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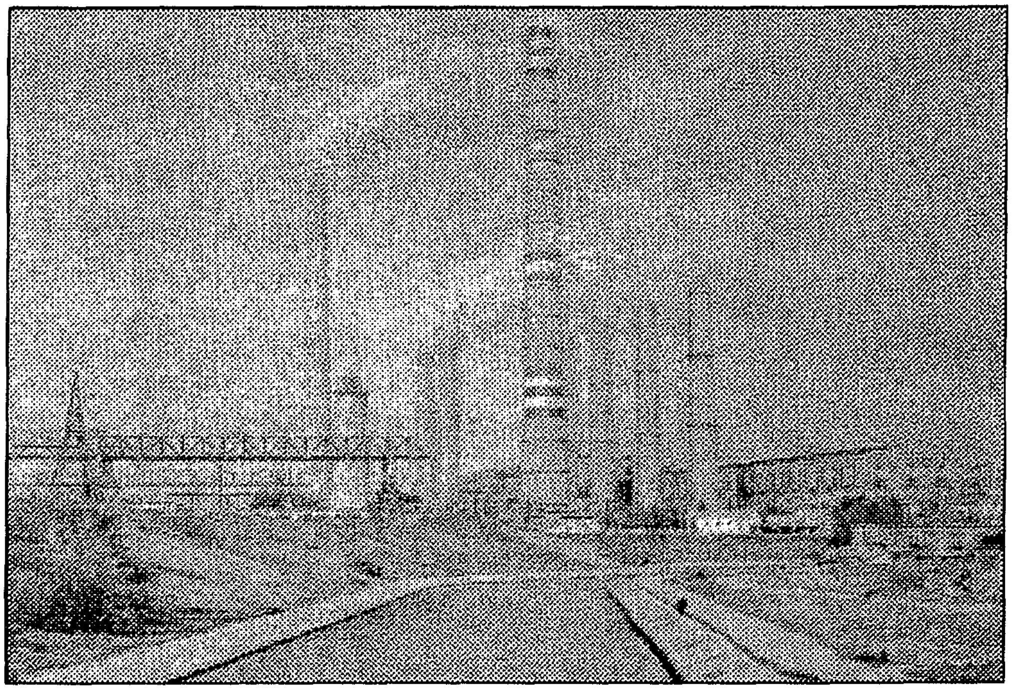
US/UKRAINE JOINT POWER PLANT UPGRADE PROJECT

REHABILITATION OF LUGANSK GRES

FINAL REPORT



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Submitted by: *Burns and Roe Enterprises, Inc.*

Submitted to: *U.S. Department of Energy*
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EXECUTIVE SUMMARY

The purpose of this investigation and report is to develop technical definition and cost estimates for the rehabilitation of three power plant boiler/turbine generator units at Lugansk GRES. It is understood that this information will be utilized by others to perform financial analyses on the various alternatives. The results are for the World Bank which is considering a loan to the government of the Ukraine for the rehabilitation of Lugansk GRES.

The scope of work is to develop technical details, and estimates of performance and capital cost for the following units at Lugansk GRES:

I. Rehabilitation of 200 MW Units Nos. 10 and 13, considering alternative fuels of either the existing high-ash coal or a beneficiated coal.

For each of these units and fuel alternatives, the following options were to be addressed:

Option 1 - Minimal refurbishment, with only emission of particulates controlled to prescribed limits.

Option 2 - Minimal refurbishment, with emissions of particulates, SO_2 and NO_x controlled to prescribed limits (improved emission control).

Option 3 - Boiler furnace converted to double arch firing configuration, with improved emission control.

Option 4 - Extensive refurbishment, with improved emission control.

II. Replacement of two boilers, a 100 MW turbine generator and auxiliary equipment, all previously decommissioned, with a new 125 MW unit consisting of a turbine generator, two half -size circulating fluidized bed boilers and auxiliary equipment.

III. Rehabilitation of common plant equipment and systems affecting performance and cost of the above units (the need for a new make-up water treatment system has been identified).

The objectives to be accomplished with this scope are:

- Extended life: 15 years for rehabilitated units, 30 years for the replacement unit.
- Increased power generation - To achieve rated capacity where possible for Options 1-3, and additional capacity for Option 4.
- Improved efficiency

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- Reduced use of supplementary fuel
- Reduced flue gas emissions

RESULTS: REHABILITATION OF UNITS NOS. 10 AND 13

Option 1 - Minimal Refurbishment/Minimal Emission Control

Due to age and worn condition of both units, numerous plant components must be repaired or replaced. A detailed listing is included in Tables 2.2-1A and 1B, and 2.2-2A and 2B of Section 2. The main items included in this listing are the following:

Boiler

- Refractory, insulation, lagging and casing
- Tubing in furnace walls, superheater, reheater and economizer
- Attemperators
- Air preheater seals and ducts
- Firing system, including mill liners, classifiers and burners
- Emission Control - New electrostatic precipitators

Turbine

- High pressure and intermediate pressure sections (Unit 10 only)
- Last stage blading in low pressure turbine
- Governor components and critical valves

Balance of Plant

- High temperature steam piping systems
- Boiler feed and condensate pumps
- Feedwater heaters

Electrical

- All power control and instrument wiring, conduit and cable tray
- 220 KV switchyard equipment
- Switchgear transformers and motor control centers

Controls

- New distributed control system
- Controls and control valves

Option 2 - Minimal Refurbishment/Improved Emission Control

The refurbishments for this option are the same as in Option 1 except that low NO_x producing burners and a selective non-catalytic reduction system are added for NO_x emission control, and a semi dry flue gas desulfurization system is added to control sulfur dioxide emissions.

