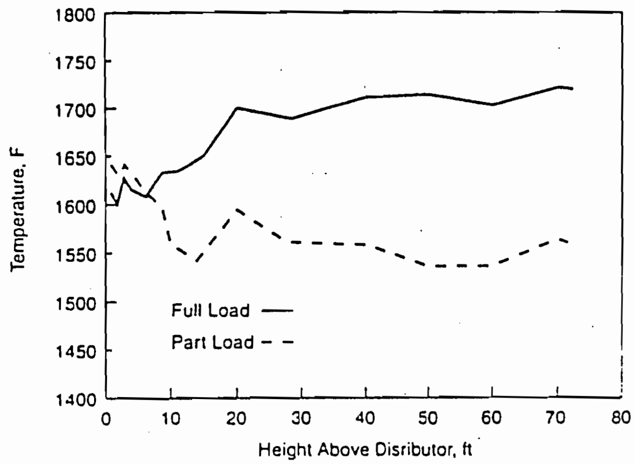

Figure 5 Furnace temperature profiles.

Table 2
Coal Properties – Mississippi Limestone

Proximate Analysis, % wt		Ultimate Analysis, % wt	
Moisture	3.68	Moisture	3.68
Volatile Matter	5.38	Carbon	49.46
Fixed Carbon	49.84	Hydrogen	1.12
Ash	41.10	Nitrogen	0.40
Gross Heating Value,	7518	Sulfur	2.68
Btu/lb (Kcal/kg)	(4177)	Ash	41.10
		Oxygen	1.56

Particle Size Distribution

U.S. Screen	Micron	% Smaller
#4	4700	100.0
8	2360	87.5
16	1200	58.9
30	600	35.8
50	300	21.3
100	150	12.8
200	75	7.9

Table 3
Sorbent Properties – Mississippi Limestone

Chemical Analysis, % wt	
$CaCO_3$	97.8
$MgCO_3$	0.5
$SiO_2 + Al_2O_3$	0.6
Moisture	1.1

Particle Size Distribution

U.S. Screen	Micron	% Smaller
12	1400	99.8
16	1200	95.1
30	600	75.7
50	300	44.1
100	100	16.8
200	75	6.8

or 8.5 feet) and the furnace shaft (above 2.6 meters) were maintained during the full-load test to provide the solids circulation rate required for efficient operation of a CFB boiler and wide load turndown. At full load, all solids collected by the secondary separator (cyclone) were recirculated to the furnace. During part-load operation, the solids circulation through the furnace (shaft pressure differential) was controlled, along with the excess air and primary-to-total air ratio, to maintain the temperature in the primary zone required for stable combustion of schtib without the use of supplemental fuel. This was done by reducing the solids recycle flow rate from the cyclone and accumulating the bed material in the secondary recycle storage tank. During steady-state part-load operation, the tank was full, and part of the solids collected by the cyclone were purged.

Carbon conversion efficiency (97.1% and 97.2% at full load and part load, respectively) was at an acceptable level considering low fuel reactivity and a smaller than desirable (for this type of fuel) combustor height.

No agglomerate formation in either the lower furnace or in the U-beam/particle transfer hopper areas was observed during the testing. The solids transfer hopper and the discharge port showed reliable operation providing internal recycle of solids collected by the U-beams back to the furnace.

Maintaining stable combustion of low-reactivity schtib required special attention. It was found that during start-up op-

Table 4
Test Results

Test Parameter	Test 1	Test 2
Operation	Full-Load	Part-Load
Coal Flow, kg/hr (lb/hr)	378 (834)	205 (453)
Velocity, m/s (ft/s)	5.9 (19.3)	3.5 (11.5)
Primary Zone Temp., K (F)	1152 (1615)	1156 (1621)
Shaft Average Temp., K (F)	1196 (1693)	1119 (1555)
Excess Air, %	24	39
Primary-to-Total Air Ratio	0.68	0.65
Carbon Conversion Efficiency, %	97.1	97.2
Ash Split, % (Flyash/Bottom Ash)	48/52	49/51
Pressure Differential		
Primary Zone, kPa (in. w.c.)	6.92 (27.9)	6.65 (26.8)
Upper Shaft, kPa (in. w.c.)	3.57 (14.4)	0.50 (2.0)
Secondary Collector Recirculation Flow, kg/hr (lb/hr)	767 (1693)	209 (462)
Solids Temperature Leaving Secondary Collector, K (F)	665 (738)	591 (605)
Sulfur Capture Efficiency, %	89	84
Ca/S Ratio, mole/mole	1.85	1.77
Carbon Content, %		
Flyash	6.0	6.2
Bottom ash	0.2	0.5
Flue Gas Composition		
Oxygen, %	4.1	5.9
CO, ppmv (mg/Nm³ @ 6% O_2)	206 (0.26)	138 (0.17)
SO_2, ppmv (mg/Nm³)	351 (1.00)	432 (1.23)
NO_x, ppmv (mg/Nm³)	166 (0.34)	140 (0.29)

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eration, the fuel feed should start at a bed temperature not lower than 1072-1089K (1470-1500F), and supplemental fuel should be fired until the lower furnace temperature reaches 1144K (1600F). During "normal" operation, stable combustion could be maintained with lower bed temperatures of 1116-1127K (1550-1570F) but it was safer to keep it not lower than 1144K (1600F).

Emission Performance During CFB Testing of Anthracite Schtib

Flue gas emissions for CO, NO_x and SO_2 are included in Table 4. NO_x emissions (0.34 g/Nm^3 and 0.29 g/Nm^3 at full and part load, respectively) were higher than those usually observed in CFB boilers burning higher reactivity bituminous coals. This can be explained by the elevated furnace temperature level and coal burnout distribution in the furnace. Considerable fuel burnout in the zone above the overfire air nozzles, where the excess air was 24%, reduced the combustion staging effect and resulted in higher NO_x generation. During partial load operation, NO_x emissions were somewhat lower than at full load despite a substantially higher excess air level. Conceivably, this is the result of the combustion of comparatively larger portions of fuel in the primary zone under substoichiometric conditions. The observed NO_x emissions were close to the level predicted by A.Yu. Maystrenko et al (1996) based on the pilot testing of Ukrainian anthracite schtib at Lurgi and substantially lower than the limit of 0.47 g/Nm^3 (at 6% O_2) set for the CFB boilers in Ukraine. The CO emissions for the full-load test were somewhat higher than the CO emissions for the part-load test (0.26 g/Nm^3 and 0.17 g/Nm^3, respectively). This contradicts the usually observed phenomena of NO_x and CO changing in opposite directions. Similar to the previous discussion, this can be explained by the fuel burnout distribution in the furnace.

Sulfur capture results for full-load and part-load tests were quite good, despite the elevated temperature level in the furnace at full load. This may indicate a shift of the optimum temperature range for sulfur retention in CFBs to higher values when using fuels with a low volatile matter content.

Design Implications

The results of testing of anthracite schtib, as described above, help to assess the impact of properties of this fuel on the CFB boiler and material handling system design and to evaluate the expected boiler performance.

Coal Handling

Anthracite schtib properties can vary significantly. The possible range of ash, moisture, sulfur and volatile matter contents are:

Ash (dry)	32-45%
Moisture	8-12%
Sulfur (dry)	1.5-3.0%
Volatile Matter (ash, moisture free)	7-11%

Anthracite schtib received by Ukrainian power plants typically is sized to 95% below 6 mm (1/4 inch) and 100% below 12 mm (1/2 inch). Selection of sizing of anthracite schtib for CFB combustion is based on the test results and boiler design considerations. The pilot tests have confirmed that coal crushing to the minus 3 mm size, along with selected sizing of limestone, resulted in the desirable circulation rate required for proper heat transfer rate in the furnace and effective combustion and sulfur capture. The coal size distribution similar to that shown in Table 2 should be used for CFB boilers burning anthracite schtib.

With the specified schtib sizing, fuel drying to the moisture content of 6-8% is needed for fuel handling after crushing. A pneumatic coal feed to the boilers can be used with the specified coal sizing and coal drying. This considerably simplifies the arrangement of the coal feed system and is especially convenient for repowering applications where the existing coal bunkers of PC boilers are used for storage of crushed coal.

Limestone Handling

The requirements for the limestone properties and feed point arrangement are determined by the fuel properties. A high-reactivity, medium-attrition rate limestone with comparatively coarse size distribution is recommended as a sorbent when anthracite schtib is burned in a CFB furnace. This recognizes a comparatively large portion of the SO_2 release throughout the dense bed for this low volatile fuel.

Based on B&W's limestone characterization method, the limestone reactivity and attrition indices should not be lower than 2.0, and greater than 4.2, respectively. Ukrainian limestones from Komsomolsk and Novotroitsk mines in the Donbass region satisfy these requirements. The recommended size distribution of limestone should be similar to that shown in Table 3.

A pneumatic limestone feed system is recommended with uniform limestone injection in the dense bed region in the lower furnace.

Bed Solids Handling

The bottom/fly ash distribution for commercial CFB boilers will depend on the actual sizing of coal and limestone, sulfur content in coal and limestone properties. Coal characteristics play a predominant role since 65-75% of solids generated in the CFB process during anthracite schtib firing originate from fuel ash. Another important factor influencing the ash split is the fractional efficiency of the CFB solids separation system. For these reasons, the ash split observed during the tests at ARC is peculiar for the test conditions. It should be used with consideration to the factors described above when a CFB boiler is designed.

The choice of bed drain system between a fluidized bed ash cooler and screw-cooler should be carefully examined. The advantage of the former in utilization of the sensible heat of bottom ash is offset by several disadvantages, including, in the case of anthracite schtib firing: a) possibility of temperature excursions due to carbon burnout leading to agglomerate formation and b) considerable amount of cooling air/flue gas affecting boiler performance. The screw-coolers are simpler in operation, but they require more maintenance due to abrasiveness of anthracite schtib ash and make utilization of the ash sensible heat more difficult.

CFB boilers burning anthracite schtib require high solids separation efficiency to achieve the particle residence time required for high combustion efficiency. In the B&W CFB boiler this is achieved by two-stage particle separation system shown schematically in Figure 6, with high efficiency multicyclone dust collector used as a secondary separator. Solids recirculation from a secondary separator may be needed for CFB boilers with a hot cyclone solids separator burning high-ash anthracite schtib to provide adequate residence time for particles smaller

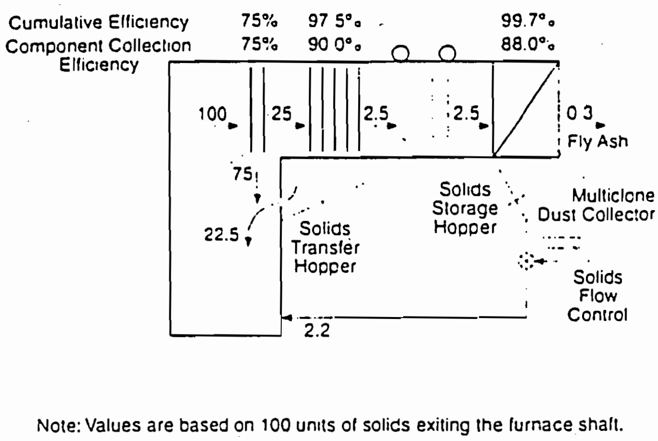

Figure 6 B&W CFB solids circulation schematic.

than 50-60 microns for which large diameter cyclones are not efficient.

Furnace Design

The furnace design recommendations, based on the results of CFB testing of Ukrainian anthracite schtib are shown in Table 5. They should be used in conjunction with coal and limestone sizing requirements given above.

Table 5
CFB Furnace Design Parameters (Full Load)

Design Parameter	Recommended Value
Excess Air, %	25
Primary Air, % of total	65
Average Bed Temperature, K (F)	
Height from the grid:	
0 to 2 m (6.5 ft)	≥ 1144 (1600)
Above 2 m	1172-1189 (1650-1680)
Average Gas Velocity	5.5-6.1m/s (18-20 ft/s)
Furnace Pressure Differential, kPa (in. w.c.)	
Total	10.0-11.2 (40-45)
Above 2 m from the grid	3.7-4.2 (15-17)
Furnace Gas Residence Time	5 seconds

The average gas velocity and furnace pressure differential were selected to provide: a) adequate furnace heat transfer rate, b) solids residence time in the furnace required for high combustion and sulfur capture efficiency, and c) wide load turndown ratio. From the experience of B&W's CFB boilers designed using this approach, the turndown ratio of 5:1 can be achieved. Although operation with loads below 50% MCR on anthracite schtib was not tested, it may be expected, based on performance prediction modeling, that a load as low as 3:1 MCR can be achieved without using supplemental fuel.

The furnace gas residence time required for a B&W CFB boiler was determined from the test results using a freeboard carbon char combustion model.

Table 6
Combustion and Emission Performance

Parameter	Value
Carbon Utilization Efficiency, %	97.0
Gaseous Emissions, mg/Nm³ @ 6% O_2	
SO_2*	508
NO_x	350
CO	250
Ca/S Molar Ratio[1]	2.1

*For 90% sulfur capture with coal specified in Table 2.

For CFB boilers having solids collection efficiency lower than that achieved by B&W's two-stage solids separation system (0.995), a greater furnace residence time would be needed to achieve the same carbon utilization while burning anthracite schtib.

Combustion and Emission Performance

For coal and limestone properties described above and proper design of the furnace and solids handling systems, the expected values of combustion and emission performance parameters within a 50 to 100% MCR load range are as shown in Table 6. The carbon utilization and limestone utilization (Ca/S ratio) performance is assumed somewhat lower than that observed during the tests due to the expected impact of less thorough mixing in large boiler furnaces as compared with the pilot unit.

CFB Boiler Design for Ukrainian Power Plants

Babcock & Wilcox and its Ukrainian licensee, Kharkov Central Design Bureau, have jointly developed designs of schtib-fired CFB boilers of 250 ton/hr (550,000 lb/hr) and 670 ton/hr (1,474,000 lb/hr) capacity for repowering of Ukrainian power plants. The results of the pilot testing of high-ash Ukrainian anthracite were used to design these boilers.

The 250 ton/hr and 670 ton/hr CFB boilers, shown in Figures 7 and 8 are designed to replace typical PC-fired boilers TP-230 (230 ton/hr, 9.8 MPa, 510C) and TP-100 (640 ton/hr, 13.8 MPa, 545/545C), respectively.

The CFB boilers, utilizing B&W's patented compact internal recycle CFB design, fit into existing boiler cells. For the 250 ton/hr CFB boiler, the building height is to be increased by about 7.5 m. The 670 ton/hr CFB fits into the existing building height. A more detailed description of these boilers is provided by Belin et al (1996).

Conclusion

Anthracite schtib can be successfully burned in a CFB boiler. The best combustion performance is achieved with an average bed temperature around 1172K (1650F). Stable combustion without supplemental fuel firing was demonstrated in the load range of 55 to 100% MCR. Combustion and emission performance at full load was characterized by about 97% combustion efficiency, near 90% sulfur capture with a Ca/S molar ratio of 1.85, and NO_x emissions of 0.34 g/Nm³. Coal crushing to a 3 mm top size is needed to provide adequate solids circulation and combustion efficiency. Design recommendations for a CFB combustion system are made, based on the test results. B&W's CFB technology, featuring a high collection efficiency two-stage solids separation system, is suitable for efficient utilization of anthracite schtib. The designs of typical 250 ton/hr and 670 ton/hr CFB boilers are developed for repowering of Ukrainian power plants.

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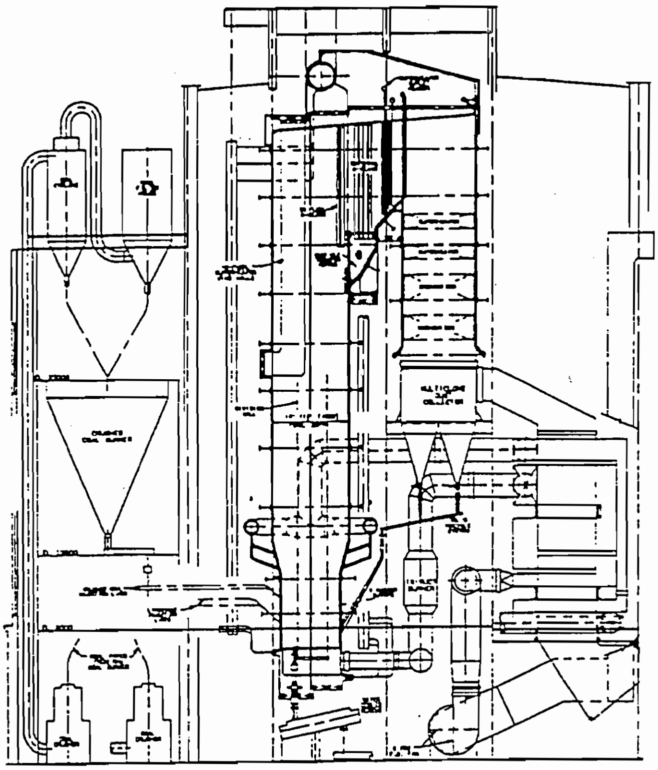

Figure 7 Arrangement of 250 ton/FB boiler.

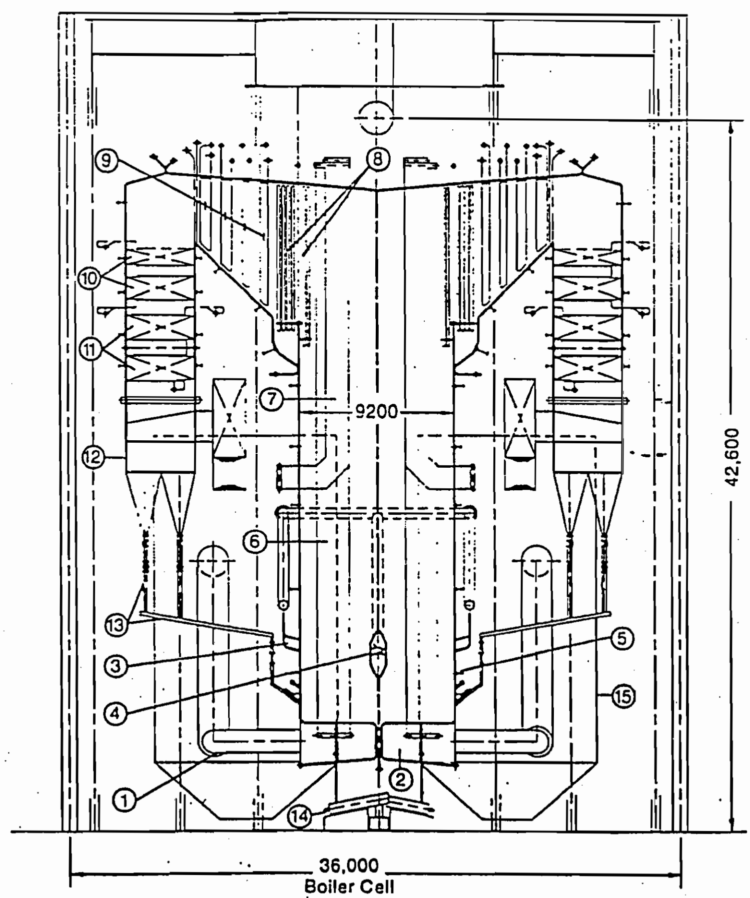

Figure 8a Arrangement of 670 ton/hr CFB boiler (front section view).