Option 3 - Furnace Conversion to Double Arch Configuration/Improved Emission Control

The refurbishments for this option are the same as in Option 2 except that the entire furnace enclosure is replaced with welded membrane tubing, in a double arch firing configuration, and the furnace wet bottom ash system is replaced with a dry bottom type. Also new higher capacity ball mills are required to achieve full capacity with the existing coal.

The recommended NO_x emission control system will not meet the NO_x limit prescribed for this option. The limit is extremely stringent and is inconsistent with European standards. It is recommended that the limit be questioned. The recommended equipment will meet the same NO_x limit as in the other options.

Option 4 - Extensive Refurbishment/Improved Emission Control

The refurbishments for this option are the same as in Option 2, except for the following additions.

Boiler- Entire furnace enclosure replaced with welded membrane tubing; higher capacity ball mills for the existing coal.

Turbine - New 225 MW turbine generator, including all auxiliary equipment.

Balance of Plant - Larger capacity equipment and piping.

RESULTS: REPLACEMENT OF BOILERS NOS. 13 AND 14, AND TURBINE NO. 6

The new unit consists of a 125 MW steam turbine generator, with balance of plant equipment and two half-sized circulating fluidized bed (CFB) combustion boilers. The new unit replaces decommissioned 100 MW Turbine No. 6 and Boilers Nos. 13 and 14.

Each boiler is a single drum, natural circulation unit, of two stage solid collection design with a forced draft fan and an induced draft fan. The coal feed system includes a hammermill crusher with volumetric feeder and screw feeder. Limestone is dried in a rotary dryer, crushed in a vertical spindle roller screen mill and conveyed pneumatically to the furnace. A fabric filter controls particulate emissions.

The 125 MW turbine generator is suitable for installation on the pedestal of the original 100 MW machine. The turbine has a high pressure section and a double flow low pressure section. The balance of plant equipment includes a condenser, six feed water heaters necessary pumps, piping and controls.

Performance and cost data are as follows:

Turbine gross output, MW	125
Turbine gross heat rate, Kcal/kWh	2042
Unit net output, MW	114.4
Unit net heat rate, Kcal/kWh	2595
Total cost estimate (U.S. dollars)	$105,376,386
Cost/net KW (U.S. dollars)	$921

RESULTS: NEW MAKE-UP WATER TREATMENT SYSTEM

A new make-up water treatment system is required to provide water of improved quality and avoid the use of the existing troublesome evaporators. The system consists of cartridge filters, reverse osmosis vessels and mixed bed demineralizers. It receives softened water from the existing pretreatment system and delivers demineralized water to each of three refurbished units.

The total cost (in U.S. dollars) is $2,690,360.

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UNIT NO. 10
PERFORMANCE & COST

		OPTION 1 MIN REFURB/MIN EMISSION CONTROL		OPTION 2 MIN REFURB/IMP EMISSION CONTROL		OPTION 3 ARCH FIRING/IMP EMISSION CONTROL		OPTION 4 EXT REFURB/IMP EMISSION CONTROL	
	CURRENT CONDITION	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
TURBINE GROSS OUTPUT, MW	139.0	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
TOTAL COST ESTIMATE (U.S. DOLLARS)		$51,644,386	$51,644,386	$61,695,304	$63,839,992	$78,512,986	$78,005,978	$83,862,916	$83,472,394
COST/NET KW (U.S. DOLLARS)		$393	$277	$472	$345	$430	$422	$406	$400

UNIT NO. 13
PERFORMANCE & COST

		OPTION 1 MIN REFURB/MIN EMISSION CONTROL		OPTION 2 MIN REFURB/IMP EMISSION CONTROL		OPTION 3 ARCH FIRING/IMP EMISSION CONTROL		OPTION 4 EXT REFURB/IMP 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	1972	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
TOTAL COST ESTIMATE (U.S. DOLLARS)		$45,690,263	$45,690,263	$56,342,884	$58,469,606	$72,302,718	$71,719,468	$84,750,542	$84,266,451
COST/NET KW (U.S. DOLLARS)		$339	$245	$420	$316	$396	$388	$410	$403

REHABILITATION OF LUGANSK GRES

1.0 INTRODUCTION

1.1 BACKGROUND

The Ukraine, as one of the Newly Independent States (NIS) of the former Soviet Union is still going through transition from its highly centralized communist government to privatization and a free market economy. Coincident with this has been a marked slowing of the economy and in particular a significant reduction in requirements for electric power generation.

Within the power generation sector, however, there have been several factors which have exacerbated the ability to generate needed power levels even in a reduced demand period:

- As a result of the accident at Chernobyl nuclear plant Western nations have put pressure on Ukraine to shut down the two operating Chernobyl units. However, Ukraine is unwilling to comply without sufficient replacement power.

- The current economic recession has put significant pressure on the Ukraine power industry to generate electricity from domestic fuel sources.

- Domestic coals for the most part are not of prime quality. Much of the higher quality coal is exported for hard currency, leaving lower quality coal for power generation boilers.

- The low quality coal not only cause higher boiler maintenance, but requires that a significant number of units co-fire natural gas and/or oil in order to maintain generation capability. The Ukraine has very limited resources of gas and oil and must import them from Russia, causing a severe cash drain on the economy.

Burns and Roe Services Company, as a Technical Support Contractor to Department of Energy's Pittsburgh Energy Technology Center (DOE/PETC), was assigned the task of performing an engineering analysis for rehabilitating three turbine generator units and their boilers at Lugansk GRES in order to improve plant generation and efficiency, and reduce environmental impact. The analysis was conducted by Burns and Roe Enterprises, Inc. an affiliate of Burns and Roe and Roe Services Company. This activity is part of a USAID Clean Coal Power Plant Program managed by DOE/PETC. Concurrent with this analysis, DOE/PETC is separately developing details of a coal preparation plant suitable for supply of beneficiated coal fuel to two of the units. This report presents the results of the analysis, considering both fuels, together with recommended modifications, performance improvements and estimated costs.

Under a separate contract from DOE, Gilbert/Commonwealth, Inc. will conduct various financial analyses based on the results of this engineering analysis. The results of the financial analyses will be submitted to the World Bank as part of a Bankable Package. The World Bank is considering a loan to the government of Ukraine for the rehabilitation of Lugansk GRES.

1.2 GENERAL DESCRIPTION OF PRESENT PLANT

The Lugansk GRES power station, when completed in 1969, had a generating capacity of 2300 MWe. The station name was Voroshilovgrad GRES and it was changed upon the breakup of the Soviet Union. The station was constructed in three phases. Phase 1, consisting of fourteen boilers and seven 100 MWe turbine generators, went operational between 1956 and 1958. Four 200 MWe units each with a boiler and turbine generator were installed as Phase 2 between 1961 and 1963 and four more as Phase 3 between 1967 and 1969.

All of the units were originally fueled by Ukraine anthracite coal containing about 15-18% ash and 4% volatile matter with a heating value of approximately 6010 kcal/kg (LHV basis). Over the past 15-20 years the quality of fuel delivered to the plant has worsened to the present 34-36% ash, 4% volatiles and a heating value of 5200 kcal/kg (9379 Btu/lb). The increased ash content, decreased heating value, and age have caused deterioration throughout the power plant.

Except for the two boilers in Phase 1 building that provide district heating for the nearby community of Shastye, the remaining boilers and some of the steam turbine generators with related equipment have been dismantled.

The 200 MWe generating units have been derated to about 145 MWe-175 MWe due to various states of boiler deterioration. It is necessary to cofire with natural gas or mazut (heavy fuel oil) to deliver sufficient energy to boilers to maintain flame stability and to meet derated steam requirements when sufficient coal is not available. The gas and mazut are imported from Russia and must be purchased with scarce hard currency, worsening the national debt. Atmospheric emissions are either uncontrolled (SO_2 , NO_x) or inadequately controlled (particulates).

1.3 SCOPE OF WORK

The scope of work for this investigation is to develop conceptual designs, and estimates of performance, capital costs and operating costs for the following:

- Rehabilitation of 200 MWe Unit No. 10 (in the Phase 2 Section) and Unit No. 13 (in the Phase 3 Section) to improve performance and extend service life. Alternative fuels

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to be considered are a beneficiated coal with 18 percent ash and the coal presently used with 36 percent ash.

- Replacement of two 50 MWe boilers, Nos. 13 and 14, and 100 MWe turbine generator No. 6, and related balance of plant equipment (all in the Phase 1 Section) with two 62.5 MWe circulating fluidized bed boilers, a 125 MWe turbine generator and the required balance of plant equipment.

The following options for the refurbishment of the 200 MWe Units 10 and 13 are to be developed and evaluated, both with the beneficiated coal and the coal presently fired:

1. Minimal package of upgrades to increase power generation above its present derated level and reduce its unit cost, with only particulate emissions controlled to prescribed limits for reconstructed boilers.

2. Minimal package of upgrades as in Item 1 except SO_2, NO_x and particulate emissions controlled to prescribed limits for reconstructed boilers.

3. Boiler furnace converted to arch firing, with SO_2, NO_x and particulate emissions controlled to prescribed limits for reconstructed boilers.

4. Extensive package of upgrades to increase power generation above the original 200 MWe level and reduce its unit cost, with SO_2, NO_x and particulate emissions controlled to prescribed limits for reconstructed boilers.

The objectives for rehabilitating/repowering the units are as follows:

1. Extended Life

The service life of the rehabilitated boiler/turbine units will be extended at least 15 years.

The service life of the repowered CFB boilers and turbine unit will be at least 30 years.

2. Increased Power Generation

Generation from the derated condition of the 200 MWe units will be increased and, if possible, the rated capacity, or higher, will be achieved.

As the CFB boiler/turbine unit is expected to be complete replacement, it will be designed to achieve the rated capacity.

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3. Improved Efficiency

Heat rate, the cost in heat energy input to a unit for each unit of electrical generation, will be improved with each element of equipment modified or replaced, which are not sole for life extension.

4. Reduced Use of Supplementary Fuel

The rehabilitated boilers will require no more than the originally designed quantity of supplementary oil or natural gas fuel, when firing the beneficiated coal, unless required for control of No_x emissions.