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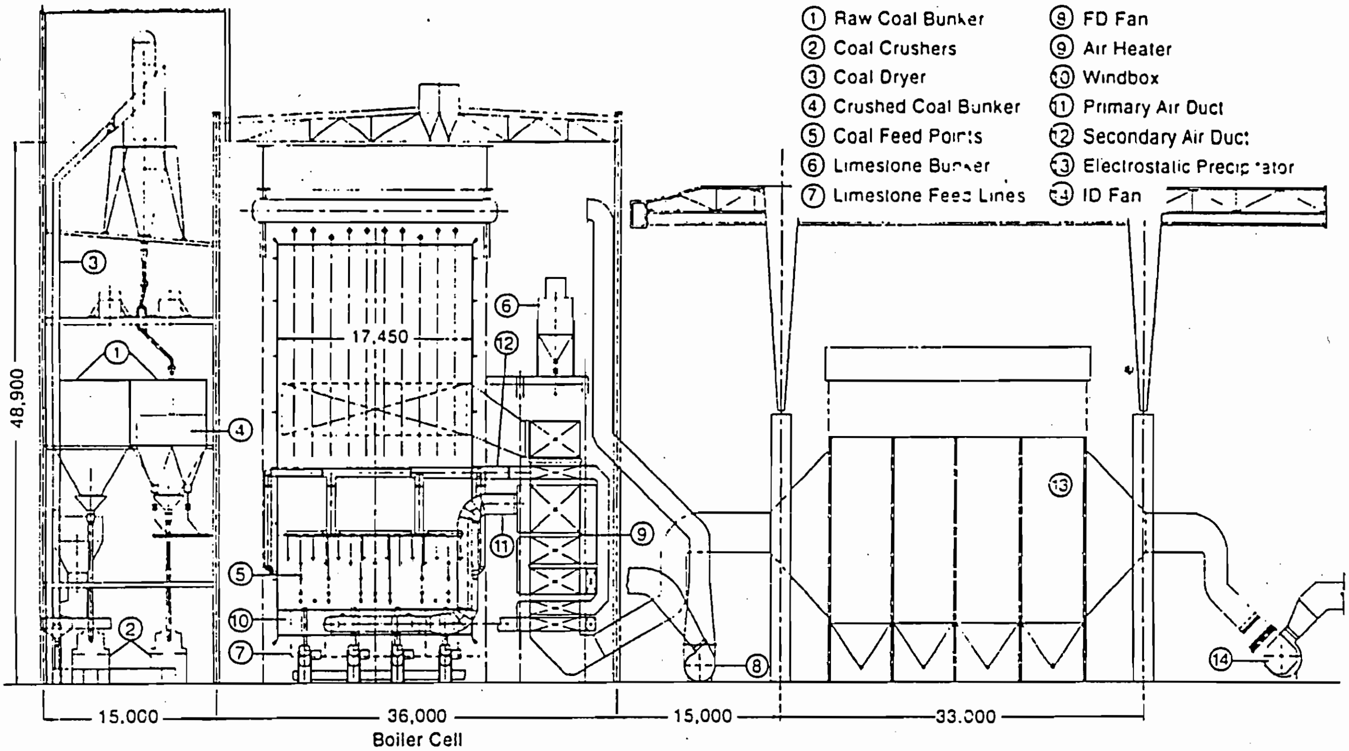

Figure 8b Arrangement of 670 ton/hr CFB boiler (side section view).

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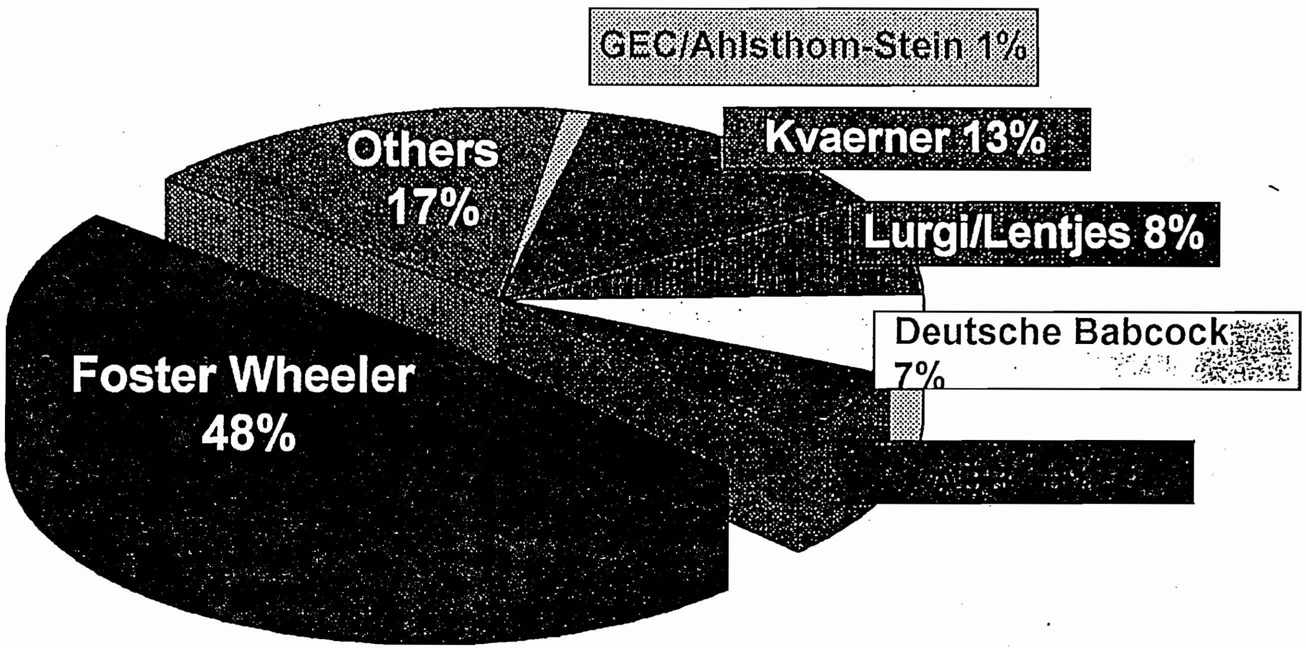
FOSTER WHEELER

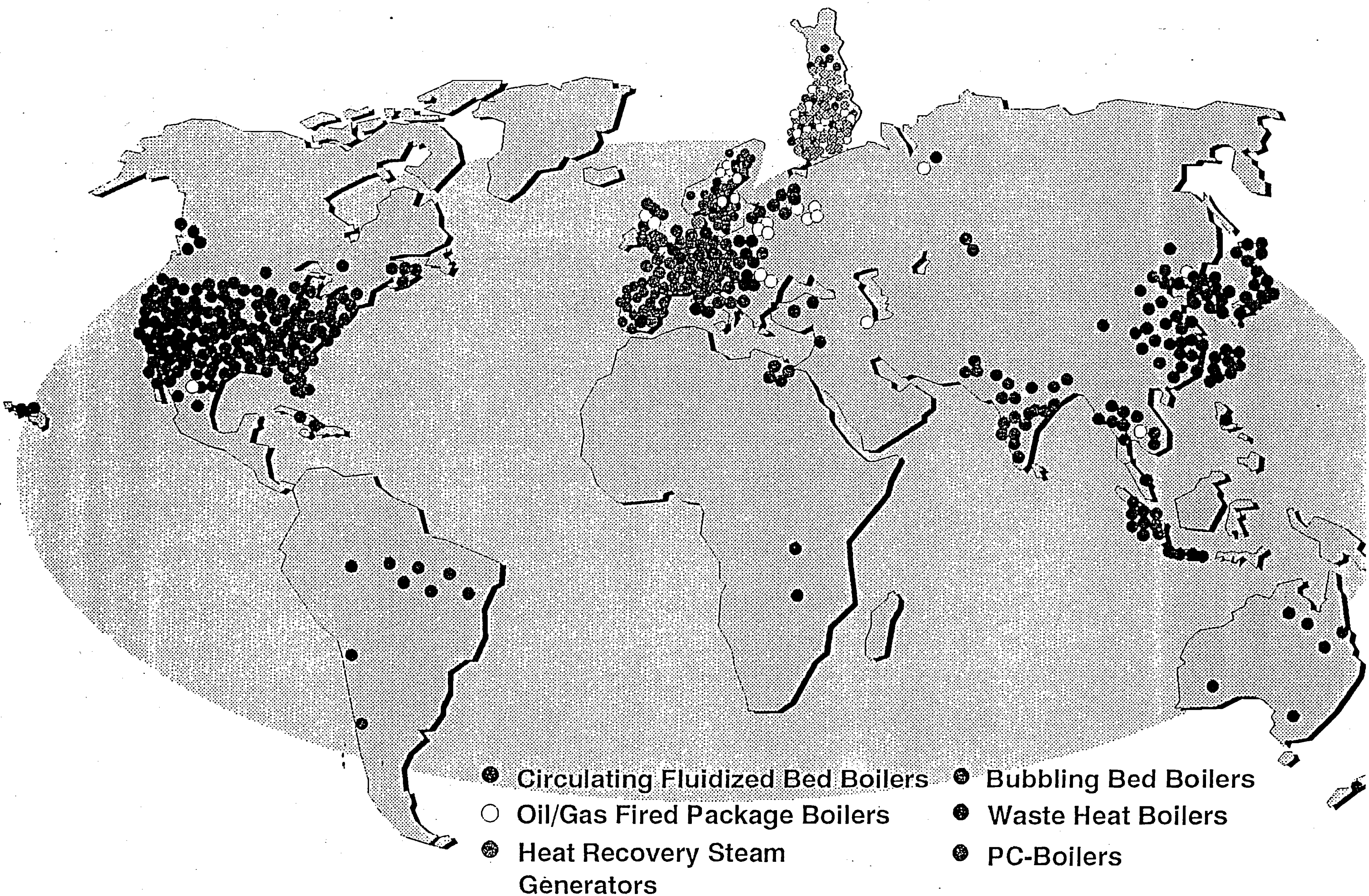
Foster Wheeler: Market Leader in CFB Technology 1980 - 1996



Excludes CFB's Designed in China

Source: McCoy Power Report

FOSTER WHEELER ENERGY INTERNATIONAL, INC.
References Around the World



FOSTER WHEELER

FLUID BED EXPERIENCE

OVER 20 YEARS EXPERIENCE IN FLUID BED COMBUSTION

- Fluid Bed Combustion from the 1960´s
- Pioneer in CFB, started beginning of the 1970´s

125 BUBBLING FLUIDIZED BED (BFB) BOILERS

- 119 in operation
- 6 under construction

178 CIRCULATING FLUID BED (CFB) BOILERS

- 143 in operation
- 35 under construction
- Biggest unit in operation 165 MWe
- Biggest unit under construction 235 MWe

SIZES UP TO 400 MWe AVAILABLE

FOSTER WHEELER

CFB Technology Offers Wide Fuel Flexibility

- *Coal*
  - Anthracite
  - Bituminous
  - Sub-Bituminous
  - Lignite
- *Waste Coal*
  - Bituminous Gob
  - Anthracite Culm
- *Petroleum Coke*
  - Delayed
  - Fluid
- *Woodwaste*
  - Bark
  - Chips
  - Wood Dust
  - Forest Residue
  - Demolition Wood
- *Peat*
- *Oil Shale*
- *Oil*
- *Gas*
  - Natural
  - "Off" Gases
- *Sludge*
  - Paper Mill
  - De-Inking
  - Municipal
- *Refuse Derived Fuel*
- *Paper Waste*
- *Tires*
- *Agricultural Waste*
  - Straw
  - Olive Waste

FOSTER WHEELER

Examples of Fuels Used in Commercial Foster Wheeler CFB Applications

Fuel	Unit size MW th	LHV MJ/kg	Moisture %	Ash content % in d.s.	Sulphur content % in d.s.
Brown coal	55 - 520	10 - 24	17 - 51	15 - 55	0.9 - 7.8
Coal	25 - 409	14 - 27	4 - 30	6 - 45	0.4 - 6.2
Petroleum	28 - 160	25 - 32	2 - 10	1 - 10	2.8 - 6.6
Coal refuse	72 - 120	8 - 21	6 - 39	31 - 65	0.3 - 11.0
Oil shale	40 - 156	3 - 6	8 - 12	62 - 67	2.7 - 3.1
Wood waste	15 - 150	6.5	61	2.9	0.08
Bark	43 - 150	6	61	2.3	0.05
Sludge	14 - 240	2.6 - 4.1	50 - 60	10.1 - 47	0.0 - 0.5
Peat	7 - 299	8 - 10	36 - 52	2 - 10	0.2 - 0.9

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Foster Wheeler: Extensive Experience With Anthracite and Other Low Volatile Fuels

- 56 Arch-Fired Units
  11,000 MWe

- 26 Utility Arch-Fired Units
  9,080 MWe

- Units in Service Over 30 Years

- Sizes to 660 MWe

Foster Wheeler Has Extensive CFB Experience With High Ash Fuels

NAME	% ASH	% S	HHV kcal/kg
Gilberton	45	0.28	3334
Cambria	54	2.7	2717
Grant Town	53	6.1	3195
North Branch	58	3.0	2458
Morgantown	49	3.0	3611
Panther Creek	45	0.4	3889
Colver	46	2.2	3778
Northampton	40	0.6	3500
Hunosa	61	0.8	2088
Mt. Carmel	70	0.4	1805
Turow	23	0.6	2330 (9.75 MJ/kg)
PAMA	62.5	0.9	1088
Porici	33	0.6	4785
Neijiang	32	4.0	5430

Foster Wheeler Has Extensive CFB Experience with Anthracite Coal

PROJECT	FUEL ANALYSES (%)			START-UP
	Volatile	Ash	Sulfur	
Gilberton	7.5	45	0.28	1988
Kobe Steel	10.3-15	9-15.3	0.4-0.9	1988
Chofu	8.7-12.4	14.3-15.5	0.16-0.37	1988
Hirohata	5.5-10.5	9-15.5	0.16-0.9	1989
Mt. Carmel	7.3	63.6	0.25	1989
Kakogwa	15.0	9.0	0.9	1990
Omikenshi	10.3-13.1	14.3-16.4	0.05-0.4	1992
Panther Creek	7.8	36.0	0.4	1993
Hunosa	17.2	61	0.8	1994
Northampton	15.7	37.6	0.4	1995
Sanko Paper	12.4	14.3	0.37	1995
Nihon Cement	8.65	15.5	0.16	1996
CMIEC/Neijiang	10.6	22.1	3.1	1997

Colver & Northampton
Fuel Flexibility - Anthracite & Bituminous Waste

	Colver	Northampton
Capacity, MWe	100	100
Steam Flow, t/hr (SH/RH)	356/317	361/331
Steam Pressure, MPa (SH/RH)	17.4/3.8	17.4/3.8
Steam Temperature, °C (SH/RH)	540/540	540/540
Major Dimensions		
Furnace Height, m	31.5	31.5
Furnace Width, m	13.5	13.5
Furnace Depth, m	6.7	6.7
Cyclone Diameter, m	2 x 6.6	2 x 6.6

Colver & Northampton
Fuel Flexibility - Anthracite & Bituminous Waste

FUEL	COLVER	NORTHAMPTON
Type	Bituminous Gob	Anthracite Culm/Silt
Moisture, %wt	5.0	8.2
Ash, % wt	38.6	38.7
Sulfur, % wt	2.2	0.6
HHV, Kcal/Kg	4,240	4,410
Volatiles, %	17.5	6.9
EMISSION LIMITS		
NO_x, mg/MJ	90	45
SO_2, mg/MJ	140	58
CO, mg/MJ	99	68
PERFORMANCE		
Start Commercial Operation	May 1995	August, 1995
Availability	99%	98.9%

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Colver:
Waste Coal Firing

Capacity, MWe	1 x 100
Steam Flow, t/hr (SH/RH)	356/317
Steam Pressure, MPa (SH/RH)	17.4/3.7
Steam Temperature, °C (SH/RH)	540/540

<u>Major Dimensions</u>

Furnace Height, m	31.5
Furnace Width, m	13.5
Furnace Depth, m	6.7
Cyclone Diameter, m	2 x 6.6

Colver: Waste Coal Firing

FUEL	COAL
Moisture, % wt	8.0
Ash, % wt	37.8
Sulfur, % wt	2.5
Volatiles, % wt	17.5
HHV, kcal/kg	4,445
SCHEDULE	
Contract Award	March 1993
Start of Erection	Ocober 1993
Commercial Operation	May 1995
AVAILABILITY	
Boiler Availability, %	98.9

Colver:
Waste Coal Firing

PARAMETERS	GUARANTEE	TEST
Capacity, t/hr	356	358
Boiler Efficiency, %	85.30	87.97
NO_x, mg/MJ	90	58.5
SO_2, mg/MJ	139.5	132.8
CO, mg/MJ	99	35.6
Hydrocarbons, mg/MJ	4.5	0.45
Ammonia Slip, ppm (dv)	5	1
Limestone Flow, t/hr	15.7	12.3

BURN TEST FOR UKRAINIAN ANTHRACITE AND ANTHRACITE WASTE

- **Anthracite and anthracite waste from Donbass area were burned in November 1997 in Foster Wheeler´s R&D Center in Finland in 1 MWth CFB pilot unit**

- **Eight test runs were performed with anthracite and anthracite waste and with a mixture of both fuels**

- **The test results confirm that both anthracite and anthracite waste can be burned efficiently and in environmentally friendly manner in Foster Wheeler CFB boiler**

BURN TEST FOR UKRAINIAN ANTHRACITE AND ANTHRACITE WASTE

Proximate analysis		Anthracite	Anthracite waste
Moisture	w-%	3.7	7.6
Volatiles	w-% in d.s.	5.5	5.0
Ash, 815°C	w-% in d.s.	48.1	41.4
Fixed carbon	w-% in d.s.	46.4	53.6
Ultimate analysis			
C	w-% in d.s.	46.6	53.2
H	w-% in d.s.	1.54	1.27
N	w-% in d.s.	0.70	0.67
S	w-% in d.s.	1.39	0.94
Ash, 815°C	w-% in d.s.	48.10	41.4
O as difference	w-% in d.s.	1.67	2.52
Higher heat value (HHV)	MJ/kg in d.s.	16.53	18.52

Limestone analysis

Component	w-% in d.s.
CaCO3	93.77
MgCO3	1.46
Inert	4.78
Moisture (w-%)	0.17

BURN TEST FOR UKRAINIAN ANTHRACITE AND ANTHRACITE WASTE

Test results

Emissions

	ppm (dry)	mg/MJ
NOx	78 - 130	54 - 94
CO	76 - 124	30 - 50
SO2	70 - 83	47 - 78
Ca/S	1.7 - 2.4	

Sulfur capture	93 - 96 %
Combustion efficiency	94 - 98 %

BURN TEST FOR UKRAINIAN ANTHRACITE AND ANTHRACITE WASTE

Conclusion

- Based on the Foster Wheeler´s extensive operating experience with high ash anthracite fuels and the results of the burn test Donbass anthracite and anthracite waste are very suitable fuels for CFB.

- The Foster Wheeler CFB can offer many advantages for the combustion of Ukrainian anthracite and anthracite waste
  - Stable and safe operation at all loads and with wide variety in fuel ash and sulfur content
  - Wide turndown
  - Low emissions
  - High fuel efficiency
  - Low auxiliary power comsumption
  - High avialability

UPGRADING UKRAINE POWER PLANTS BURNING ANTHRACITE USING CFB TECHNOLOGY

by

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presented at

Ukraine/U.S. Joint Conference on Ukraine
April 21-24, 1998

ABSTRACT

As the worldwide trend for more flexible, cost effective, environmentally friendly solid fuel utility power generation continues, circulating fluidized bed (CFB) technology has established itself as an alternative to pulverized coal and combined cycle steam generation. Combustion Engineering, Inc. continues to draw on its own design and operating experience for utility applications to introduce many product enhancements for its next generation of fluidized bed boilers for utility power generation.

This paper will discuss the design of CFB boilers for utility power generation and the CFB technology options available to utility customers, as an alternative to pulverized coal and combined cycle utility steam generation, to better meet environmental and plant availability requirements. The paper will also discuss the issues that must be considered in retrofitting existing units with CFB technology.

INTRODUCTION

The driving force for continued interest in scaling up the CFB technology for utility steam generation is its ability to achieve low sulfur oxide and nitrous oxide (SOx and NOx) emissions without the need for post-combustion equipment such as selective catalytic reduction systems and wet or dry flue gas desulfurization systems.

ABB-CE UTILITY BOILER EXPERIENCE

Combustion Engineering, Inc. (hereafter referred to as ABB-CE), a wholly owned subsidiary of ABB, Inc., has designed, supplied, and constructed a large proportion of the world's steam generators used in utility applications for more than seventy (70) years.

Employing licensed circulating fluidized bed (CFB) process technology, ABB-CE has also designed and/or constructed many existing large size CFB units. These units range in size up to 200 MWe and burn a variety of fuels including anthracites, lignites, and sub-bituminous coals.

Based on our experience in designing utility boilers for operation worldwide, ABB- CE has independently developed a cost effective and improved CFB unit to better meet the specific requirements of our utility customers and to include many product enhancements to the CFB technology. This new, independently developed CFB unit provides more flexibility to allow each utility user to customize its design by providing many options such as superheat, reheat and evaporative heat transfer surface either as hanging surface in the furnace, as in traditional utility boilers, or in bubbling bed fluid bed heat exchangers, or in a combination of both, forced or natural steam and water circulation systems, regenerative or tubular air heaters, and top or combination top and bottom unit structural support systems.

Backpass design for CFB units is very much similar to that of pulverized coal utility boilers. Recent design improvements in regenerative air heater seals have reduced the leakage to an acceptable level thus giving, in addition to the tubular air heater, another option for heat recovery in CFB applications.

ABB-CE CIRCULATING FLUID BED UTILITY EXPERIENCE

Figure 1 illustrates the development of the fluid bed technology within ABB-CE. The predominant focus for technology commercialization has been on the circulating fluid bed process. Included in this development is a dramatic scale-up in unit capacity from 65 MW to 200 MW and a transition to reheat steam generation applications for improvement in overall plant heat rate for utility power generation.

The following is a brief description of utility size CFB steam generators which ABB-CE has designed and built. Using licensed CFB process technology, ABB-CE has designed a number of utility grade CFB boilers and, using its own independent FLEXTECH™ technology, ABB-CE has also designed a number of utility grade CFBs.

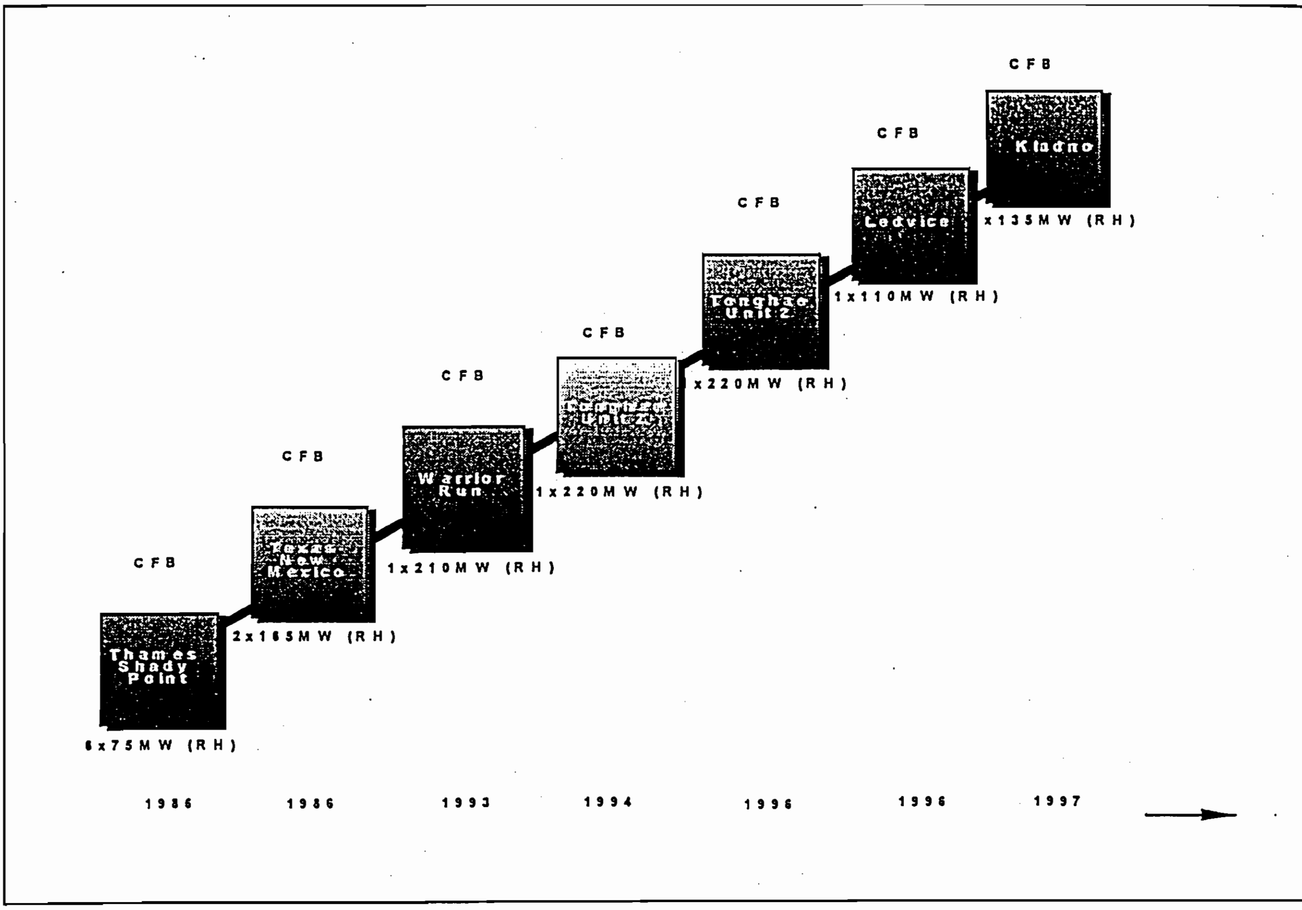

Figure 1: ABB-CE Fluid Bed Reheat Project Development

	Start Engineering	Start Steel Erection	Initial Fire	Commercial Operation
AES Warrior Run	Early 1995	Mid 1997	Mid 1999	Fall 1999
Tonghae Unit 1	Late 1994	Late 1995	Fall 1997	Mid 1998
Ledvice	Spring 1996	Early 1997	Early 1998	Mid 2000
Kladno	Early 1997	Early 1998	Early 1999	Late 1999

Table 1: ABB-CE Utility CFB Project Milestones

Texas-New Mexico Power Company (TNP)
ABB-CE entered into a consortium arrangement to provide two CFBs units employing licensed CFB process technology to the Texas-New Mexico Power (TNP) Company. (Refer to Figure 2. for a TNP unit arrangement.) These two (2) 150 MWe net generating units went into operation in 1990 and 1991, respectively, and fire a lignite with a higher heating value of six thousand seven hundred thirty-three (6733) BTU/LB (15.66 MJ/kg) and a moisture content of thirty and seven tenths percent (30.7%) by weight. The two TNP units have successfully demonstrated the use of circulating fluid bed technology in a utility application. To accomplish this, many significant design innovations were utilized along with a major scaling up of components and systems. Among the equipment scaled was the furnace that is one and a half (1.5) times larger in plan area than ABB-CE's previous largest furnace for CFB units employing licensed CFB process technology. The TNP furnace has water-cooled walls similar to ABB-CE's pulverized coal utility boilers. To accommodate such a large furnace and meet process requirements, these units were also the first to have four (4) solids recirculation cyclones operating in parallel. A steam-cooled backpass is used to enclose the superheat, reheat, and economizer heat transfer surfaces, again very similar to ABB-CE's conventional utility boilers. The final heat recovery from the flue gas is accomplished by using air heaters. The fluid bed heat exchangers, containing the final superheater, reheater, and evaporative surfaces, are an integral part of the furnace waterwalls.

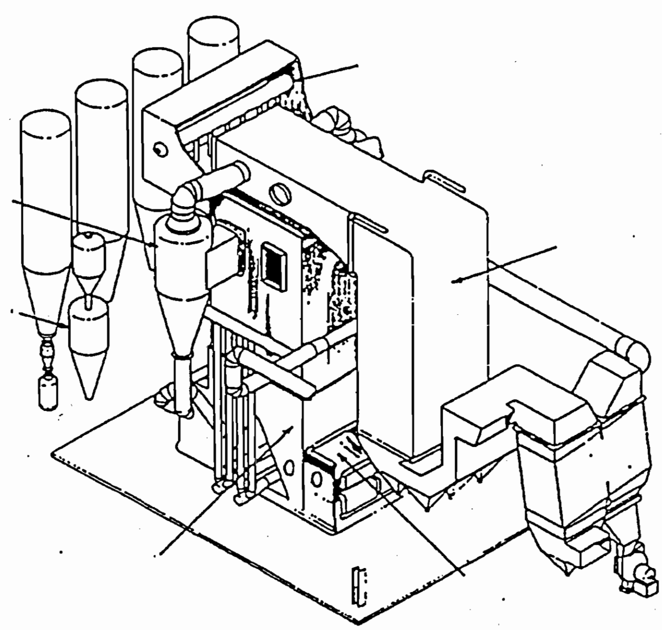

Figure 2: TNP Unit Arrangement

AES Warrior Run
The Warrior Run contract, awarded to ABB-CE in 1993, also uses licensed CFB process technology and is intended to be a "replicate" of the Texas-New Mexico CFB units. The AES Warrior Run unit, scheduled for operation in 1999, is a bituminous coal-fired CFB unit located in Cumberland, Maryland in the United States. The boiler, generating superheat and reheat steam, will produce 200 MWe power.

Tonghae Thermal Power Plant

Combustion Engineering Inc. has been awarded contracts for the design of two 200 MWe net FLEXTECH™ CFB boilers firing a Korean anthracite fuel (See Figure 3.). The units are designed to burn fuel with up to 45% ash, 15% moisture, and a Higher Heating Value ranging from 6660 to 8280 Btu/lb dry (15.49 to 19.26 MJ/kg). These circulating fluid bed boilers are located on the east coast of the Republic of Korea, about one hundred twenty-five (125) miles east of the city of Seoul, along the shores of the Tonghae Sea. These fluidized bed boilers are required to fire a range of seven (7) different fuels, achieve a boiler turndown to thirty percent (30%) load, and meet the customer's superheat and reheat steam temperature control and start-up time requirements (See Table 1 for the milestone schedules for all ABB-CE utility CFB projects.).

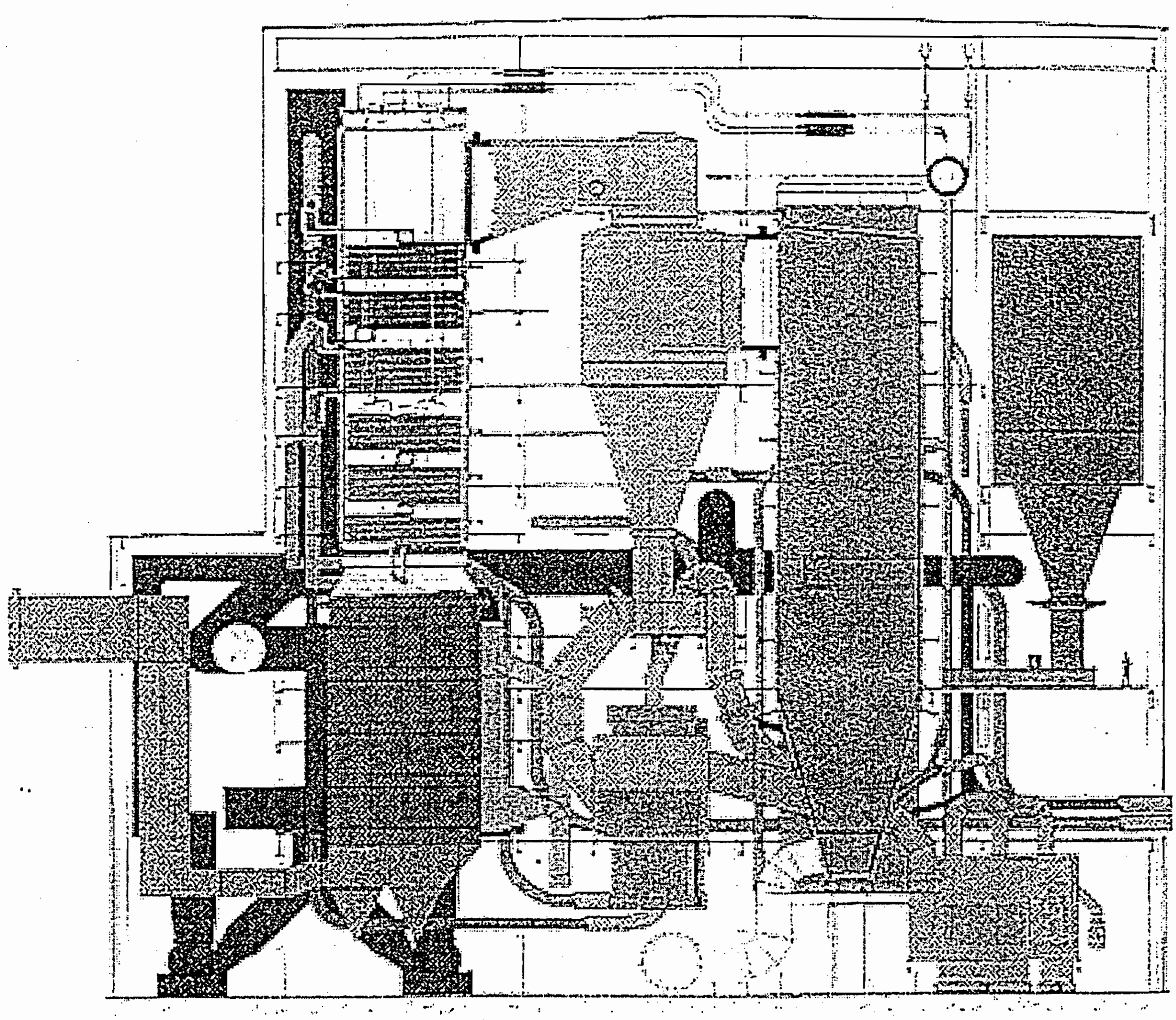

Figure 3: Tonghae Unit Arrangement

Ledvice Power Station

ABB-CE, in a joint effort with ABB Energeticke Systemy s.r.o., has also designed a 110 MWe CFB firing brown coal for the Ledvice Power Station in the Czech Republic (See Figure 4.). The brown coal fuel will contain up to thirty-one percent (31%) moisture and thirty-three percent (33%) ash by weight. For this project, the new CFB option was chosen over a boiler retrofit option and a natural gas combined cycle option for continued power production at the Ledvice Power Station and to replace a pulverized coal-fired steam generator that has been in operation since 1969.

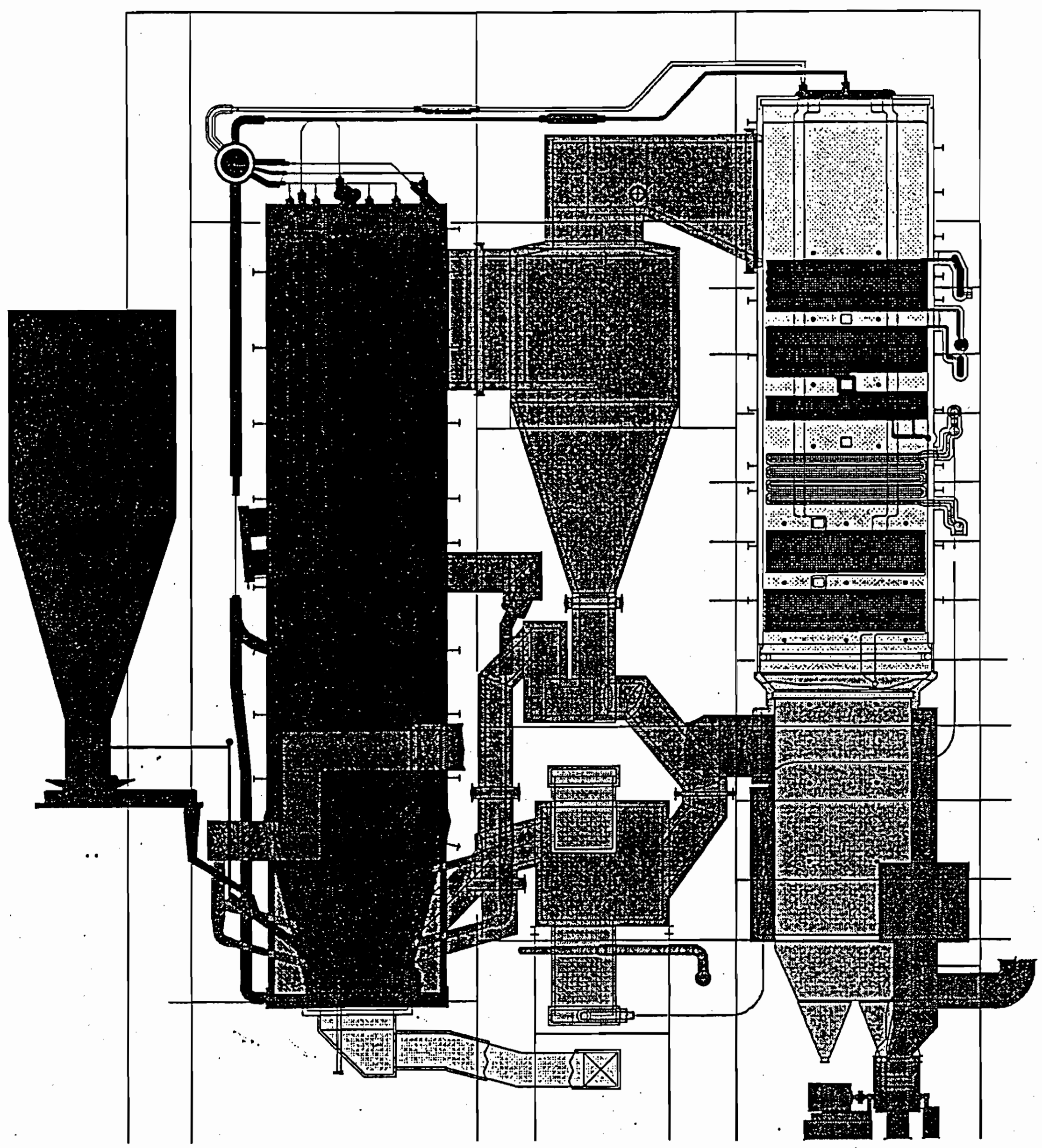

Figure 4: Ledvice Unit Arrangement

Energy Center Kladno
ABB-CE also is responsible for the design and supply of another FLEXTECH™ CFB in the Czech Republic; the 135 MWe Energy Center Kladno CFB. This unit is designed to fire brown coal and/or a sub-bituminous coal. The brown coal contains up to twenty-nine percent (29%) moisture and thirty-one percent (31%)ash, while the sub-bit coal contains up to sixteen and a half percent (16.5%) moisture and thirty-two and a half percent (32.5%) ash. The higher heating values for the fuels range from 7000 to 8150 BTU/Lb (16.28 to 18.95 MJ/kg).

Future Utility CFB Projects
Currently, based on its demonstrated scale-up success, low emission capabilities, and fuel flexibilities, the CFB offers an attractive alternative to many customers for their mid-sized (300-450 MW) utility applications.

Recent and ongoing inquiries show the continued growth of the CFB utility offering. One application involves two units, each of which would generate 350 MWe with a single reheat cycle. These units would fire a forty-five percent (45%) moisture brown coal. Another application requires two CFB boilers, each generating 250 MWe power while firing bituminous coal. A third such utility size application, will have two boilers with reheat cycle, each generating 250 MWe while firing 40% lignite fuel. All of these units are designed to meet strict emission levels while burning poor quality fuels (with low volatiles, high ash, high moisture, high sulfur, or low heating value) which indicate the flexibility of CFB technology for utility power generation.

TECHNOLOGY OVERVIEW
Employing licensed circulating fluidized bed (CFB) process technology, Combustion Engineering, Inc. has designed and/or constructed many existing CFB units. These units range in size from 15 MWe to 200 MWe and fire a variety of fuels including lignites, anthracites, sub-bituminous coals, and biomass products. While all of the ABB-CE CFB units have had good, solid operating performances, it was realized that there was still room for improvement in CFB unit offerings. In particular there was a need to address the scale-up concerns. Utilizing its own utility grade pulverized coal experiences, its own scientific studies, and the operating histories of numerous CFBs worldwide, ABB-CE has independently developed its own CFB technology, the FLEXTECH™ technology, to address these concerns.

TONGHAE OVERVIEW
In late 1994, ABB-CE began contract engineering on the 220 MWe (gross) Tonghae Thermal Power Plant Circulating Fluid Bed. In the first quarter of 1996, ABB-CE received an order to commence work on an additional, duplicate CFB unit to be located at the Tonghae Power Plant site. Both of these units employ ABB-CE's own, independently developed FLEXTECH™ CFB technology.

When FLEXTECH™ engineering work began, and especially when work commenced on the Tonghae project, ABB-CE looked to establish its CFB technology niche in the utility grade project market to enable it to make use of its long-standing accomplishments in utility power generation while making use of cost-effective CFB product developments that have occurred over recent years. Today, the CFB technology is considered a mature technology, and it is not uncommon to see requests for reheat steam generation, CFB-fired projects in the 100 - 250 MWe (net) range worldwide. Additionally, though, is the challenge presented from burning the atypical, unusual fuels associated with CFB applications. To date, ABB-CE has contracts to provide engineering and/or additional work on three utility grade CFB units that utilize the FLEXTECH™ technology. Each of these units has presented its own design challenges that are due to the different fuels fired. ABB-CE believes it has successfully addressed these requirements while still offering a utility grade product similar in stature to those of its pulverized coal offerings.

CFB COMPATIBILITY WITH HIGH-ASH UKRAINE ANTHRACITE

The high-ash anthracite fuel used for power generation in Ukraine is a low volatile fuel which is not easily and efficiently burned in traditional pulverized fuel steam generators. Fuels of this type usually require a support fuel such as #2 or #6 oil to maintain stability at reduced loads. In the CFB unit, the high circulating mass provides the ignition source for combustion without relying on fuel volatility, even at reduced loads.

PROVEN UTILITY "PIECES"

As alluded to above, ABB-CE has a long-standing tradition of being a leader in utility grade, pulverized coal steam generation applications. When designing the FLEXTECH™ utility grade offering, ABB-CE reflected on its pulverized coal offerings to see where it could make use of proven, cost-effective offerings. Three (3) systems were identified; the water/steam circulation system, the air and gas fan systems, and the backpass pressure part arrangement systems.