5. Reduced Flue Gas Emissions

Emissions in flue gas, consisting of particulate matter, sulfur dioxide and nitrogen oxides, will be controlled to within the following limits:

	Emission Limit mg/m^{3*}		
	Particulate Matter	SO_2	NO_x
1. Rehabilitation of Units 10 and 13			
a. Minimal Upgrade			
Particulate only	150	N/A	N/A
Particulate, SO_2, NO_x	150	800	480
b. Arch Firing			
Particulate, SO_2, NO_x	150	800	240
c. Extensive Upgrade			
Particulate, SO_2, NO_x	150	800	480
2. Replacement of Boilers 13 and 14			
Particulate, SO_2, NO_x	150	600	470
*Based on 40% excess air in flue gas for Units 10 and 13 and 6% oxygen in flue gas for Boilers 13 and 14			

1.4 APPROACH TO THE STUDY

Mobilization of the project commenced with the review of existing reports and documents pertaining to the Ukraine power system in general and Lugansk GRES in particular. An earlier report, "Ukraine Thermal Power Plant Rehabilitation Study," prepared by KEMA Nederland B.V. and Comprimo Consulting Services B.V., was also reviewed, as background information.

A Ukrainian engineering firm with detailed knowledge of Lugansk GRES was retained to obtain data needed for the investigation. A questionnaire listing required details was prepared and transmitted to this firm. The information was gathered and transmitted back to the project. Subsequently, several additional listings of data were obtained in the same way.

A team of power plant experts from the project inspected the Lugansk GRES power plant units, accompanied by representatives from the Ukrainian engineering firm. Comprehensive discussions were conducted with plant personnel. Answers to the previously submitted questionnaire were discussed in depth. Engineering drawings were inspected and numerous documents reviewed.

The data collected were analyzed and various alternatives for refurbishment or replacement were considered and evaluated. Pricing for the selected alternatives was developed including prices for replacement equipment. Availability of some items of replacement equipment sourced from Ukraine or from other CIS countries was established by the Ukrainian engineering firm and budget costs obtained. Budget pricing for western-supplied equipment and services was obtained from vendors in the United States, and from data from Burns and Roe files for similar installations.

2. SUMMARY: OPTIONS FOR REHABILITATION OF UNITS NOS. 10 AND 13

2.1 GENERAL

This section summarizes the results of the investigation for the rehabilitation of Units Nos. 10 and 13, considering the alternatives of firing the existing (uncleaned) coal and the coal to be cleaned by the benefication process being developed separately. The options considered for both Unit No. 10 and Unit No. 13 are following:

Option 1:

> Minimal rehabilitation to extend service life to 15 years, to increase power generation above its present derated level, and to improve its efficiency. Only particulate emissions in boiler flue gas effluent are to be controlled to within prescribed limits.

Option 2:

> Minimal rehabilitation, the same as in Option 1, except emission of SO_2, NO_x and particulates are to be controlled to within prescribed limits.

Option 3:

> Boiler furnace converted to double arch firing, otherwise same as Option 2.

Option 4:

> Extensive rehabilitation to increase generation above the original (200 MW) rating and improve its efficiency, with SO_2, NO_x and particulates controlled to within prescribe limits.

This summary is presented by main categories of plant equipment. The investigation results are very similar for the two units. Rehabilitation differences between the units are explained, as well as differences due to burning the two fuels.

The recommended rehabilitation items are presented in a task matrix table at the end of this section. Also, tables of Performance Summary and Cost Estimate Summary are presented.

2.2 RECOMMENDED REFURBISHMENT

(For Summary, refer to Tables 2.2-1A and 1B for Unit 10 and Tables 2.2-2A and 2B for Unit 13).

2.2.1 Boiler and Boiler Auxiliaries

2.2.1.1 Minimal Refurbishment

A major problem with these boilers is the excessive ambient air ingress through refractory insulation, lagging and casing. These must be repaired as the air leakage lowers combustion efficiency and increased the need for continuous supplementary fuel.

The boilers also have major tubing problems, requiring repair or replacement: furnace wall, superheater and reheater pendants, low temperature reheater and economizer.

Boiler attemperator system are worn and need replacement.

Seals in the regenerative air preheaters are worn, resulting in excessive air ingress which has overloaded the ability of the induced draft fans and is cooling flue gas in the ducts, causing corrosion. The ducts and their expansion joints will be repaired or replaced. Also, sootblowers will be added to the air preheaters, to permit on-line cleaning.

The firing system of each boiler has abrasion and erosion damage. The liner of each ball mill must be replaced, along with ducting and conduits where this damage has occurred. The existing static classifiers must be replaced with modern dynamic classifiers which will increase pulverized coal fineness and product a more stable flame with less supplementary natural gas fuel required and higher combustion efficiency.

The fuel injector type burners of Unit 10 and the swirl type burners of Unit 13 are worn and distorted, and will be refurbished or replaced for Option 1, Minimal Emission Controls. However, for Option 2, Improved Emission Controls, these will be replaced with low NO_x producing burners.

Other items requiring refurbishment or replacement included control and isolating dampers, furnace slag tap refractory lining, and sootblowers.

A burner management system will be added to each boiler to improve plant safety. Also a continuous emission monitoring system for NO_x, SO_2, CO and particulates will be added.

2.2.1.2 Conversion to Double Arch Firing

With this option, the entire furnace enclosure is replaced with welded membrane furnace and roof tube panels, and a double arch firing configuration with tube openings for slot

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type, low NO_x producing, pulverized coal burners. Also, the furnace bottom ash collection configuration is changed to a dry bottom type. Full load is achieved when firing cleaned coal; however, new higher capacity ball mills are required when firing the existing coal. Otherwise, the same refurbishments noted in Section 2.2.1.1 apply.

2.2.1.3 Extensive Refurbishment

This option includes the same refurbishments as noted in Section 2.2.1.1, except that the entire furnace enclosure is replaced with welded membrane furnace and roof tube panels. The original furnace configuration will remain. Also, new higher capacity ball mills are required for firing the existing coal.