ABB-CE's utility grade pulverized coal units have frequently used forced circulation systems to assure that no pressure parts will suffer overheating and the resultant material damage and/or deformation. The forced circulation systems typically make use of three (3) - 50 % capacity or two (2) - 100% capacity boiler water circulation pumps. Pulverized coal-, natural gas-, and oil-fired units have much greater heat absorption rates (BTU/ft^2) than do CFB units. For this reason, CFB units do not have the same potential for pressure part overheating as do other units. For the FLEXTECH™ utility grade offerings that include evaporative fluid bed heat exchangers or hanging evaporative panels in the furnace, detailed circulation analyses are done to determine the potential for surface overheating and the need for boiler water circulation pumps. In many cases, because of the lower heat fluxes, rifled tubing can be used in place of the pumps. The rifled tubing is much less prone to overheating and deformation than is smooth tubing (due to different film coefficients) and it allows for the elimination of the boiler water circulation pumps from the regular maintenance schedule.

There has always been discussion about the correct fan requirements (size and number) for a CFB unit. That is, there is discussion on the size of the fan, 50% capacity, 60% capacity, or 100% capacity, and the amount of fan redundancy that is proper for a CFB application. In recent years, ABB-CE has been offering single 100% capacity fans for all our utility grade pulverized coal applications up to 300-400 MWe in size. With the maturation of the CFB technology and the resultant reduction of its fan head requirements, many suppliers worldwide are currently capable of offering primary air, secondary air, or induced draft fans for CFB applications. In light of this, ABB-CE offers single 100% capacity fans for its FLEXTECH™ units.

The convective horizontal backpass on an ABB-CE utility grade CFB unit consists of superheat, reheat, and economizer surface arranged similarly to that in pulverized coal units. Long used on pulverized coal units, this backpass arrangement causes no performance concerns. Since most CFB units produce a dry flyash, backpass fouling potential is insignificant. A FLEXTECH™ utility grade CFB unit can include two proven, yet not so common, product enhancements; a split backpass and an in-line spiral fin economizer. The split backpass design has been incorporated on the Kladno unit. This design allows independent superheat and reheat temperature control on those units that do not include fluid bed heat exchangers. By use of a flue gas damper located beneath the parallel superheat and reheat sections, gas flow can be proportionately directed to the superheater or reheater depending on their temperature requirements. The steam-cooled partition wall between the superheater and reheater surfaces also serves as additional superheater surface. Split backpass designs have a long-standing operating record on various utility grade designs including some CFB applications. For base-loaded, single fuel-fired CFB units, the split backpass design offers a more cost-effective means of temperature control than would a unit including fluid bed heat exchanger superheat and/or reheat surface.

ABB-CE has many years of operating experience with both new and retrofit spiral fin economizers on pulverized coal-, oil-, and gas-fired utility grade units that include spiral fin economizers. This experience has allowed us to include an in-line spiral fin economizer offering on the FLEXTECH™ CFB offerings. Based on the in-line tube arrangement, wide economizer tube spacing, and the typical dry CFB flyash, the potential for economizer surface plugging has been eliminated. For biomass-fired CFB units and certain other situations, bare tube economizers would still be offered. A spiral fin economizer also offers a customer significant space and weight savings from the more typically offered in-line, bare tube economizer.

PROCESS AND EQUIPMENT OVERVIEW

The other major components in the FLEXTECH™ utility grade CFB boiler will now be discussed. These components have been grouped by their location; in the primary loop or the secondary loop. The primary loop consists of the equipment in the circulating solids path while the secondary loop includes the equipment in the clean flue gas path.

Primary Loop

For utility applications, conventional pulverized coal-fired boilers and CFB boilers have the same basic design requirements. Regardless of technology, the furnace requires the same mechanical design features. The major difference is in the method of fuel feed which, for CFB applications, requires special considerations such as placement of the coal silos and arrangement of furnace front wall openings. Because of differing process requirements in fuel combustion, the furnace width to depth ratio is larger for CFB boilers, necessitating a slightly different mechanical design approach.

Fuel type and sizing are the primary factors affecting CFB furnace design. A particular fuel has a corresponding combustion air, fluidization velocity, attrition rate, and furnace pressure profile associated with it. Using these numbers, the furnace is sized to maintain a particular cross-sectional velocity throughout the furnace.

Again, following the successes of our utility grade pulverized coal units, ABB-CE has designed its furnace to incorporate a top-supported design. Besides allowing for easier erection, the top-supported design allows for a quicker transition from lower to upper furnace regions thereby minimizing the lower waterwall refractory zone and maximizing furnace heat transfer.

Drawing on extensive data involving lower furnace design and the CFB furnace height - fuel sizing - solids densities - heat transfer relationship, a new furnace sizing limitation has been established, which places the new furnace height between that associated with the licensed CFB process technology previously used by ABB-CE and that of the so-called "tower units". As one would expect, the taller furnace results in a lower solids density in the upper furnace region. The decreased solids density allows use of refuse and chemical recovery unit experience to introduce hanging Primary Loop Heating Surfaces in the furnace. Installing hanging superheater or reheat surfaces in the furnace is a well established design practice for the utility boilers. Additionally, ABB-CE has included this hanging surface in its refuse and chemical recovery units for many years. The environment in a CFB furnace is much more benign than the corrosive, erosive environments of these operating refuse and chemical recovery units. To date, ABB-CE has included hanging Primary Loop Heating Surfaces in the design of two of its utility grade FLEXTECH™ boilers. One of these makes use of hanging superheater panels and the other includes both superheater and evaporative panels.

The use of hanging Primary Loop Heating Surfaces and a reference to the FLEXTECH™ furnace design allows for a modularity to be built into the furnace sizing as unit size continues to increase, as will tend to be the case with utility applications. That is, from the FLEXTECH™ CFB design, ABB-CE has established fuel, limestone, and air mixing guidelines to use for future unit design. In essence, these guidelines have established furnace depth guidelines and standards. As unit size continues to increase, ABB-CE will increase furnace width appropriately and adjust fuel and limestone feed systems to allow for a modular unit increase. The key to the FLEXTECH™ design flexibility is its modular design.

Secondary Loop
As previously mentioned, the convective, horizontal backpass of the FLEXTECH™ CFB design resembles that of a traditional pulverized coal-fired utility grade unit. This CFB backpass will allow inclusion of a regenerative air heater as used on the pulverized coal fired- units or a tubular air heater. Through the use of an enhanced sealing system, the regenerative air heater is able to withstand leakage across the high air-to-gas differential on a CFB to the point where single digit leakage will be achieved.

RETROFITTING CFB TO EXISTING POWER PLANTS

The retrofitting of existing power plants with CFB technology can be approached in two ways. The first and most difficult is to convert an existing boiler to a CFB. Many design parameters must be reviewed in order to determine the feasibility of such a conversion. Design parameters such as furnace plan, the amount of convective surface, gas velocities through the sections, waterwall circulation system, sootblower coverage, all fans and auxiliary equipment are evaluated. In addition, the structural integrity of the boiler and ductwork must also be evaluated and may require upgrading. In most cases, the retrofitting of an existing boiler with CFB technology is not cost effective.

The second approach is to design and install a CFB unit into the same space that the existing boiler presently occupies. This will require the removal of the existing boiler and the custom design of a CFB unit that will fit in the same boiler footprint. To accomplish this task, ABB-CE would utilize FLEXTECH™ CFB technology as discussed above, so both the space constraints and the lowest possible cost are balanced. Again, the main concern is space and the essential parts of the CFB unit (i.e., furnace, cyclone and a backpass) must properly fit. Using a tower design along with a split backpass may, in many cases, provide the best design for the space available. Of course, retrofitting CFB technology in existing power plants will also be more expensive that a new CFB plant but utilizing the existing steam turbine cycle can well offset the cost difference.

PROVEN TECHNOLOGY

The CFB technology is, indeed, a proven mature technology that has been implemented on several utility grade applications. The operating utility CFB units have shown that this technology is capable of further scale-up with minimal technical or commercial risk.

AVAILABILITIES AND CAPACITY FACTORS

The availabilities of operating CFB boilers are in the range of ninety-five to ninety-nine percent (95 to 99%), excluding scheduled outages, and the capacity factors for these same boilers in the range of ninety-seven to ninety-nine percent (97 to 99%). The operating performance record has proven the CFB technology to be on par with pulverized coal-fired boilers and to be a viable system for mid-size utility projects.

FUEL FLEXIBILITIES

The operating experience of the many CFB boilers that are in use has proven an unmatched fuel flexibility and environmental performance that can be tailored to specific utility plant performance requirements. A CFB system can be designed to efficiently burn a wide range of fuels, including anthracite culm, anthracite, bituminous coal, sub-bituminous coal, brown coal, petroleum coke, oil shale, oil, gas, sludge, and biomass. The CFB system can also achieve over ninety-five percent (95%) sulfur dioxide (SO_2) removal and low nitrous oxide (NO_x) emissions by maintaining low furnace temperatures while meeting stringent cycling and dispatching requirements.

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UKRAINE /U.S. JOINT CONFERENCE ON UKRAINE CLEAN COAL POWER PLANT UPGRADE OPPORTUNITIES

ALTERNATIVES FOR POWER SUPPLY OF LUGANSK OBLAST

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April 1998

Absract

A joint team with membership from the US Department of Energy and the Ukrainian energy ministry MINENERGO has defined a project to upgrade power generation at Lugansk GRES power station. The project developed by the joint US-Ukrainian team includes extensive rehabilitation of one 200 MWe unit with PC boiler using cleaned anthracite schtyb, and installation of a new 125 MWe unit consisting of two 62.5 Mwe CFB boilers and one 125 Mwe turbine. It is assumed that CFB boilers will be firing fuel derived from wet and dry anthracite mining and cleaning waste. To make sure that the proposed project is the least-cost option, the World Bank has requested U.S. DOE to conduct an additional study to compare the proposed project with two other options. The first option assumes the installation of the CFB power unit as a stand-alone plant located close to sources of waste fuel to eliminate/reduce the fuel transportation cost. The second option assumes no rehabilitation of the units at the Lugansk plant, but replacement of this capacity with power imported from other regions of Ukraine via a new transmission line.

The study performed by a joint U.S./Ukraine team included: 1) estimations of capital and O&M expences for the construction of a greenfield CFB unit, 2) estimations of capital and O&M expences for the construction of a new transmission line and the refurbishment of generating capacity choosen for replacement of the capacity at Lugansk GRES, and 3)economic analysis for these two options in comparison with the basic option, described above. Four figures-of-merit were used for comparison of options, namely 1) levelized cost of electricity, 2) economic rate of return, 3) cumulative net present value (NPV), and 4) cost of new capacity ($/kWe).

The major results show that the base-case project, with installation of the CFB unit at Lugansk GRES and modernisation of one 200 Mwe PC unit is superior to the options with the construction of the CFB unit as a stand-alone plant near the waste fuel resources, and the replacement of Lugansk GRES capacity with power imported from other regions of Ukraine via a new transmission line.

INTRODUCTION

The Lugansk Power Plant Upgrade project has been developed for the anthracite burning power plant in eastern Ukraine as a cooperative study of USDOE and the Ukrainian Ministry of Power and Electrification, Minenergo. The recommended project includes extensive rehabilitation of one 200 MWe TP-100 boiler/turbine unit and installation of a new 125 MWe unit consisting of two 62.5 MWe CFB boilers and one 125 MWe turbine. It is proposed to feed the rehabilitated PC unit with cleaned schtib and the CFB boilers with fuel derived from wet and dry coal mining and cleaning waste. The Lugansk Power Plant study considered several options, including the above recommendation. A report was submitted to the World Bank in late 1996.

The World Bank has reviewed the report and has requested DOE to evaluate the following additional issues:

- estimate the capital cost and cost for electricity for a greenfield 125 MW CFB unit located at the source of waste fuel and compare it to the Lugansk GRES rehabilitation option;

- estimate the capital cost and the cost of electricity if a new transmission line is built to import electricity to the Lugansk region and compare it to the Lugansk GRES Rehabilitation option.

To meet the schedule requirements and to obtain relevant local data, a study was performed as a joint effort of Science Application International Corporation (SAIC), Parsons Power Group, and several Ukrainian design and research organizations under the direction of Kharkov Central Design Bureau "Kotloprominvest" of Minenergo of Ukraine. These organizations are:
- Ukrainian National Dispatch Center
- Donbass Regional Dispatch Center
- Donetsk Power Industrial Company
- Ukrainian Coal Energy Technology Center, Minenergo
- Design company "Electrosetproect"

The tasks evaluated in this study are: "Greenfield CFB Power Plant at Waste Fuel Source," and "Construction of a New Transmission Line to the Lugansk Region."

In the following report, the analyses done for both tasks are briefly described, and the results are presented in three sections. Section 1 contains details of capital cost estimate for the option with construction of the greenfield CFB power plant. Section 2 describes details of capital cost estimate for the case of importing electricity to the Lugansk region from the Dneprov region. Section 3 contains information on fuel and fuel transportation costs and a discussion of the results of economic analysis of both options described in previous sections. These options are compared with the base case scenario with refurbishment of a 200 MW PC unit and installation of a new 125 MW unit with two CFB boilers at the Lugansk GRES.

GREENFIELD CFB POWER PLANT AT WASTE FUEL SOURCE

To estimate the capital cost for the construction of the greenfield CFB power plant the information presented in the report "Rehabilitation of the Lugansk GRES" was used. This report was prepared by Burns and Roe Enterprises, Inc in 1995, and contains a detailed estimate of capital investment required for the construction of a new power unit consisting of two 62.5 MW CFB boilers and one 125 MW turbine at the Lugansk GRES. The installation of such a unit is planned in a space previously occupied by two 50 MWe boilers and one 100 MWe turbine, and utilizing the existing infrastructure and facilities.
For the greenfield facility capital costs for additional equipment and facilities are determined and the total capital cost for the greenfield CFB unit is estimated, as well as O&M.

Determination of the CFB plant potential location.

The major idea of this project is to build the greenfield CFB power plant in close proximity to the waste fuel reserves to avoid the transportation cost. A selection of a particular site for the greenfield CFB plant construction was based on several criteria . The criteria used for selection of the plant site were as following:

- Availability and quality of waste fuel;
- Availability of water for cooling and feed water supply;
- Ability to connect the proposed unit to the existing grid;
- Environmental protection issues.

Fuel availability and quality. It was initially decided to select a single coal beneficiation plant located near an anthracite mine(s). Ash settling ponds of the coal beneficiation plant can be used as a source for wet coal beneficiation waste(schlamm), and coal waste piles located near mines can be used as a source for dry coal waste (culm). But analysis of data, presented in [Ref.1,2] shows that there is not a single coal beneficiation plant in the Donbass Region with reserves of coal waste (both dry and wet) sufficient for fueling of the 125 MW CFB unit for 25 -30 years. Therefore it was decided to look not for a single coal beneficiation plant, but for a cluster of two, three or more of them located in close proximity, which will minimize fuel transportation cost. Also, at least one of these plants should have a technology ready (or able to be upgraded for low cost) for recovering of the fuel from culm.
The Yanovskaya coal preparation plant was selected as the best candidate. It is one of the biggest coal preparation plants in the Donbass region (actually number four by capacity), and has a working process line for culm beneficiation. It is located between two other large coal beneficiation plants - Komendantskaya and Nagolchanskaya. The territory of the Yanovskaya Plant has sufficient space for a construction of the CFB power plant with the necessary infrastructure. The selected site is located 1000 m away from ash settling ponds of the Yanovskaya plant. Four piles of dry anthracite waste are also located near the site. These piles contain about 6 million tonnes of culm from dry beneficiation of run-of-mine coal from the mine "Yanovskaya".
Fuel reserves at the chosen site and at the closest coal preparation plants were determined

according to the best available data [Ref.2]. It is shown in [Ref.1} that the reserves of wet waste will be sufficient for fueling of the 125 MWe CFB unit:

- in the radius of 1 km - for more than 2 years;
- In the raduis of 40 km - for more than for 10 years.

The reserves of anthracite culm located near the Yanovskaya plant are sufficient for fueling of the CFB unit for more than one year.The reserves of anthracite culm in the radius of 40 km can provide fueling of 125 MWe unit for more than 40 years, but the problem with reserves of this type of waste is that they are distributed on that territory and need to be delivered to the Yanovskaya beneficiation plant for re-processing, which will require transportation expenses.

In addition, combustion tests were conducted at the Coal Energy Technology Center of Minenergo of Ukraine. These tests have shown that the quality of both types of waste fuel at Yanovskaya beneficiation plant is sufficient for use as a fuel for CFB boilers without other supplementary fuel.

Water availability. The proposed site for the CFB plant is located in a region with very limited water resources, and the quality of water in natural sources (the river Mius) is not consistent with the power plant design requirement. Therefore, a closed-cycle cooling water system was chosen with use of forced draft cooling towers. Water flow necessary for cooling of turbine condenser and auxiliary equipment is 22000 m3/hr. Losses for blowdown, evaporation from cooling tower and for other needs are 720 m3/hr. These losses will be replaced by water pumped from the Seversky Donets river through a 50 km pipeline.

Connection to the main electric transmission and distribution grid. An electrical transmission and distribution grid of 110 kV exists in the area of the CFB power plant potential location. Therefore it is proposed to organize the output from the newly constructed plant with 110 kV lines, which requires the construction of a 110 kV switchyard on the plant. The connection of the CFB power plant with the system is planned to be through the existing two 110 kV electrical lines between the substations Yuzhnaya and Schterovskaya. It will require the construction of 5 km of new line with replacement of two 110 kV switches.

Environmental protection issues. Calculations show that maximum ground -level concentration of pollutants will not exceed permitted concentrations both for separate components, and for the dimensionless total concentration index ($SO_2 + NO_x$). Therefore, the construction of the new 125 MW CFB unit will not create any problems with air emissions.
Purification of oil contaminated waste water is to be performed on the waste water cleaning facility, and cleaned water is to be discharged to the Mius river.

Estimation of capital and O&M costs for construction of a greenfield CFB power plant.

Additional construction work, facilities and equipment necessary for the installation of a stand-alone CFB plant were identified in comparison with the design specification for the 125 MWe unit with CFB boilers presented in the project developed by B&R [Ref.3]. These include such major facilities as a building, foundation, a feed water system, a coal yard, an ash handling and removal system, a stack, a cooling tower, and other. A detailed estimate of incremental capital expenses is presented in Appendix A, Table 1. These incremental expenses are $58.587 million, and the total capital cost of the greenfield CFB unit constitutes $154.551 million. In addition, the capital cost for construction of facilities for connection of the new plant with the existing electric distribution and transmission grid is $1.128 million.

To make this option consistent with the base case, it was assumed that one PC unit will be refurbished at the Lugansk GRES with features used in the base case and prepared for combustion of cleaned schtyb. The cost of such an option was estimated in [Ref. 3] as $73.114 million.
The base case scenario also includes the upgrade of common facilities for the whole Lugansk plant -- a water treatment facility and a coal yard. A capital cost for the upgrade of these facilities allocated to 350 MW of capacity constitutes $15.108 million. The new water treatment facility and the coal yard will be build for the stand-alone CFB plant. Therefore , the cost of these common facilities at the Lugansk GRES was scaled down to reflect a reduction in total installed capacity, and only a part of this cost allocated to 225 MW is used in capital cost estimate. This part constitutes $ 14.482 million.

The total capital cost for the case with refurbishment of one 200 MWe PC unit at the Lugansk GRES and installation of greenfield 125 MWe unit with CFB boilers is $247.277 million. This is $63.091 millionb greater capital cost that computed by Burns & Roe for siting the 125 Mwe of CFB capacity at Lugansk GRES.

CONSTRUCTION OF A NEW TRANSMISSION LINE

To estimate the capital investment necessary for the option with replacement of power developed in the Lugansk GRES with the power imported from other regions, a selection of a particular power plant with extra installed capacity was made with the help of various Ukrainian organizations (the National Dispatch Center, Minenergo, the Regional Dispatch Center, and other). A detailed analysis of current condition of transmission lines into the Lugansk Oblast and a capital cost necessary for the refurbishment of this equipment was made in cooperation with several Ukrainian design companies. A design specification for a new transmission line was developed, and an estimate of the capital and O&M costs necessary for construction and operation of such a new line was conducted by a Ukrainian design company, which specializes in design of electric transmission and distribution lines.
Estimated capital and O&M costs were used for development of figures-of-merit for the case of replacement of power produced at the Lugansk GRES with imported electricity. These figures were compared with those for the base case scenario with refurbishment of one of 200 MW PC units and installation of a new 125 MW unit with two CFB boilers at the Lugansk GRES.

Power supply in the Donbass Power Region and in the Lugansk Oblast .

A power transmission and distribution grid scheme was provided by the Donbass Regional Dispatch Center and is presented Fig. A-1.

Currently a deficit of generating capacity exists in the Lugansk Oblast. Maximum demand in the Oblast is 1.5 to 2.0 million kW, which is higher than existing generating capacity in the Lugansk GRES. About 40% of maximum demand is supplied by the Lugansk GRES with the remaining 60% imported from the central regions of Ukraine through the transmission and distribution grid of the Donetsk Oblast. In the whole region supplied by Donbassenergo with its 5 power plants and dispatched by the Donbass Regional Dispatch Center there is a deficit of electricity production.
This supply deficit in the Lugansk Oblast is due to two major reasons.
The first reason -- the current restriction of electricity production at the Lugansk GRES -- was well discussed elswhere [Ref.3,4,5,6,7]. It is due to the bad condition of existing equipment, low quality of anthracite, and restrictions on purchase of natural gas, significant amounts of which are necessary to keep boilers running.
The second reason is the weak connection of the Lugansk Oblast with the Donetsk Oblast.
The major connection imports 900 MW on a 330 kV line that is transformed to 220 kV and is connected to the Lugansk GRES through 6 lines. Therefore, even though the Donetsk region is importing significant amount of electricity from central areas of Ukraine, only a limited amount of that power can be transported to the Lugansk Oblast.
Another way to import electricity is the 500 kV line coming from the Northern part of Ukraine. The Lugansk GRES is connected to this line through a very old one 220 kV line with length of about 100 km.While the capability to import power to the Oblast over this 500 kV line is significant, the 220 kV line is a bottleneck that limits this capability (only 200 MW) and the reliability, since it is a single line.
This 500 kV line was used to provide the transmission of additional electricity for its import to the Southern part of Russia in exchange for electricity, which was transmitted from the Central areas of Russia to Northern part of Ukraine (Kharkov Oblast) and supplied by several Russian nuclear plants. Currently these connections are not in operation, therefore the 500 kV line is not in use now.

Alternatives for the Improvement of Power Supply to the Lugansk Oblast.

Two alternatives can be considered to improve the situation with power supply in the Lugansk Oblast. One alternative is the extensive modernization of the Lugansk GRES not only with refurbishment of existing boilers, but possibly with installation of new generating capacity. Another option is to fulfill the increasing demand in the Oblast with import of electricity from other areas of Ukraine where extra capacity can be found.

Even the World Bank has requested to evaluate the possibility of replacement of only 350 MWe, in general it means that the Lugansk GRES should be shutdown after the physical limits of equipment are exceeded. Without investment, operating costs will continue to increase, reliability and performance will continue to decrease, support fuel requirements will increase, and safety concerns will require a shutdown. In that case the whole demand of the Lugansk Oblast will need to fully rely on imported power. Extensive discussions with Ukrainian specialists, representing different organizations [Ref. 5, 8] helped to highlight several reasons to keep in operation the Lugansk GRES and, possibly, even support expanding the plant capacity. These reasons are:

- The Lugansk plant is the only power generating facility in the Lugansk region (which has a very developed industrial climate.) Major users are coal/anthracite mines and coal preparation facilities, which are very power-intensive operations. The current power production at the Lugansk GRES covers only about 40% of the Oblast demand. An opinion rendered by staff of the National Dispatch Center and the Donbass Regional Dispatch Center is that new generating capacity should be built in areas having a deficit, and the existing capacity should not be retired.

- The existing transmission and distribution system in Lugansk region including connections to Donbass Oblast is old. Lines are operating at maximum load and do not have reserves for increase of power flow to the Oblast. A more detailed discussion on this subject is presented above. To increase import of electricity to the region new transmission lines, substations and other auxiliary facilities should be built. These require significant capital investment, additional O&M costs, and losses connected to transmission of large amount of electricity through long distance lines.

- The absence of a generating capacity in a region such as the Lugansk Oblast where the main demand is by industrial users, can create problems with reactive power. Even if the major amount of power is imported to the region, it will be required to generate reactive power on-site. This can be accomplished by special reactors which require additional power, or by keeping some of the Lugansk GRES capacity running. Another problem could be a static stability of the system.

- Prior to the breakup of the Soviet Union, the Lugansk Oblast was the take-off point via 500 kV, 330 kV, and 220 kV lines for the transmission of 1500 MWe to the Rostov region of Russia, which had (and continues to have) a deficit of generating capacity. This export of power was done in exchange for an import of 1500 MWe from Russia into the Northeast of Ukraine, via 500 kV lines, as part of a regional power supply balance. The connections were broken when the Soviet Union was dissolved. The areas in both countries that previously received power are currently suffering from lack of power. Both countries are committed to re-establishing the power connections in the near future.

Potential Sources to be Used for Electricity Import to the Lugansk Oblast.

The deficit of power in the Donbass Regional Dispatch Center, which includes the Donetsk and

Lugansk Oblasts, is about 2.5 to 2.7 million kW. This deficit is covered by the transport of electricity from the Dneprov region through the long lines of 330 and 750 kV. Therefore there is no extra capacity for transporting power to the Lugansk Oblast.

From three Regional Dispatch Centers (RDC) - Kharkov, Donbass, and Dneprov,- which are included in the Eastern zone of the Joint Power System of Ukraine, only the Dneprov RDC has extra capacity, therefore it was selected as a source for import of 350 MWe to the Lugansk Oblast.

Installed capacity in this region is presented by nuclear, hydro, and thermal plants. Nuclear power plants in Ukraine as in many other countries are operating in base load with very high capacity factor. Therefore they cannot be assumed as sources for extra capacity not demanded currently. Hydro plants are operating on seasonal basis, and also cannot be candidates for a stable supply of power year around.

Two large power plants in "Dneproenergo" Government Stack Power Company were evaluated as potential sources for replacement of the deficit in the Lugansk Oblast. These two are Pridneprovskaya GRES and Zaporozhskaya GRES.

The area where Zaporozhskaya GRES is located has a significant demand in electricity. This area houses the most power demanding users, which are mainly enterprises of metallurgical, chemical, and oil refinery industries. Zaporozhskaya GRES and later Zaporozhskaya nuclear plant were installed for the fulfillment of the demand of this region with the potential supply of extra power to the Southern regions of Ukraine.

Import of electricity from the Zaporozhskaya GRES to the deficit Lugansk region would lead to a necessity of transmission in return of equal capacity from any other generating source. Besides that, expenditures for a construction of transmission lines will be very large in this case. It is stipulated not only by the increased length of new lines, but by the fact that the area where Zaporozhskaya GRES and Zaporozhskaya nuclear plant are located is overloaded with existing electric transmission lines.

Taking into account all factors mentioned above, the most appropriate source for generating of additional capacity of 350 MW is to be the Pridneprovskaya GRES of "DNEPROENERGO" generating company.

Analysis of electricity demand assuming the normal operation of Ukrainian industry and forecast for the future demand show that there will not be any appreciable increase of demand in the-area of Pridneprovskaya GRES site for the next 25 years.

3. Refurbishment and Life Extension of the Major Equipment at the Pridneprovskaya GRES

The Pridneprovskaya GRES is equipped with 300 MW PC units firing anthracite schtyb from the Donetsk region. The units were commissioned in the period from 1963 to 1966. They have already overrun their life limit. Measures necessary for the refurbishment of these units in order to extend their life for an additional 25-30 years and to increase their capacity up to 325 MWe are:

Boilers - installation of membrane water walls, replacement of heat exchange surfaces, pulverized coal-,gas- and air ducts, burners, replacement of a part of the coal pulverization equipment, forced and induced draft fans, as well as reconstruction of some other parts. As a result, the boiler will be able to use less supporting fuel, and its efficiency and ecological performance should be increased.

Turbines - replacement of high- and intemittent pressure cylinders, and reconstruction of a low pressure cylinder, replacement of steam-condensate- and oil piping systems with the simultaneous increase in capacity up to 325 MW and improved efficiency of the turbine. Improvement of performance is not accompanied with the increase of refurbishment cost.

Control and instrumentation and electrical equipment - restoration of the reliability of these parts with the improvement of performance to the current level of requirements for reliability and safety of operation of the equipment.

Total cost for the refurbishment of a 300 MW unit with an increase of capacity up to 325 MWe is estimated as $71.775 million . Reestimated to 360.5[2] MWe of refurbished capacity the capital cost is $79.615 million.

Construction of a Transmission Line from the Pridneprovskaya GRES to the Lugansk GRES.

The existing electric transmission grid between Pridneporovskaya GRES and Lugansk GRES is shown Fig.A-2. It includes main transmission lines of 750, 330 and 220 kV. Electrical lines between Donbass and the power system of the Rostov Oblast are disconnected. Currently a separate operation of the Donbass and Kharkov power systems is accepted because Kharkov power system is working in parallel with the Join Power System of Russia. Historically, the operation regimes of main transmission lines between Dneprov and Donbass power systems are characterized by amounts of power transmitted close to maximum permitted levels in the direction from Dneprov to Donbass. Because of unequal distribution of the total power flow between existing lines 750 and 330 kV, 330 kV lines between Pridneprovskaya GRES and SS Krasnoarmeyskaya are overloaded first. Calculations show that it is appropriate to assume that the large power flow towards Donbass will continue in the future.

[2] As shown below, the transmission line has 3% losses. To deliver 350 MWe to the Lugansk Oblast, 360.5 MWe should be loaded to the transmission line on the Pridneprovskaya GRES side.

To transmit additional power of 350 MW from the Pridneprovskaya GRES toward Donbass it is necessary to construct an additional electric transmission line of 750kV from Pridneprovskaya GRES to Lisichansk with the length of more than 300 km. A substation 750/220 kV is to be built in Lisichansk. This substation should be equipped with one autotransformer 750/220 kV with capacity of 800 MVA and two two-line lines 220 kV to the substation 220 kV in the Lugansk region.

Existing electric transmission lines 220 kV in the Lugansk Oblast have sufficient capacity for transmission of power to lower voltage users' substations.

A 750/330 kV autotransformer with 1000MVA capacity and switchgear 750 kV are to be installed at Pridneprovskaya GRES, and existing 330 kV switchyard should be reconstructed.

Capital expenditures necessary for the organization of transmission of 350 MW of electricity to the Lugansk region are presented in Appendix A, Table 3. The total capital cost for the line and substation construction is $208 million. Since a new line can transmit 800 MWe, the capital cost of the line was reduced to reflect the fact that only a part of line capacity will be used for the transmission of 360.5 MW. This part is valued at $97.73 million.
Transmission losses for transmission of 350 MW from Pridneprovskaya GRES to Lugansk GRES for the distance of more than 300 km will average, for different regimes, about 3 %. Annual O&M costs were estimated as: a) for electric transmission lines 220 and 750 kV - $0.6 million, and b) for substation 220/750 kV - $1.9 million.

Amount of land to be allotted for the permanent use for the additional grid elements is about 200 thousand sq.m., and this allotment is included in the estimate of construction costs.

ECONOMIC ANALYSIS.

Fuel cost

The estimation for the base case (generation of all power at Lugansk GRES) was made in [Ref.4] based on fuel cost data from 1995. It was decided to update this information and to use for comparison the 1997 fuel prices. These prices (undelivered) are shown in Table 1.

Fuel transportation costs have also changed significantly. Instead of $1.27 per tonne for delivery to the Lugansk GRES (average distance 100 km) the cost now is $2.23. This cost is used in case 1a to update the base case estimate.
It is assumed that in case 2 cleaned schtyb is continued to be supplied for 225 MW PC unit at the Lugansk plant and transportation cost for this schtyb is also $2.23 per tonne. While the CFB plant in this case is build on-site of the coal beneficiation plant to avoid transportation cost, the fuel supply will still require loading/unloading operations. Also, as stated above, the reserves of fuel on Yanovskaya plant are sufficient for the first several years. After that the fuel must be transported from Komendantskaya and Nagolchanskaya coal beneficiation plants, located 30 - 36

km apart from Yanovskaya plant. The average transportation cost of $1 per tonne is conservatively used for waste fuel delivered to the CFB unit.
In case 3 the transportation cost of a cleaned schtyb to Pridneprovskaya GRES is estimated as $5.00 per tonne for the average distance of 300 km from the Donbass region.

O&M costs

O&M costs were assumed equal in all cases except case 3. In the case 3 in addition to O&M costs for production of electricity (which is assumed equal to other cases) the O&M costs for operation of the new transmission line and the new substation were estimated as $2.5 million per year.

Economic analysis

Four figures-of-merit were used to evaluate different project options. These figures are economic internal rate of return, net present value, cost of capacity, and cost of electricity. They were estimated for the following options:
Case 1 - the base case (original) with extensive rehab of one 225 MW unit for combustion of cleaned schtyb and 125 MW CFB unit. This case is taken from the 1996 report prepared by Parsons Power Group.
Case 1a - the base case with updated fuel and fuel transportation costs;
Case 2 - the case with refurbishment of 225 MW PC unit at the Lugansk power plant and construction of a CFB power plant at the greenfield site near the Yanovskaya coal beneficiation plant.;
Case 3 - the case with refurbishment of 360.5 MW of capacity at Pridneprovskaya GRES and construction of a new transmission line for import of electricity to the Lugansk region.
Case 4 - the case with refurbishment of 360.5 MW of capacity at Krivorozhskaya GRES and construction of a new transmission line for import of electricity to the Lugansk region. The capital cost for the refurbishment of 300 MW unit was taken from [Ref.6] and adjusted to the capacity 350.6 MWe. This cost was estimated as $46.578 million, and is a very conservative assumption because in [Ref.6] it was determined that 300 MW units at Krivorozhskaya GRES require only Level I refurbishment, while the most recent evaluation (1995) [Ref.7] recommends Level II refurbishment, which will have a capital cost close to the capital cost for Pridneprovskaya GRES (see above).
The capital costs for the transmission line and for fuel transportation were estimated using data for case 3 with the adjustment for the longer electrical line and fuel transportation route (400 km instead of 300 km used in case 3).

The cases 1, 1a, and 2 are estimated for two options of fueling of the CFB unit: 1) with combustion of 30% schtyb/70%schlam mixture, and 2) with combustion of cleaned culm. The results are presented in Table 2. It is obvious that the case 1a is the most economically valuable as compared to the others.

CONCLUSIONS

1. Extensive discussions with Ukrainian specialists, and analyses of current situation with energy supply in the Lugansk Oblast show the necessity to keep the Lugansk GRES in operation and possibly even support expanding the plant capacity, because:
   a) the Lugansk GRES is the only power generating facility in the region with very power intensive users;
   b) existing transmission and distribution system in the region is too old and weak to provide sufficient energy supply for the Oblast in case this energy needs to be imported from other regions;
   c) the Lugansk GRES played a very important role in the joint operation of Russian and Ukrainian power systems, serving as a take-off point for the transmission of 1500 MW to the Rostov Oblast in Russia in exchange for power imported to the Northeastern part of Ukraine from Russia. It is planned by both countries to re-establish these connections, so the Lugansk GRES will again have a very important role.

2. Economic analyses show that modernization of the Lugansk GRES with extensive refurbishment of one 200 MWe PC unit with the increase of its capacity up to 225 MWe and with the installation of a new 125 MWe unit with two CFB boilers is superior to the two other evaluated options - construction of CFB unit as a greenfield power plant, and substitution of generating capacity at the Lugasnk GRES by power imported from other regions of Ukraine. All four figures-of-merit used for comparison of options look better for the base case.

3. It is feasible to build a stand-alone CFB power plant close to the sources of waste fuel. A coal beneficiation plant with reserves of anthracite schlamm and the ability to clean anthracite culm can be used as such a source. However, no one single coal beneficiation plant in Ukraine can serve as a fuel source for 125 MWe power unit, therefore such a unit should be build between several closely located coal cleaning facilities and mines.

4. Reasons for the option with construction of a greenfield CFB to be less attractive than the base case scenario are:

   Construction of the CFB unit at the Lugansk GRES in the place formerly occupied by 100 MW units can save significant capital investment because of use of existing facilities and power plant systems, which would be necessary to build if the unit was constructed as a stand-alone plant;

   In spite of significant reduction of fuel transportation cost, such cost still cannot be avoided because of: a)cost of loading/unloading operation, and b) after some period of time fuel would need to be delivered from other coal beneficiation plants.

5. Additional capacity to cover the reduced capacity of the Lugansk plant is available on thermal power plants in the Dneprov region. However, all power units in this region have

accumulated about 200,000 or more hours of operation and require significant refurbishment to serve as sources for efficient and stable energy supply to the Lugansk region for the next 25 - 30 years.

6. Construction of a new transmission line is necessary for the transmission of power to cover the deficit in the Lugansk Oblast in case the Lugansk GRES will not be refurbished. Assuming significant amount of energy to be transmitted (350 MW and more) and significant length of the line (over 300 km), the new line should be built for 750 kV and equipped with the new substation 750/220 kV, because the transmission grid in the Lugansk Oblast is operating at 220 kV.

7. Reasons for the option with the construction of a new electrical transmission line and transport of electricity from other areas of Ukraine to be less attractive than the base case scenario are:

   - Significant capital investment is necessary for the refurbishment of generating capacity that can be used for supply of electricity to the Lugansk region;

   - Significant capital investment is necessary for the construction of a new transmission line and auxiliary facilities to provide reliable, stable and safe transmission of power to the Lugansk Oblast;

   - Transmission of significant amounts of energy over the long distance transmission lines is accompanied by losses of 3% and additional O&M;

   - Because all thermal power plants in the Dneprov region are using anthracite schtyb from the Donbass region, the cost of fuel transportation for the distance of more than 300 km is greaterthan for its transportation to the Lugansk GRES.

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8. Discussions in Ukraine., May 13-21, 1997 and personal communications with::
   Mr. Alexander Voyevoda, Chief Dispatcher and Deputy Director of the National Dispatch Center;
   Mr. Evgeny Zorin, Chief of the Department of Optimization of Electrical Regimes
   Mr. Igor Smirnov, Director General of Donbassenergo
   Mr. Konstantin Torzhevsky, Head of the Board of Investments and Foreign Loans, Minenergo of Ukraine
   Mr. Nikolay Borisov, Deputy Head of the Board of Investments and Foreign Loans, Minenergo of Ukraine
   Dr. Alexander Maystrenko, Deputy Director of Coal Energy Technology Center, Minenergo of Ukraine
   Mr. Moisey Levin, Director of Kharkov Central Design Bureau
   Mr. Vasily Karachevtsev, Chief Designer, Kharkov Central Design Bureau
   Mr. Yury Grechikhin, Director, Donetsk Power Industrial Company
   Mr. Michail Michailov, Director of Lugansk GRES
   Mr. Sergey Ivanov, Chief Engineer of Donbassenergo
   Mr. Anatoly Machno, Chief Engineer of Lugansk GRES
   Mr. Sergey Kardashev, Deputy Director of Donbass Regional Dispatch Center

Table 1. Input Data for Economic Analysis

Components	Case 1	Case 1a	Case 2	Case 3	Case 4
Capacity , MW					
PC	225	225	225	360.5	360.5
CFB	125	125	125	-	-
Total at Lugansk	**350**	**350**	**350**	**350**	350
Capital Cost (Million $ US)					
PC upgrade	73.114	73.114	73.114	79.615	46.578
CFB	95.964	95.964	154.551	-	-
El.lines	-	-	1.128	97.73	104.545
Water treatment/coal yard	15.108	15.108	14.482	11.869	11.869
Total	**184.186**	**184.186**	**247.277**	**189.214**	**162.993**
Fuel for PC boiler					
Nat. gas (1000m3/hr)	2.85	2.85	2.85	4.57	4.57
Cleaned schtyb(tonne/hr)	80	80	80	129	1.29
Fuel for CFB					
Option I — Cleaned culm(tonne/hr)	76	76	76		
Option II — 70% Schlamm/30% Unclean. schtyb (t/hr)	70	70	79		
Fuel cost ($/t) undelivered	Delivered	Delivered	Delivered	Delivered	Delivere
Nat. gas ($/1000 m3)	89.27	83.00	83.00	83.00	83.0
	Delivered	Undeliver	Undeliver	Undeliv	Undeliv
Cleaned schtyb	46.97	48.07	48.07	48.07	49.07
Uncleaned schtyb	28.39	32.25	32.25	-	
Cleaned culm	12.02	8.35	8.35	-	
Schlamm	7.94	8.62	8.62	-	
Transportation cost ($/tonne)	1.27	2.23	2.23	5.00	6.34
PC boiler	1.27	2.23	1.00	-	
CFB boiler					
Additional O&M (Million $/year)	-	-	-	2.500	2.700

Table 2. Summary of Economic Results

Project Scenario	Total Annual MWh	Economic Internal Rate of Return[a]	NPV[a] (1000$)	Cross-over Capacity Factor[b]	Cost of Capacity $/kWe	Total COE without Emission Credit	Total COE with Emission Credit	COE Components, US$/kWh Capital	COE Components, US$/kWh Fuel	COE Components, US$/kWh O&M
"Without Project"[c]	502,999	0	0	NA	$1,113[c]	$0.0398	$0.0385	$0.0108	$0.0252	$0.0037
Case 1 (Original) Extensive Rehab (1 Unit) using Cleaned Coal with CFB using 30%schtib /70%schlam	1,982,476	14.7%	$64,200	42.4%	$570	$0.0323	$0.0297	$0.0112	$0.0181	$0.0031
Case 1 (Original) Extensive Rehab (1 Unit) using Cleaned Coal with CFB using Cleaned Culm	1,982,476	14.8%	$65,758	42.0%	$570	$0.0322	$0.0295	$0.0112	$0.0178	$0.0032
Case 1a (New Fuel Costs) Extensive Rehab (1 Unit) using Cleaned Coal with CFB using 30%schtib /70%schlam	1,982,476	13.2%	$41,504	49.0%	$570	$0.0342	$0.0314	$0.0112	$0.0200	$0.0031
Case 1a (New Fuel Costs) Extensive Rehab (1 Unit) using Cleaned Coal with CFB using Cleaned Culm	1,982,476	14.5%	$60,636	43.1%	$570	$0.0327	$0.0299	$0.0112	$0.0183	$0.0032
Case 2 (New Fuel Costs) Extensive Rehab (1 Unit) using Cleaned Coal with Remote CFB using 30%schtib/70%schlam	1,982,476	10.42	$6,604	66.8%	$725	$0.0370	$0.0342	$0.0142	$0.0196	$0.0031
Case 2 (New Fuel Costs) Extensive Rehab (1 Unit) using Cleaned Coal with Remote CFB using cleaned Culm	1,982,476	11.6%	$26,057	58.7%	$725	$0.0354	$0.0326	$0.0142	$0.0180	$0.0032
Case 3 (New Fuel Costs) Extensive Rehab (1 Unit) Remote Location (360.5MW) using Cleaned Coal	1,982,476	3.63%	($51,143)	NA	$543	$0.0409	$0.0387	$0.0108	$0.0260	$0.0042
Case 4 (New Fuel Costs) Extensive Rehab (1 Unit) Remote Location 2 (360.5MW) using Cleaned Coal	1,982,476	3.64%	($42,229)	NA	$478	$0.0402	$0.0380	$0.0095	$0.0264	$0.0043

Note:
a. The Economic Internal Rate of Return and Net Present Value for the project scenarios are based on the incremental differences between the with project and without project scenarios; therefore these values are zero by definition for the without project scenario.
b. Capacity Factor at which NPV = 0.
c. The Without Project Scenario is based on a replacement unit installed in 2011.