2.2.2 Emission Controls

2.2.2.1 Minimal Emission Controls

Minimal Emission Controls (upgrading of only particulate emission control equipment) applies only to Option 1 for Minimal Refurbishment.

Achieving the prescribed limit of 150 mg/Nm^3 requires collection efficiencies of 99.6% and 99.1% for the uncleaned coal and cleaned coal, respectively. Two methods of achieving this were investigated:

Electrostatic Precipitator (ESP)
Fabric Filter

The existing particulate control equipment (Unit 10's wet ash scrubbing system and Unit 13's ESP) were worn and very inefficient, and replacement was required.

New ESP's were selected, based on lowest cost.

2.2.2.2 Improved Emission Controls

Under this option, particulate, NO_x and SO_2 emissions are all controlled to within prescribed limits.

Particulates

For particulate control, new ESP's will be utilized, as in Section 2.2.2.1.

NO_x

NO_x emissions will be reduced to about 1000 mg/Nm^3 with the low NO_x producing burners noted in Section 2.2.1.

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Additional NO_x reduction efficiency required to meet the prescribed 480 mg/ Nm^3 limit for the present furnace configuration with a wet bottom ash system are 52% and 40% for the uncleaned coal and cleaned coal, respectively. A selective non-catalytic reduction (SNCR) system for reducing post-combustion NO_x has been selected for accomplishing this.

For the double arch furnace configuration with a dry bottom, the prescribed 240 mg/ Nm^3 limit is very costly to attain. The following methods were investigated.

Selective Catalytic Reduction
Hybrid Selective Catalytic Reduction

Selective Catalytic Reduction (SCR) utilizes a catalyst in the flue gas stream outside the furnace. The catalyst uses ammonia as the reducing agent. The catalyst is costly and the frequency of required replacement adds to the overall cost ($13 million/unit).

Hybrid Selective Catalytic Reduction is a new approach being explored by the industry. It involves a combination of Selective Non-catalytic Reduction with a small SCR catalyst. There have been demonstrations of this technology, but not wide spread use. This system is also very costly ($5.6 million/unit) and the effectiveness of this technology has not yet been proven.

Because of the excessive costs of SCR and Hybrid SCR, neither system has been included in the report results for the double arch furnace option. The equipment selected (low NO_x burners plus SNCR) will meet only the 480 mg/ Nm^3 limit as in the other options. The validity of the 240 mg/Nm^3 must be questioned, as European Union Directive limits NO_x at 1300 mg/Nm^3 for coals with less than 10 percent volatiles.

Sulfur Dioxide

To achieve the prescribed limit of 800 mg/Nm^3 of SO_2 emissions, the following flue gas desulfurization technologies were investigated:

Dry Processes (Furnace and Duct Injection)
Wet Processes
Semi Dry Processes

The details of these processes are discussed in Section 4.3.2.3.

The Semi Dry flue gas desulfurization technology was selected, based on low cost. The Dry Processes could not accomplish the required desulfurization. The selected spray dryer desulfurization equipment will be installed upstream of the ESP.

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2.2.3 Turbine Generator

2.2.3.1 Minimal Refurbishment

The turbine in Unit 10 has had a history of cracks occurring in the high pressure (HP) and intermediate pressure (IP) cylinders. These have been repaired, but with the age and cycling service being experienced, cracking is expected to continue. Also the IP steam flow path of Turbine 10 is distorted. Both the HP and IP turbine sections of Unit 10 will be replaced.

All critical valves have also experienced cracks and will be replaced: HP stop, reheat stop and intercept valves.

Turbine governor parts have experienced significant wear and will be replaced.

The low pressure (LP) turbine seems to be satisfactory, but recurring wearout of the last stage blades has been a problem on both turbines. These will be replaced.

The turbine control system will be replaced with a modern electro-hydraulic system.

The turbine lubricating oil coolers are leaking and will be replaced.

Makeup water evaporators in the cycle of each turbine will be removed, as the new makeup water treatment system will provide the makeup requirements. This will allow an increase in generation and improved efficiency.

2.2.3.2 Extensive Refurbishment

With this option, a complete replacement of the 200 MW turbine system with a new 225 MW modern unit with all its auxiliaries is selected. Generation will be increased, and reliability and efficiency improved.

The new turbine is manufactured specifically for replacing the 200 MW design and fits on the same pedestal.

2.2.4 Turbine Balance of Plant

2.2.4.1 Minimal Refurbishment

Much of the existing equipment in the turbine balance of plant of Units 10 and 13 is very worn and must be replaced in order to achieve extended life and improved efficiency. This equipment includes the boiler feedwater pumps, the condensate pumps and the high pressure and low pressure feedwater heaters.

The high temperature steam piping systems, carrying main steam and hot reheat steam, must be replaced due to degradation in metal structure.

The existing condenser tube cleaning system must be replaced with a modern, more effective system.

2.2.4.2 Extensive Refurbishment

All equipment and piping in the turbine balance of plant, with capacities directly associated with the present 200 MW design capacity, must be replaced with larger sizes suitable for the new 225 MW unit rating.

2.2.5 Electrical Systems and Equipment

2.2.5.1 Minimal Refurbishment

Much of the electrical equipment in both units are of obsolete designs and are in a deteriorated condition. Insulation on all wiring and cabling is also in very poor condition. To achieve extended unit life, most of the equipment and all wiring and cabling must be replaced.