Fig. A-1. Lugansk Oblast Power Transmission Grid and Connections with Donetsk Oblast

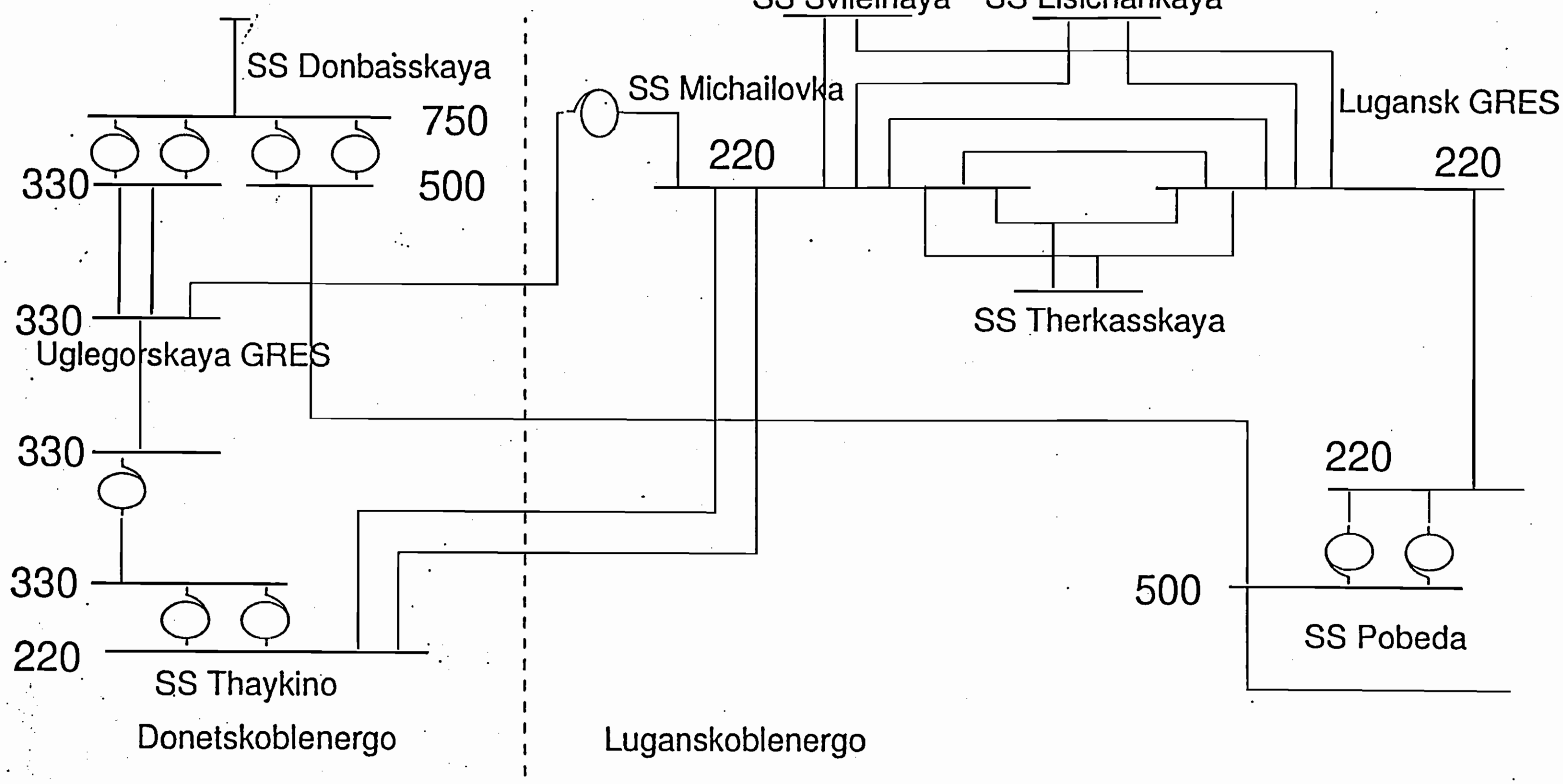
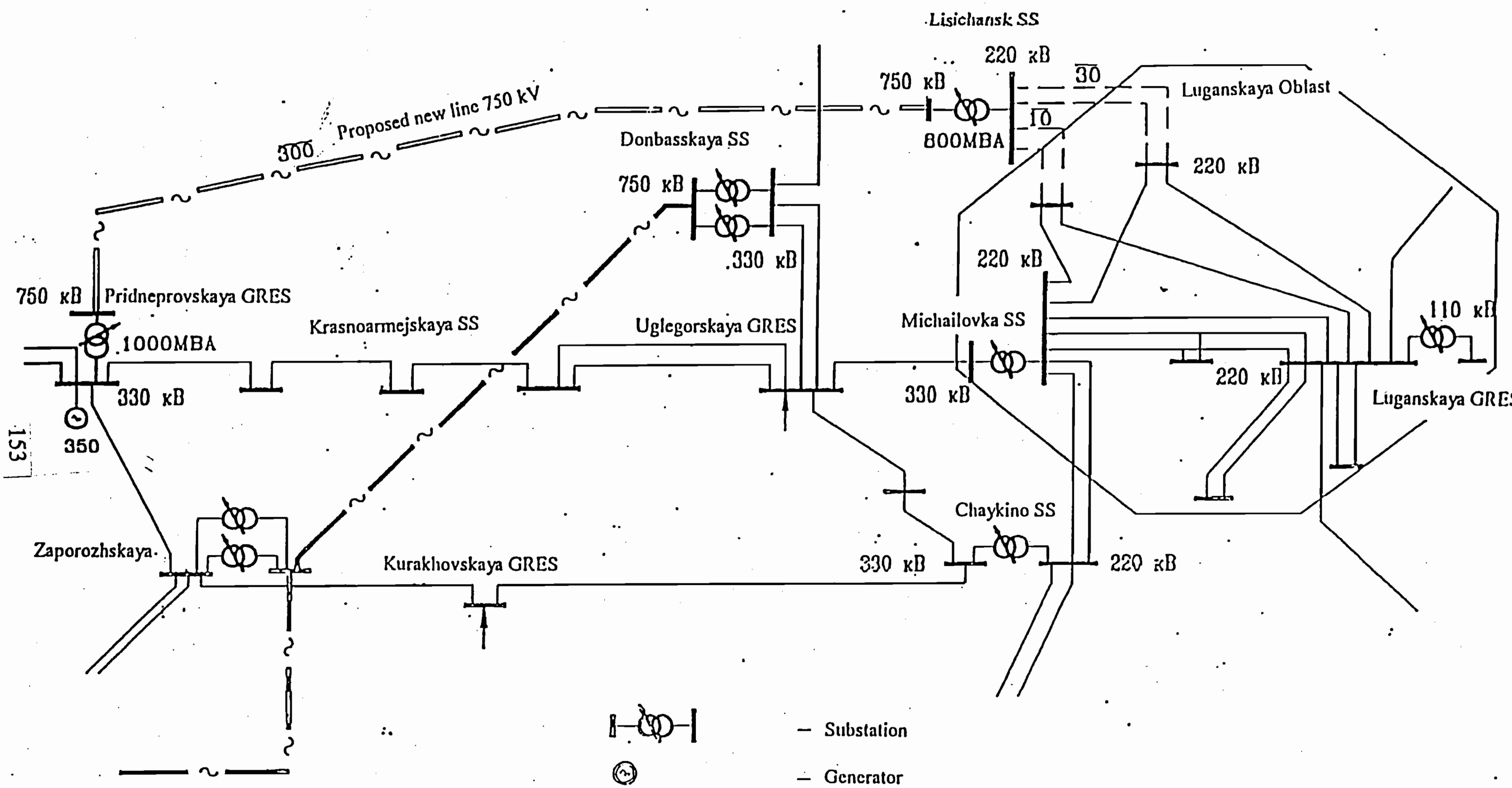


Fig. A-2. Construction of a Transmission Line from the Pridneprovskaya GRES to the Lugansk GRES



U.S./UKRAINE JOINT CONFERENCE ON UKRAINE CLEAN POWER PLANT UPGRADE OPPORTUNITIES

Opening Remarks for Session V Role of International Financial and Technical Organizations

by
Barbara N. McKee
Director, Office of Coal and Power Import and Export
U. S. Department of Energy

Electricity is critical to both economic and human development in the Ukraine and, indeed, everywhere in the world. In the Ukraine, as elsewhere in the world, the need for capital for the electric power sector far outstrips the funds available from official sources such as governments and multilateral institutions. A recent study by my office in the U.S. Department of Energy estimated that $2.3 trillion will be needed worldwide for electric power development over the next 15 years. As a result, private financing is being sought by countries throughout the world. International competition for private capital for power projects is fierce. The same study, however, showed that this capital is available. Many investors and developers are eager to fund electric power projects, but only in those countries that create the conditions to attract it. Those conditions include:

- A financially independent and viable electric power industry,
- A clear and transparent legal and regulatory infrastructure,
- Compatible expectations about financing the industry among all involved parties,
- And, eventually, domestic capital to complete financing.

The key to attracting private capital -- and to lessening dependence on government finance -- is to ensure that the power industry itself is financially viable in that it:

(1) can rely on sufficient revenues from customers,
(2) is run according to sound business principles that investors can understand, and
(3) is free from government intervention that would make investors look to government guarantees.

The recent Asian financial crisis clearly demonstrates how investors move quickly to redirect capital when conditions change. You have probably heard much about the danger of this crisis spreading to other countries. But I believe that it also creates an opportunity because those investors and developers are now actively seeking new markets in which to develop power plants.

The Government of the Ukraine has already started the process to reform both its economy and its electric power sector. As we will hear, much remains to be done. Favorable investment conditions have yet to be facilitated by the government. These conditions will benefit all sectors of the economy, not just electric power.

We have already heard about the progress being made by the Ukraine. In this session, we will hear the perspectives of international technical and financial organizations involved in the electric power industry including the World Bank, project developers and financial institutions. A common understanding of the requirements is necessary if the Ukraine is to successfully attract private capital to its electric power industry.

Creating a better quality of life for the people of the Ukraine means making progress simultaneously on both affordable clean energy and economic development. That, along with attracting private finance to electric power in the Ukraine, will be an ongoing challenge. But the challenge can be met if we are creative in developing a viable electric power sector based on cost-effective and efficient clean coal technologies in a fair and transparent investment climate. As we have seen already, there is much to do, but much can be accomplished. Continued cooperation and the exchange of ideas, as we are doing in this conference, can play a key role in meeting the challenge.

World Bank Guarantee Program

Ukraine/U.S. Joint Conference

on

Ukraine Clean Coal Power Plant

Upgrade Opportunities

April 22, 1998
Takeshi Sugai

World Bank Group

International Bank for Reconstruction and Development (IBRD)
Founded: 1945; 180 member countries

International Development Association (IDA)
Founded: 1960; 159 member countries

International Finance Corporation
Founded: 1956; 171 member countries

Multilateral Investment Guarantee Agency
Founded: 1988; 141 member countries

World Bank Role

Independent Power Projects

- Policy/Advisory
  - project preparation
  - technical assistance
- Financial
  - loans (to or through governments)
  - partial guarantees (debt only)

Eligibility for Bank Guarantees

- Borrowing member countries
  - 78 IBRD and "blend" countries
  - 63 IDA-only countries
- Reform programs acceptable to Bank
- Government desire to lower the cost of private investment in infrastructure

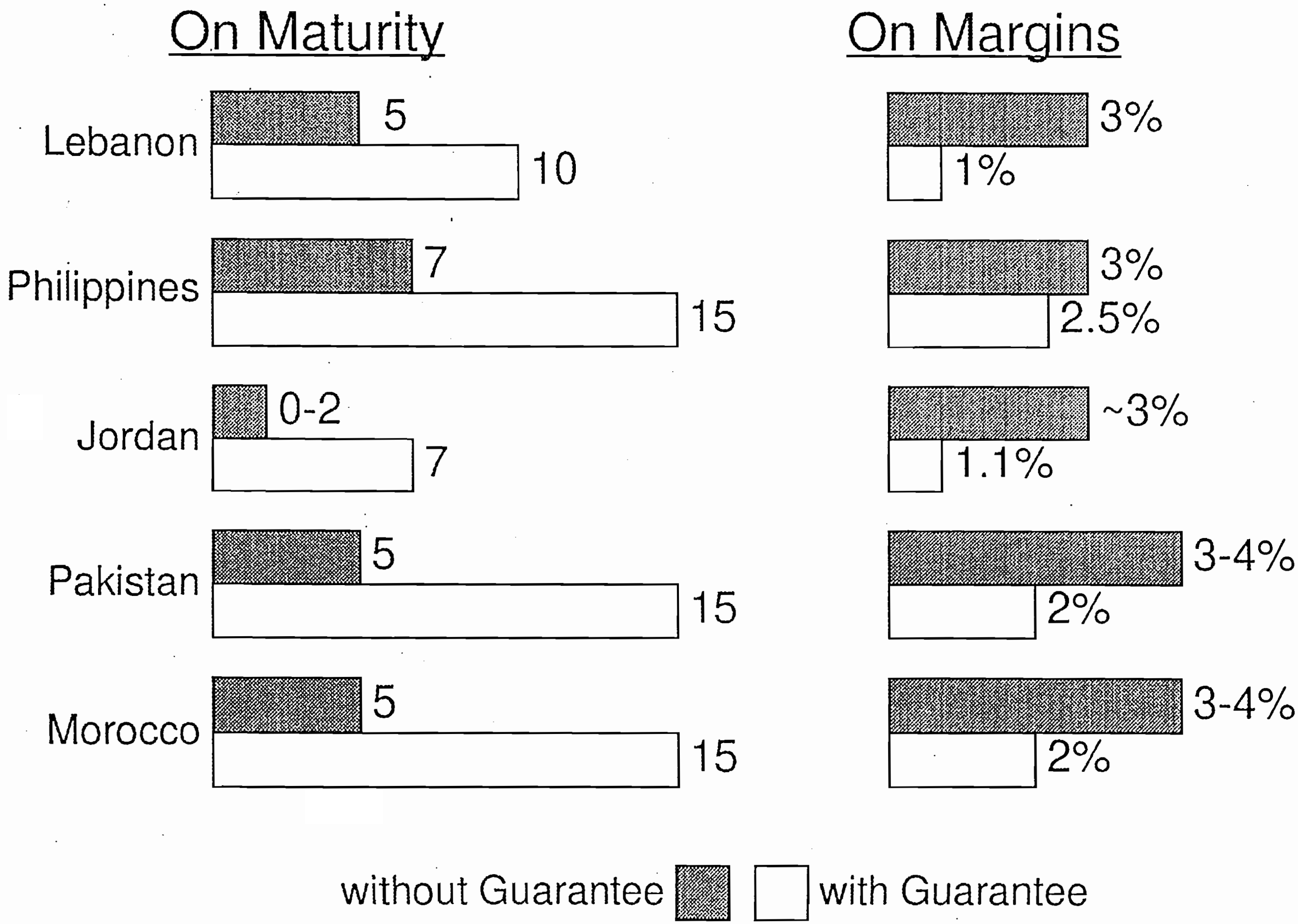
Guarantees: Advantages

- To the Government
  - tariff reduction
  - selective risk allocation

- To the Private Investors
  - opening-up markets for debt financing
    - lower cost of capital
    - more competitive cost structure
  - selective risk allocation

World Bank Guarantees

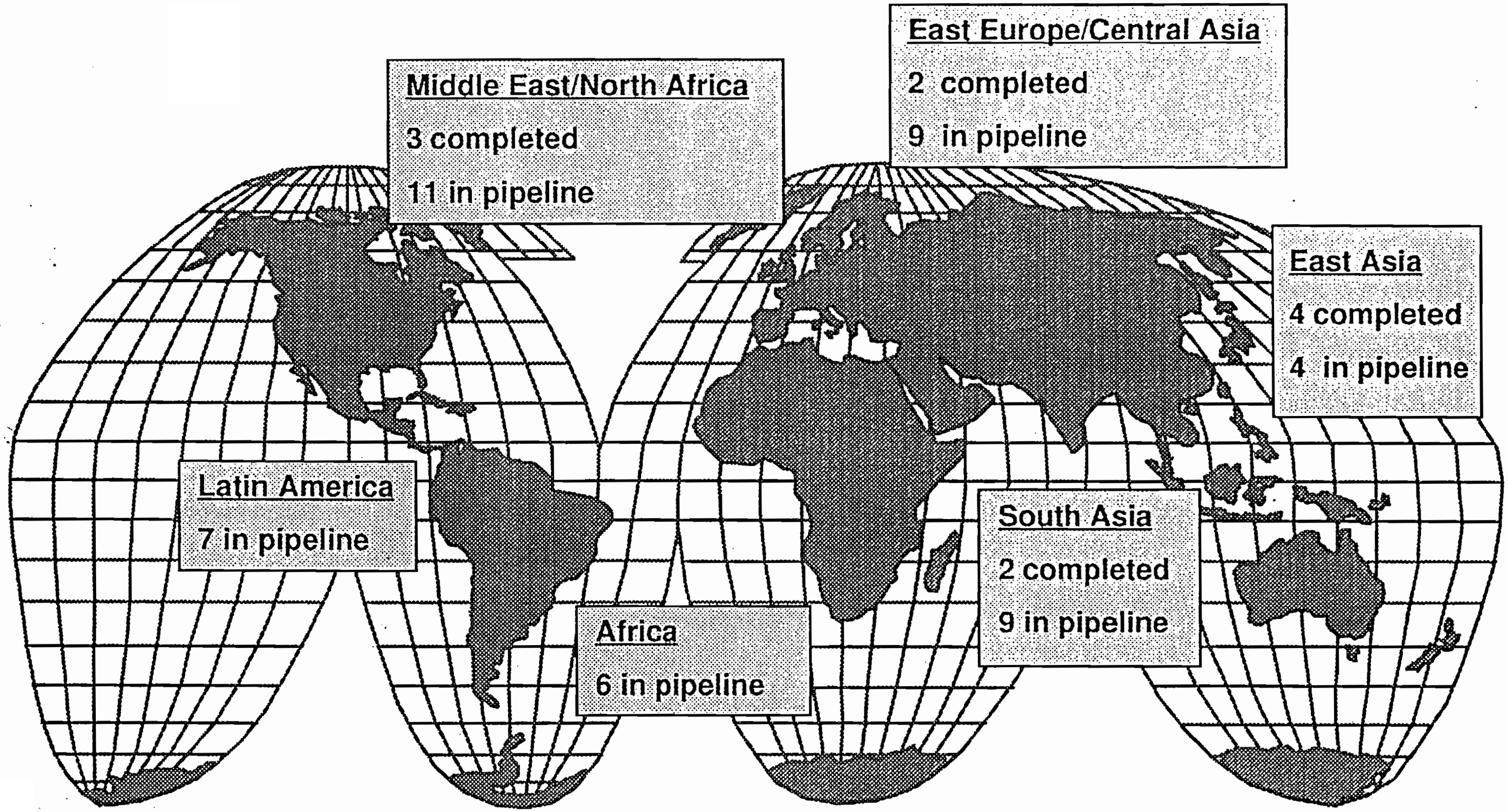
Impact on Debt Terms



World Bank Guarantee Highlights

- Operations in 1994-97
  - 11 completed (mobilized over US$1 billion in projects worth US$12 billion)
  - 47 in pipeline
  - mostly private sector projects; some public
- Project size
  - $200m-$1.8bn
- Primarily infrastructure sectors
  - power, pipelines, roads, water supply

Guarantee Operations Regional Breakdown
30 September 1997



Project Pipeline Diversification

30 September 1997

Sector	Operations
Power	19
Transport	9
Water Supply	7
Oil & Gas Pipelines	3
Trade & Multi-sector	9
Total	47

Guarantee Program

- ❖Flexibility----Financial Structure
  Commercial bank loans
  Public bonds
  Currency

- ❖Last Resort / lowest level necessary

- ❖Counter-guarantee
  ----Bank's Articles of Agreement

- ❖Lending program treatment

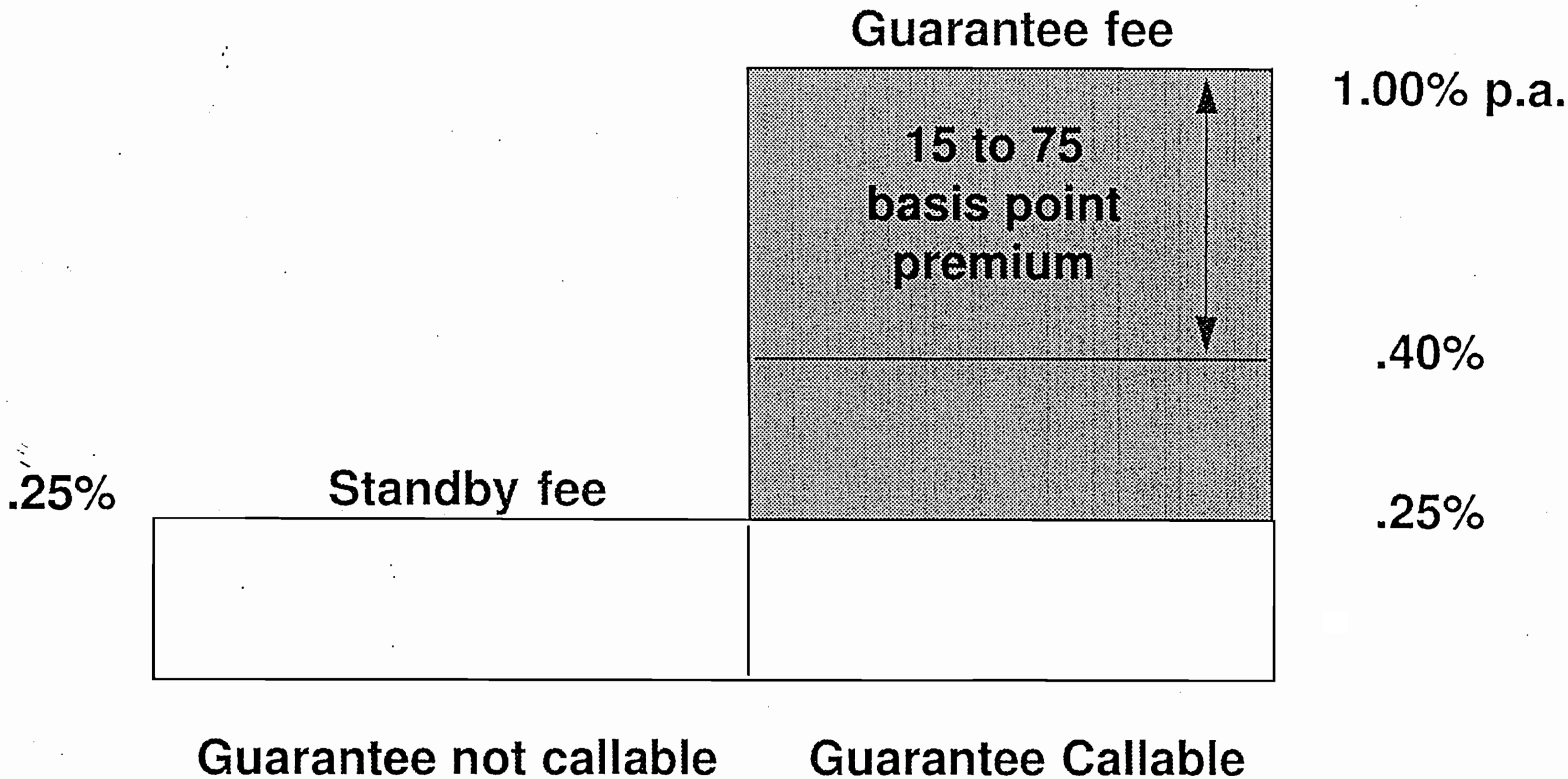
- ❖Regulatory Treatment

Processing of Guarantees

- Request to World Bank for guarantee
- Environmental assessment
- Appraisal and financial structuring
- Completion of negotiations
  - project and financing agreements
  - guarantee agreement
- Indemnity by Government to World Bank
- Approval by Board of Executive Directors

Fee Schedule

- Initiation Fee: 15 b.p. (Min. U$100,000)
- Processing Fee: 50 b.p.
- Standby Fee: 25 b.p.
- Guarantee Fee: 40 b.p. ~ 100 b.p.


Guarantee fee
1.00% p.a.
15 to 75
basis point
premium
.40%
.25%
Standby fee
.25%
Guarantee not callable
Guarantee Callable

Types of World Bank Guarantees

<u>IBRD and "blend" countries</u>

- Partial Risk
- Partial Credit

<u>IDA countries</u>

- Enclave
- Partial Risk

Partial Risk Guarantees

Risk coverage:	Government contractual obligations (guarantee of debt service payments if government breaches its obligations)
Guarantee Amount:	Debt only (principal and/or interest)
Term:	Up to 15-20 years

Partial Risk Guarantees

Guarantee Trigger: Sequence of Events

- Government (utility) does not comply with its contractual obligations
- Project Company suffers cash flow shortage
- Lenders tap into debt service reserves
- Continuing shortage leads to debt service default
- Government (utility) fails to make stipulated compensation payments
- Lenders submit a claim to the Bank
- If in disagreement, parties use dispute resolution procedures
- Arbitration confirms Government liability
- Bank pays lenders & seeks indemnity from Government

Basic Risk Allocation

	Project Company	Government
Completion	delays construction cost	permitting & licensing siting
Performance	output operations availability	payments
Fuel	supply	price
Currency	exchange rate	offshore banking exchange rate availability/convertibility
Inflation	interest rates	general inflation
Force Majeure	inside fence	outside fence
Political/Change in Law	-	domestic policies

Pakistan - Uch Power Project

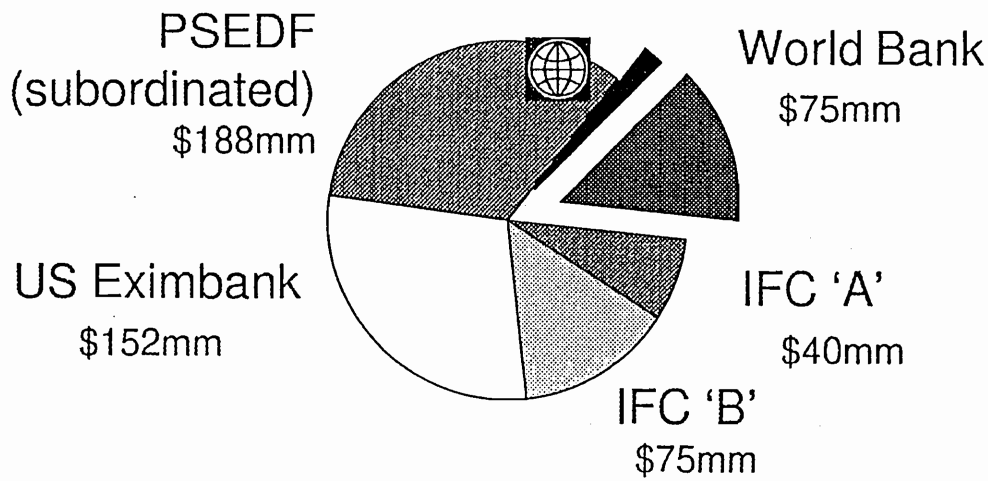
World Bank Partial Risk Guarantee

586 MW gas-fired power station

Sponsors: Tenaska, Midlands, GECC

Total cost: US$690 million

Sources of debt:



Pakistan - Uch Power Project

World Bank Partial Risk Guarantee

Risk coverage:	Government contractual obligations (guarantee includes payment obligations of power purchaser and fuel supplier, FX, and termination payments)
Investment coverage:	Commercial bank debt
Amount:	100% of commercial bank loan; 14% of project debt
Term:	15 years

Morocco - Jorf Lasfar Power Project

World Bank Partial Risk Guarantee

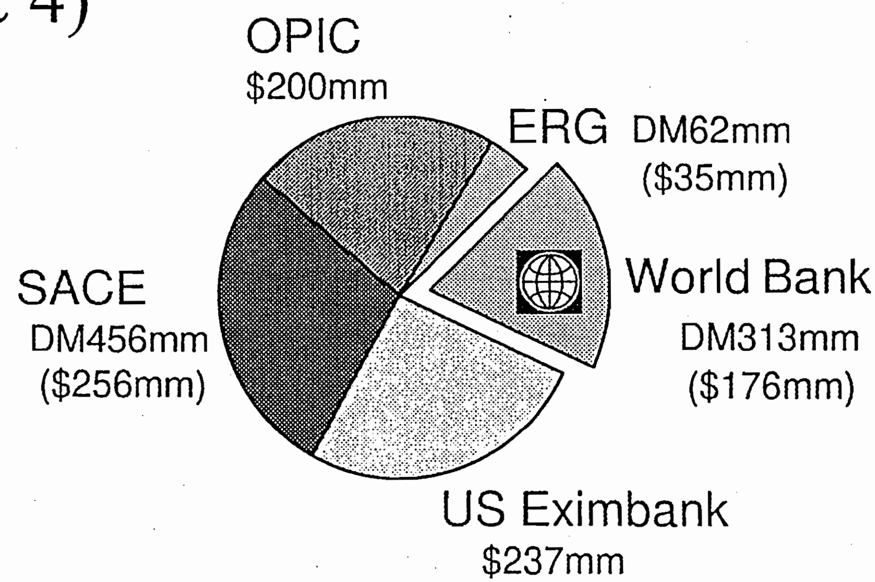
1,356MW coal-fired power station

Sponsors: ABB and CMS

Total cost: US$1,100 million (new units 3 & 4)

175

Sources of debt:



Morocco - Jorf Lasfar Power Project

World Bank Partial Risk Guarantee

Risk coverage:	Government contractual obligation (guarantee of termination payment if government breaches its obligations)
Investment coverage:	Commercial bank debt only (principal and 6 months interest)
Amount:	100% of commercial bank loan; 19% of project debt
Term:	15 years

Partial Credit Guarantees

Risk coverage:	All risks; only a portion of the loan (e.g., specified payments in future)
Investment Coverage:	Debt only (principal and/or interest)
Amount:	$ amount flexible
Term:	Up to 15-20 years

China - Ertan II Hydroelectric Project

World Bank Partial Credit Guarantee

3,300 MW hydroelectric power station

Borrower:	People's Republic of China (public sector)
Lenders:	Commercial banks US$150 million equivalent
World Bank Guarantee:	US$50 million principal payments years 12-15

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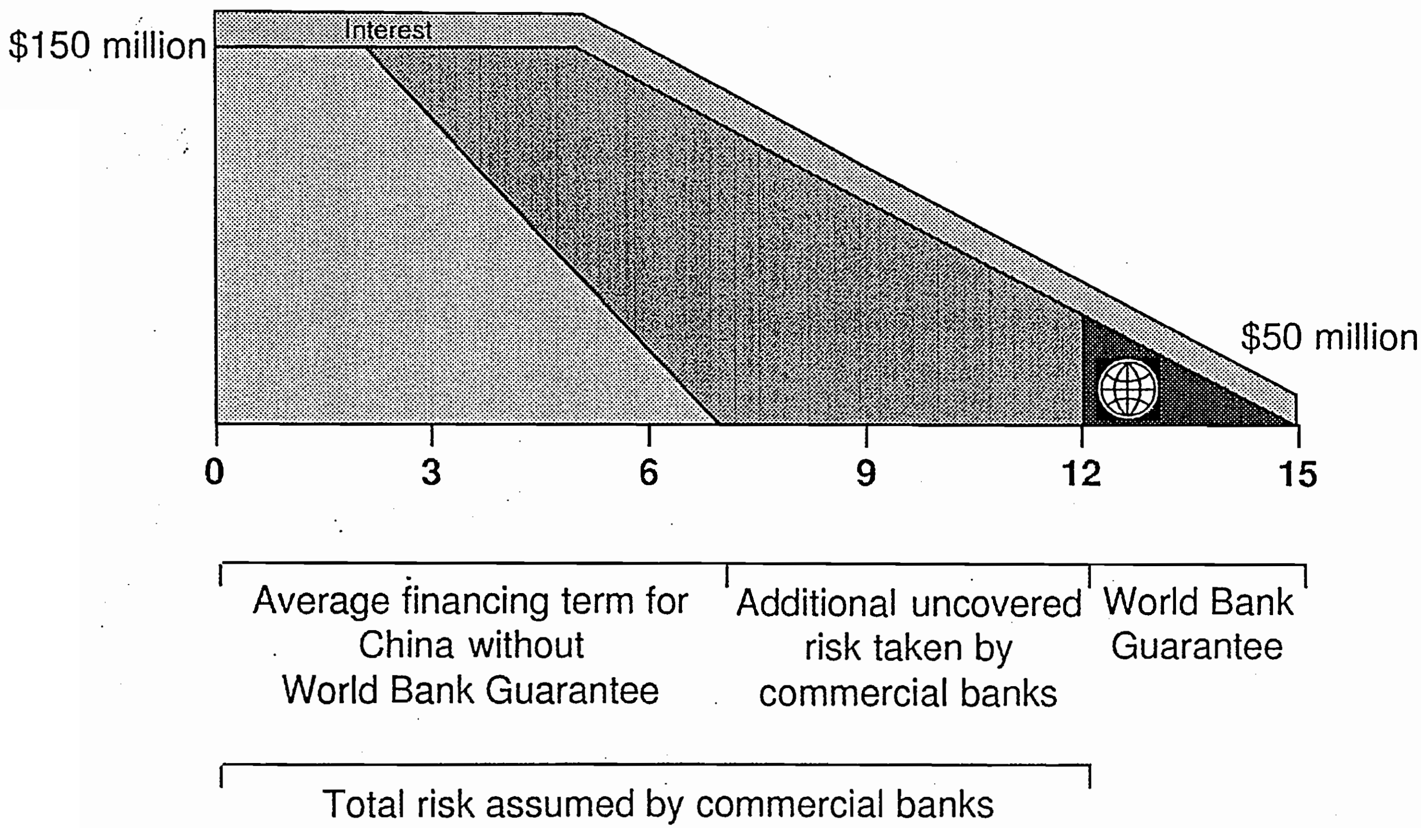
China - Ertan II Hydroelectric Project

World Bank Partial Credit Guarantee



Lebanon - Power Sector Project

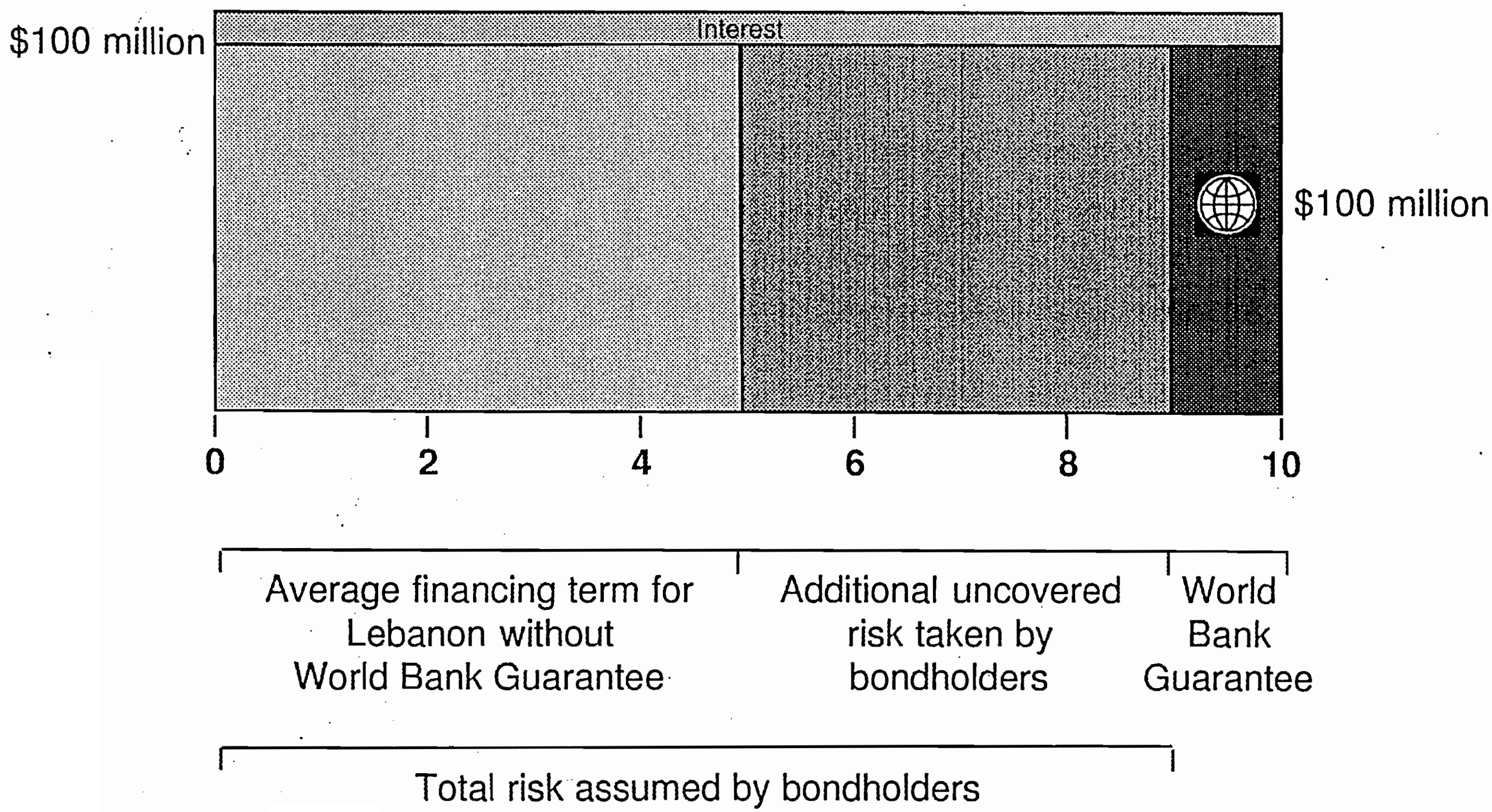
World Bank Partial Credit Guarantee

Power Sector Restructuring
and Transmission Project

Borrower:	Republic of Lebanon
Lenders:	Rule 144A placement US$100 million bullet
World Bank Guarantee:	US$100 million principal payment in year 10

Lebanon - Power Sector Project

World Bank Partial Credit Guarantee



Investments in the Ukraine Power Generation Sector. A Foreign Investor's Viewpoint

M. Bertram

ABB ENERGY VENTURES

Investments in the Ukraine Power Generation Sector

A Foreign Investor's Viewpoint

SLIDE 1

Ladies and Gentlemen,

There is no question, the Ukraine power generation sector requires investments. All participants in this conference pointed at the need for refurbishing and upgrading Ukraine power plants. As a representative of ABB Energy Ventures, a group that takes worldwide responsibility for ABB's equity investments in the power sector, I'm glad to have the opportunity to talk to such audience about the viewpoint of foreign investors on Ukraine.

SLIDE 2

Let's have a look at what drives foreign investments. In general terms, it is the potential reward that results out of the investment. This could be the desire to create a strategic foothold in a growing market, or the potential for short-term gains if investors believe that the share price is to be undervalued, or simply the goal of extending operations in a foreign country. Every investor has his own agenda, and will take investment decisions accordingly. What prevents investments, is obviously the risk of not achieving the desired reward. Thus, an investor will start identifying the rewards and risks. He will invest if he sees a fair balance between them. In other words, investments in a more risky environment are not a problem as long as the investor expects a higher reward. Let's leave this theoretical ground aside, and move to the specifics to the Ukraine power generation market.

SLIDE 3

The Ukraine power generation sector can be a rewarding target for investments. There is a tremendous need for investments, and this conference supports this once more. In addition, the market size is there. A population of more then 50 million people has a large domestic need for power, and the strategic location of Ukraine makes power exports to neighboring countries possible. The restructuring and separation of the power market into generation, transmission and distribution increased the transparency for foreign investors, and makes it easier to evaluate investment opportunities. Last but not least, the power generation sector has a high percentage of State-ownership, which creates privatization potential.