Essentially the entire distribution system at the 6.3 kV level and lower must be replaced. This equipment includes switchgear, motor control centers, circuit breakers, disconnect switches, potential transformers, surge arresters, protective relay system, turbine control system and the DC system. All raceways, and medium and low voltage power, control and instrument cables must be replaced.

2.2.5.2 Extensive Refurbishment

In addition to the above refurbishment items, a new generator must be provided for the new 225 MW turbine, as the existing generator cannot be modified to suit. Also a new generator excitation transformer must be provided.

2.2.6 Instrumentation and Control Systems and Equipment

As the existing instrumentation and controls are obsolete and inefficient, they will be upgraded to the same degree for both the "minimal" and "extensive" refurbishment options.

The unit control system will be replaced with a modern sophisticated distributed control system to allow efficient operation from the main control room.

The existing mechanical hydraulic turbine control system will be replaced with a modern electrohydraulic system as noted in Section 2.2.3.

A new burner management system of the programmable solid state type will be provided, as noted in Section 2.2.1.

Controls for boiler steam temperature, condensate flow and feedwater flow will be replaced. Also replaced will be locally mounted transmitters thermocouples, and pressure, temperature and level switches.

2.3 PERFORMANCE SUMMARY

Summary of performance for all Unit 10 options - refer to Table 2.2-1C.

Summary of performance for all Unit 13 options - refer to Table 2.2-2C

2.4 COST ESTIMATE SUMMARY

2.4.1 Summary by Unit

Summary of costs for all Unit 10 options - refer to Table 2.2-1D

Summary of costs for all Unit 13 options - refer to Table 2.2-2D

2.4.2 Summary by Option

Option 1. Minimal Refurbishment - Minimal Emission Control

The total project cost expressed in 1995 U.S. Dollars for Option 1 (minimal refurbishment minimal emission control) on either the existing coal or the cleaned coal is $97,334,649. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 2,621,856	$ 2,662,128
Boiler & Fuel Feed Equipment Repair/ Refurbishment	13,117,037	13,239,072
Turbine and Balance of Plant Equipment Upgrades/Repair	12,778,742	7,090,862
Instruments and Controls	2,160,245	2,217,745
Environmental Control Equipment Upgrades	3,323,320	3,323,320
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Indirects	4,609,669	4,410,693
Engineering and Construction Management	5,659,689	5,372,615
Total	$51,644,386	$45,690,263

Ukrainian labor, equipment and manufacturers and material suppliers represent $50,649,213 or 52% of the total project costs shown above.

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Option 2. Minimal Refurbishment - Improved Emission Control

Uncleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 2 (minimal boiler upgrades/improved emission control) firing uncleaned coal is $118,038,188. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 2,621,856	$ 2,622,128
Boiler & Fuel Feed Equipment Repair/ Refurbishment	13,977,824	14,652,736
Turbine and Balance of Plant Equipment Upgrades/Repair	12,778,742	7,090,862
Instruments and Controls	2,160,245	2,217,745
Environmental Control Equipment Upgrades	11,703,120	11,703,120
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	4,934,869	4,755,693
Engineering and Construction Management	6,144,820	5,886,772
Total	$61,695,304	$56,342,884

Ukrainian labor, equipment and manufacturers and material suppliers represent $49,853,116 or 42% of the total project costs shown above.

Cleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 2 (minimal refurbishment improved emission control) firing cleaned coal is $122,309,598. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 2,621,856	$ 2,662,128
Boiler & Fuel Feed Equipment Repair/ Refurbishment	13,977,824	14,652,736
Turbine and Balance of Plant Equipment Upgrades/Repair	12,778,742	7,090,862
Instruments and Controls	2,160,245	2,217,745
Environmental Control Equipment Upgrades	13,674,320	13,657,820
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	5,004,869	4,825,093
Engineering and Construction Management	6,248,308	5,989,394
Total	$63,839,992	$58,469,606

Ukrainian labor, equipment and manufacturers and material suppliers represent $49,927,116 or 41% of the total project costs shown above.

Option 3. Arch Fired Boiler - Improved Emission Control

Uncleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 3 (arch fired boiler/ improved emission control) firing uncleaned coal is $150,815,704. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 3,192,000	$ 3,192,000
Boiler & Fuel Feed Equipment Repair/ Refurbishment	26,435,584	26,435,584
Turbine and Balance of Plant Equipment Upgrades/Repair	12,778,742	7,090,862
Instruments and Controls	2,217,745	2,217,745
Environmental Control Equipment Upgrades	12,308,120	12,291,620
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	6,235,699	6,029,493
Engineering and Construction Management	7,971,076	7,671,586
Total	$78,512,986	$72,302,718

Ukrainian labor, equipment and manufacturers and material suppliers represent $74,389,066 or 49% of the total project costs shown above.

Cleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 3 (arch fired boiler/ improved emission control) firing cleaned coal is $149,725,446. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 3,192,000	$ 3,192,000
Boiler & Fuel Feed Equipment Repair/ Refurbishment	25,769,856	25,785,984
Turbine and Balance of Plant Equipment Upgrades/Repair	12,778,742	6,988,562
Instruments and Controls	2,217,745	2,217,745
Environmental Control Equipment Upgrades	12,508,100	12,508,100
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	6,219,093	6,009,773
Engineering and Construction Management	7,946,614	7,643,476
Total	$78,005,978	$71,719,468

Ukrainian labor, equipment and manufacturers and material suppliers represent $73,106,956 or 49% of the total project costs shown above.

Option 4. Extensive Refurbishment - Improved Emission Control

Uncleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 4 (extensive boiler and turbine upgrades/improved emission control) firing uncleaned coal is $168,613,458. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 3,238,272	$ 3,238,272
Boiler & Fuel Feed Equipment Repair/ Refurbishment	22,606,304	23,444,512
Turbine and Balance of Plant Equipment Upgrades/Repair	21,038,880	21,044,930
Instruments and Controls	2,217,745	2,217,745
Environmental Control Equipment Upgrades	12,744,820	12,717,100
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	6,414,025	6,442,245
Engineering and Construction Management	8,229,042	8,271,910
Total	$83,862,916	$84,750,542

Ukrainian labor, equipment and manufacturers and material suppliers represent $92,198,418 or 55% of the total project costs shown above.

Cleaned Coal

The total project cost expressed in 1995 U.S. Dollars for Option 4 (extensive boiler and turbine upgrades/improved emission control) firing cleaned coal is $167,738,845. This cost is to rehabilitate both Unit No. 10 and Unit No. 13 and is broken down as follows:

	Unit No. 10	Unit No. 13
Civil/Structural/Demolition Work	$ 3,238,272	$ 3,238,272
Boiler & Fuel Feed Equipment Repair/ Refurbishment	22,001,056	22,750,560
Turbine and Balance of Plant Equipment Upgrades/Repair	21,038,880	21,044,930
Instruments and Controls	2,217,745	2,217,745
Environmental Control Equipment Upgrades	12,992,320	12,964,600
Electrical Equipment Repair/Replacement	7,373,828	7,373,828
Site Construction Services	6,399,831	6,428,045
Engineering and Construction Management	8,210,270	8,248,472
	$83,472,394	$84,266,451

Ukrainian labor, equipment and manufacturers and mateiral suppliers represent $90,899,218 or 54% of the total project costs shown above.

TABLE 2.2-1A RECOMMENDED REHABILITATION OF UNIT 10

TASK MATRIX

	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
RECOMMENDED REFURBISHMENTS	OPTION 1A UNIT 10	OPTION 1B UNIT 10	OPTION 2A UNIT 10	OPTION 2B UNIT 10	OPTION 3A UNIT 10	OPTION 3B UNIT 10	OPTION 4A UNIT 10	OPTION 4B UNIT 10	OPTION 5A UNIT 10	OPTION 5B UNIT 10
BOILER										
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	X	X	X	X						
REFURBISH BOILER INTO DOUBLE ARCH CONFIGURATION					X	X			X	X
REFURBISH BOILER WITH MEMBRANE WALLS					X	X	X	X	X	X
REPAIR BACK-PASS CASING, INSULATION, ETC.	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHIELDS	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	X	X	X	X	X	X	X	X	X	X
REFURBISH AIR PREHEATERS	X	X	X	X	X	X	X	X	X	X
REPAIR INDUCED DRAFT FANS	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	X	X	X	X	X	X	X	X	X	X
REPAIR GRINDING CIRCUITS	X	X	X	X	X	X	X	X	X	X
REPLACE EXISTING MILL CLASSIFIERS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW BALL MILLS					X		X		X	
REPAIR/REFURBISH EXISTING BALL MILLS	X	X	X	X		X		X		X
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM.	X	X	X	X	X	X	X	X	X	X
INSTALL LOW NOx BURNERS			X	X	X	X	X	X	X	X
REFURBISH EXISTING FUEL INJECTORS	X	X								
INSTALL NEW BOTTOM ASH REMOVAL SYSTEM					X	X			X	X
REFURBISH SLAG TAP REFRACTORY	X	X	X	X			X	X		
REFURBISH EXISTING SOOTCLEANING SYSTEMS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	X	X	X	X	X	X	X	X	X	X
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	X	X	X	X			X	X	X	X
TURBINE										
INSTALL NEW 225 MW TURBINE & AUXILIARIES							X	X	X	X
REPLACE H.P. & I.P TURBINE CYLINDERS & CROSSOVER LINES	X	X	X	X	X	X				
REPLACE L.P. TURBINE LAST STAGE BLADING	X	X	X	X	X	X				
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	X	X	X	X	X	X				
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	X	X	X	X	X	X				
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	X	X	X	X	X	X				
REPLACE GOVERNING SYSTEM	X	X	X	X	X	X				
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	X	X	X	X	X	X				
REPLACE OIL COOLER	X	X	X	X	X	X				
INSTALL L.P. HEATER NO. 1 BY-PASS	X	X	X	X	X	X				
IMPROVE H2 SEALING SYSTEM	X	X	X	X	X	X				
CREEP MONITORING EQUIPMENT										
BALANCE OF PLANT										
REPLACE FEEDWATER PUMPS	X	X	X	X	X	X	X	X	X	X
REPLACE CONDENSATE PUMPS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW CONDENSER							X	X	X	X
ADD CONDENSER CLEANING SYSTEM	X	X	X	X	X	X	X	X	X	X
REPLACE FEEDWATER CONTROL VALVES	X	X	X	X	X	X	X	X	X	X
REPLACE H.P. FEEDWATER HEATERS	X	X	X	X	X	X	X	X	X	X
REPLACE L.P. FEEDWATER HEATERS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW HEATER DRAIN PUMPS							X	X	X	X
INSTALL NEW STEAM SAMPLING SYSTEM	X	X	X	X	X	X	X	X	X	X
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE PIPING & VALVES	X	X	X	X	X	X	X	X	X	X
REPLACE MAIN & REHEAT STEAM RELIEF VALVES	X	X	X	X	X	X	X	X	X	X