SLIDE 4

However, despite having such high potential, the foreign investment into the power generation sector during the last years was insignificant. Many ideas and project names are around, but most of them did not materialize. Projects have been cancelled, or at least delayed. In many cases, the proposed investment structure requires certain State guarantees, intended to shield the investor from political risks. However, the State is not willing to provide such guarantees, or the State budget can simply not take these obligations. What are the reasons for the obvious lack of foreign investment?

SLIDE 5

If we come back to what drives investments, we see that we need to look at the risks. There are two major issues in the Ukraine power sector an investor will look at. First, every investment in the Ukraine power generation sector is necessarily a public-private partnership, since the majority of the power plants is in the hands of the State. If you have a partner in a project, you want to understand his strategy, objectives, and decision-making process. If the main partner is the State, you need to analyze the political arena. What are the aims of the market reforms, is the privatization strategy consistent, and it is accepted and supported by policymakers and the population. Long-term investments like a stable environment. If such stability is impossible because the State is in a transition, you want to be able to predict the transition route. The signals Ukraine sends in these respects to foreign investors are often conflicting. For example, a commercial privatization, aimed at achieving the highest price for the share, attracts a totally different group of investors than a non-commercial privatization that includes investment and operating commitments. The first group would consist of investors who bet on the Ukraine stock market, the second group includes investors that are interested in having an operating base in the country. Here, consistency is required. Is Ukraine looking for foreign cash, or in addition for foreign support in developing the power industry?

SLIDE 6

The second area foreign investors will look at is the industry itself. How is the power market structured, what role play regulation and competition, and are they predictable? Do tariffs cover all operating and capital cost? At what extent are revenues collected? The main problem is of course the dramatic level of payment arrears. A recent press article said that the cash collection rate of electricity is as low as 7%. For foreigners, it is difficult to understand how the power market can function at all under these conditions. On the other hand, I personally admire Ukraine management and employees what tremendous job they do by not letting the power supply collapse. Of course I know about set-offs, barter deals etc., and it is important for foreign investors to understand better how the system functions. I will talk about it later, but let's first come to the current status opf investments.

SLIDE 7

Most of the investors are not willing and able to deal with the risks I just described. They either wait and see how the Ukraine develops, or they turn to the State and require respective support. A foreign investor has a certain risk allocation in his mind. For power plants, he guarantees efficient construction and operation of the plant. However, he is not willing to accept risks that are beyond his control. This includes typical political risks, like convertibility, expropriation etc. In addition, investors want to pass certain market risks to the State, which often include payment guarantees for the power. Governments, investors, and lenders in the whole world have developed sophisticated investment and security schemes, under which large infrastructure investments can be made in emerging markets, despite macroeconomic instability, structural problems and payment arrears. However, each of these schemes transfers the country-related risks to the State, and here is the conflict. On the one hand, the State wants to attract private initiative and investment to develop the country, on the other hand the State is required to take over many risks. Thus, the direct State support for investments needs to be prioritized. It should be aimed at investments which are either large, or are absolutely necessary for the security of the State. In all other cases, the State is requested to create such framework that allows it foreign investors to take over more risks.

SLIDE 8

Here, we need to separate the investment risk into what I call the "perceived" and the "real" risk. Perceived risk arises because a foreign investor is unfamiliar with the situation in Ukraine. As I said earlier, a 7% cash collection rate for power scares everybody who intends to invest into such market. On the other hand, the management of the Ukraine power plants deals with this issue every day, and has developed ways to survive under such conditions. Thus, an investor who is familiar with the ways the power sector functions, might be willing to deal with the non-payment risk. The risk is still there, but it is "perceived" to be lower. A second example is the investment commitment an investor has to make. Rather then making one large shot at once, he could structure the investment in successive steps. This gives him the option to learn more about the market, become familiar with the specific risks, and find ways how to control these risks. Thus, having investors to accept more risks is a two-side exercise. The investor needs to be willing to learn, and the State needs to create such framework that makes it possible for the investor to balance the risks and rewards. My impression is that things are moving. I heard that a new privatization strategy for the Ukraine power generation sector has been announced, which is a combination of privatization, operating control, and investment commitments. This would support what I said earlier, it encourages investors with a long-term commitment to Ukraine, and provides them with a way to learn gradually more, and to increase the investments commitment step by step. I encourage everybody to continue in such way, since it brings both sides together, and it makes foreign investors a part of the local economy.

SLIDE 9

Let me just summarize: The potential is there, and foreign investors are interested in Ukraine. However, there are gaps to be closed between foreign investors and Ukraine before investments will flow into the country. The main way to close these gaps is the right privatization and investment strategy. Ukraine needs investors that are willing to become part of the country, and to participate in the development of the power market. This helps Ukraine more than just a paycheck.

ENVIRONMENTAL EXPORTS PROGRAM

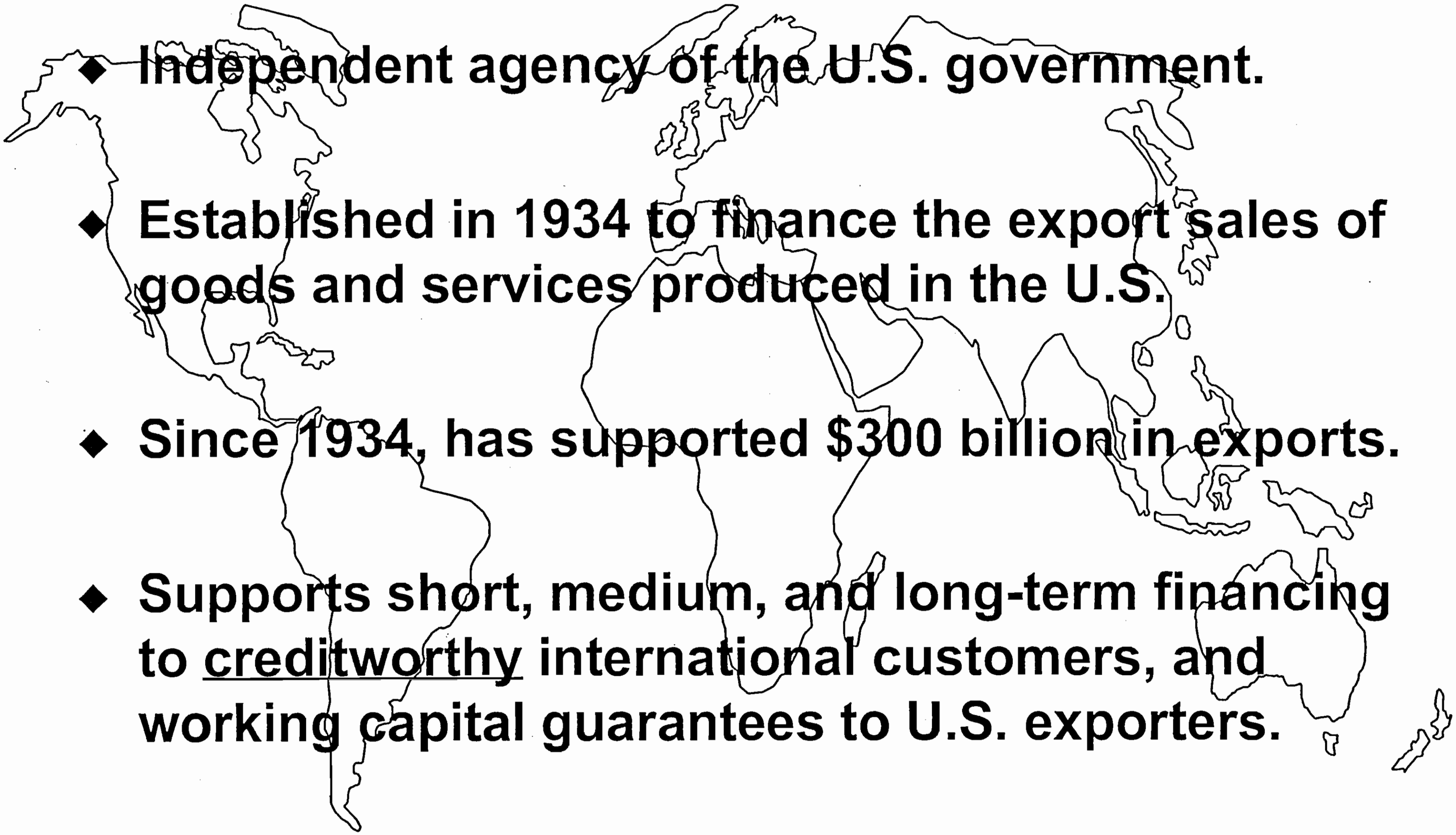
Craig S. O'Connor

Environmental Liaison Officer

Export-Import Bank of the United States

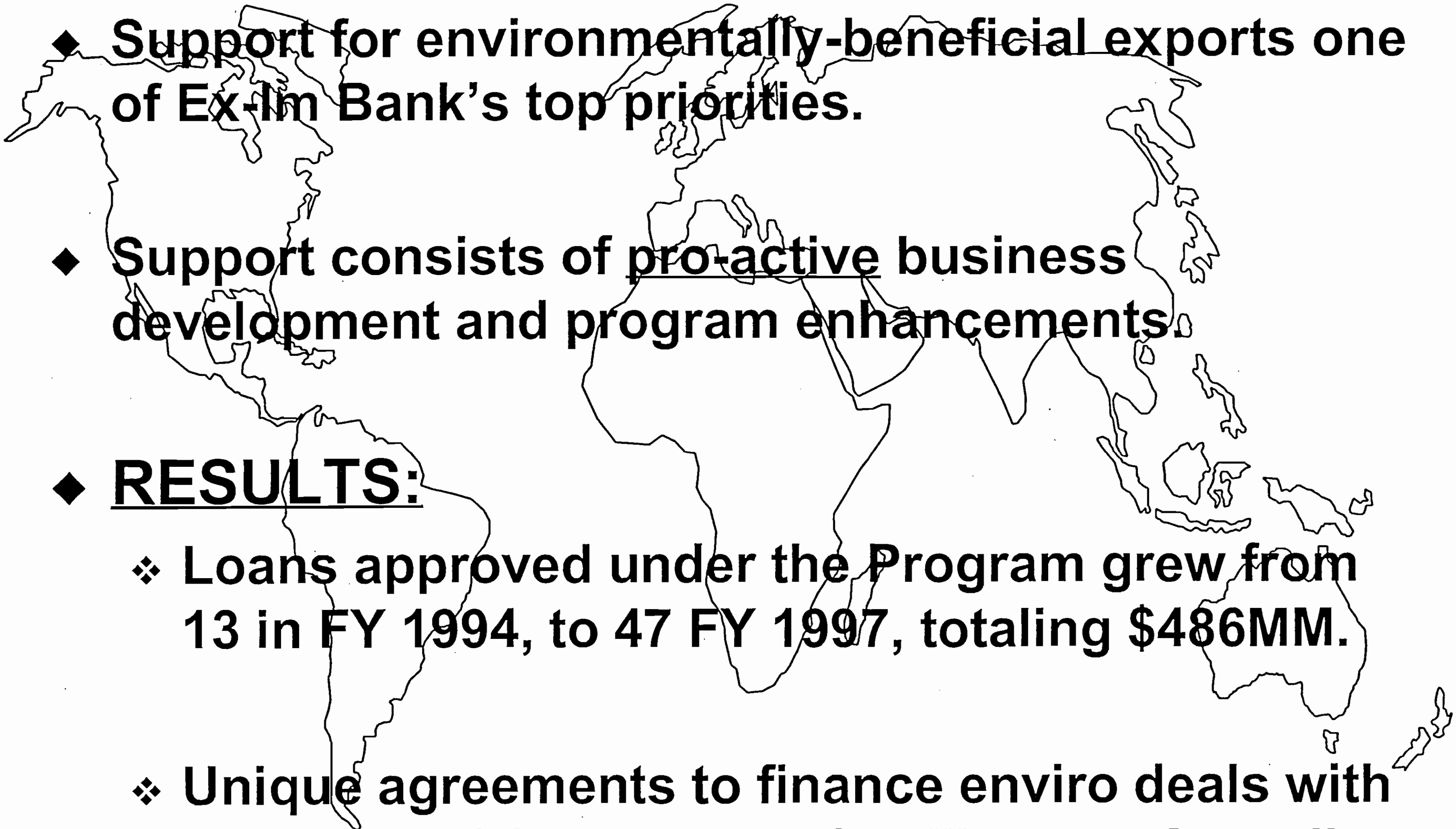
"Ukraine/U.S. Joint Conference on Ukraine Clean Coal Power Plant Upgrade Opportunities"

U.S. Ex-Im Bank



- Independent agency of the U.S. government.
- Established in 1934 to finance the export sales of goods and services produced in the U.S.
- Since 1934, has supported $300 billion in exports.
- Supports short, medium, and long-term financing to <u>creditworthy</u> international customers, and working capital guarantees to U.S. exporters.
- ***No minimum nor maximum project size.***

Environmental Exports Program



- Support for environmentally-beneficial exports one of Ex-Im Bank's top priorities.

- Support consists of <u>pro-active</u> business development and program enhancements.

- <u>**RESULTS:**</u>
  - Loans approved under the Program grew from 13 in FY 1994, to 47 FY 1997, totaling $486MM.
  - Unique agreements to finance enviro deals with Poland's BOS Bank, and Credibanco of Brazil.

Export Credit Insurance

- Enables U.S. exporters to offer short- and medium-term *credit directly to their customers.*

- Financing is often THE critical factor in winning an export sale in emerging markets. Export credit is an attractive substitute to L/Cs and local financing.

- Export credit insured by Ex-Im Bank is easily "assigned" to the exporter's bank for funding at low rates: typically LIBOR + 1/2-1%.

- Insurance premium rates are low and are typically financed as part of the credit.

Case Study: Czech Republic

- Ionics, Inc. used Short-Term Insurance to finance a $40MM waste water treatment project at a uranium mine near Prague.

- Ionics, Inc. offered 90-day payment terms to the customer, DIAMO s.p., for work performed and equipment supplied under the contract.

- With Ex-Im Bank's Insurance, Ionics, Inc. assigned their receivables to State Street Bank and received immediate funding at attractive rates.

Export Credit Insurance

- **Medium-Term Export Credit Insurance has the following features:**
  - **Repayment terms of 1-5 years, with 7-year terms for environmental projects over $350,000.**
  - **The credit must be evidenced by a valid and enforceable promissory note. Ex-Im Bank can provide the exporter with a note to use.**
  - **Provides 100% coverage against commercial and political default. The buyer makes a 15% downpayment to the exporter.**

Case Study: Mexico

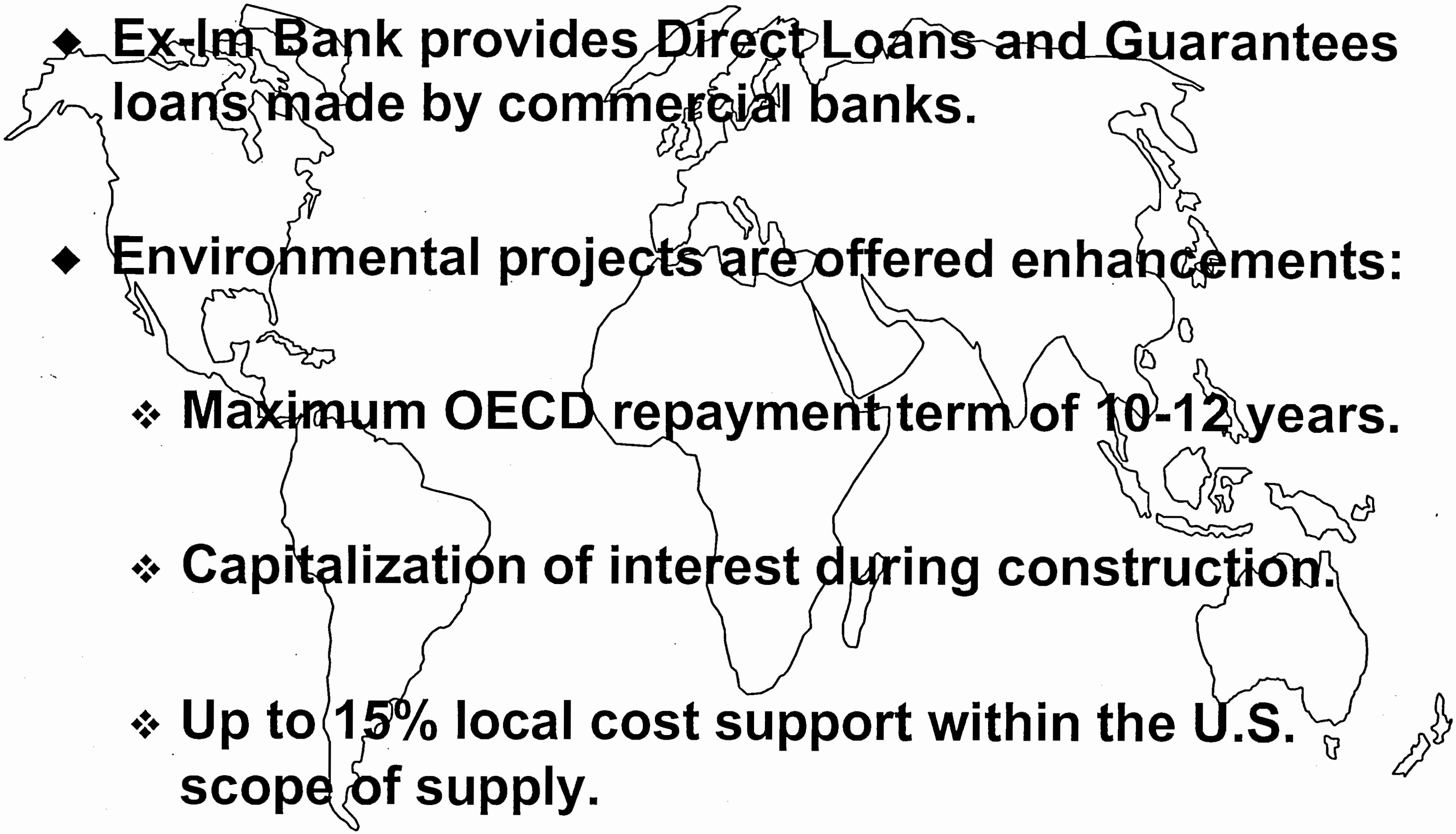
- **Zond Systems, Inc. used Medium-Term Insurance to offer 5-year financing for the sale of a $440,000 wind turbine to a cement maker in Mexico.**

- **Ex-Im Bank's Loan Officer analyzed the buyer's financial statements, credit report, and bank references to determine creditworthiness.**

- **The interest rate to the buyer set at LIBOR + 1/2%.**

- **The insurance premium - *a one-time flat charge*- set at 4.14%. Ex-Im Bank supported financing of the premium over the 5-year term (0.83% per year).**

Loan & Guarantee Program



- Ex-Im Bank provides Direct Loans and Guarantees loans made by commercial banks.
- Environmental projects are offered enhancements:
  - Maximum OECD repayment term of 10-12 years.
  - Capitalization of interest during construction.
  - Up to 15% local cost support within the U.S. scope of supply.

Case Study: Poland

- Ex-Im Bank provided a $30MM Loan Guarantee to finance the sale of circulating fluidized bed (CFB) boilers to Elektrownia Turow in Bogatynia, Poland.

- The CFB boilers supplied by Pyropower Ahlstrom were used in the upgrade of Turow Units 1 & 2.

- Ex-Im Bank provided $6.5MM in additional financing for local costs and capitalized interest.

- Ex-Im Bank's received a repayment guarantee from Poland's Ministry of Finance.

Case Study: Turkey

- Ex-Im Bank provided a $46.2MM Loan Guarantee to finance a flue gas desulfurization (“FGD”) unit for a Turkiye Elektrik A.S. plant in Kemerkoy.

- The FGD unit supplied by Babcock & Wilcox will enable the plant to operate at full capacity and meet Turkish environmental regulations.

- Ex-Im Bank provided enhancements to the Loan Guarantee that included a 10-year repayment term after installation; capitalization of interest during installation ($4.7MM); and, local cost support equal to 15% of the U.S. contract price ($6.9MM).

Ex-Im Bank support for Ukraine

- Ex-Im Bank has a partnership with the State Export-Import Bank of the Ukraine.

- Ex-Im Bank in June 1997, authorized a 5-year $66.3MM Loan Guarantee to the State Export-Import Bank to finance the sale of 369 combines and 45 tractors by Case Corporation.

- Ex-Im Bank has $249.3MM in total lending outstanding for Ukraine.

Conclusion

- Environmental exports: top priority of Ex-Im Bank.
- Ex-Im Bank is very interested in supporting clean coal power plant upgrade projects in the Ukraine.
- Ex-Im Bank is interested in any size project.

❖ www.exim.gov

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