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TABLE 2.2-1B RECOMMENDED REHABILITATION OF UNIT 10

TASK MATRIX

	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
RECOMMENDED REFURBISHMENTS	OPTION 1A UNIT 10	OPTION 1B UNIT 10	OPTION 2A UNIT 10	OPTION 2B UNIT 10	OPTION 3A UNIT 10	OPTION 3B UNIT 10	OPTION 4A UNIT 10	OPTION 4B UNIT 10	OPTION 5A UNIT 10	OPTION 5B UNIT 10
INSTRUMENTS & CONTROLS										
NEW D.C. S. SYSTEM	X	X	X	X	X	X	X	X	X	X
INSTALL NEW INSTRUMENTS & CONTROL VALVES	X	X	X	X	X	X	X	X	X	X
BURNER MANAGEMENT SYSTEM UPGRADE	X	X	X	X	X	X	X	X	X	X
ENVIRONMENTAL										
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	X	X	X	X	X	X	X	X	X	X
INSTALL SO2 CONTROL EQUIPMENT			X	X	X	X	X	X	X	X
INSTALL SNCR EQUIPMENT			X	X	X	X	X	X	X	X
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	X	X	X	X	X	X	X	X	X	X
ELECTRICAL EQUIPMENT										
220KV SWITCHYARD EQUIPMENT	X	X	X	X	X	X	X	X	X	X
6 KV SWITCHGEAR & BUS	X	X	X	X	X	X	X	X	X	X
400 VOLT SWITCHGEAR & TRANSFORMER	X	X	X	X	X	X	X	X	X	X
INSTALL NEW 225 MW GENERATOR							X	X	X	X
INSTALL NEW GENERATOR EXCITATION SYSTEM							X	X	X	X
MOTOR CONTROL CENTERS	X	X	X	X	X	X	X	X	X	X
BATTERIES & CHARGERS	X	X	X	X	X	X	X	X	X	X
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	X	X	X	X	X	X	X	X	X	X
UPS SYSTEM	X	X	X	X	X	X	X	X	X	X
POWER/CONTROL/INSTRUMENT WIRING	X	X	X	X	X	X	X	X	X	X
BUILDING LIGHTING/PANELS/RECEPT	X	X	X	X	X	X	X	X	X	X
CONDUIT & CABLE TRAY	X	X	X	X	X	X	X	X	X	X
GROUNDING	X	X	X	X	X	X	X	X	X	X
CATHODIC PROTECTION	X	X	X	X	X	X	X	X	X	X
PLANT COMMUNICATIONS/FIRE PROTECTION	X	X	X	X	X	X	X	X	X	X

TABLE 2.2-1C PERFORMANCE SUMMARY - UNIT 10

DESCRIPTION	CURRENT CONDITION	UNCLEANED COAL OPTION 1A UNIT 10	CLEANED COAL OPTION 1B UNIT 10	UNCLEANED COAL OPTION 2A UNIT 10	CLEANED COAL OPTION 2B UNIT 10	UNCLEANED COAL OPTION 3A UNIT 10	CLEANED COAL OPTION 3B UNIT 10	UNCLEANED COAL OPTION 4A UNIT 10	CLEANED COAL OPTION 4B UNIT 10
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 @ 40% EXCESS AIR, mg/Nm3(D)	6600	6600	5206	1200	1200	1200	1200	1200	1200
NOx EMISSIONS @ 40% EXCESS AIR, mg/Nm3(D)	1600	1600	1300	800	800	800	800	800	800
PARTICULATE EMISSIONS @ 40% EXCESS AIR, mg/Nm3(D)	2000	150	150	150	150	150	150	150	150

TABLE 2.2-1D COST ESTIMATE SUMMARY - UNIT 10

DESCRIPTION	UNCLEANED COAL OPTION 1A UNIT 10	CLEANED COAL OPTION 1B UNIT 10	UNCLEANED COAL OPTION 2A UNIT 10	CLEANED COAL OPTION 2B UNIT 10	UNCLEANED COAL OPTION 3A UNIT 10	CLEANED COAL OPTION 3B UNIT 10	UNCLEANED COAL OPTION 4A UNIT 10	CLEANED COAL OPTION 4B UNIT 10
CIVIL/STRUCTURAL/DEMOLITION WORK	$2,621,856	$2,621,856	$2,621,856	$2,621,856	$3,192,000	$3,192,000	$3,238,272	$3,238,272
BOILER & FUEL FEED EQUIPMENT REPAIR/REFURBISHMENT	$13,117,037	$13,117,037	$13,977,824	$13,977,824	$26,435,776	$25,769,856	$22,606,304	$22,001,006
TURBINE AND BALANCE OF PLANT EQUIPMENT UPGRADES/REPAIR	$12,778,742	$12,778,742	$12,778,742	$12,778,742	$12,778,742	$12,778,742	$21,038,880	$21,039,122
INSTRUMENTS AND CONTROLS	$2,160,245	$2,160,245	$2,160,245	$2,160,245	$2,217,745	$2,217,745	$2,217,745	$2,217,745
ENVIRONMENTAL EQUIPMENT UPGRADES	$3,323,320	$3,323,320	$11,703,120	$13,674,320	$12,308,120	$12,508,100	$12,744,820	$12,992,320
ELECTRICAL EQUIPMENT REPAIR/REPLACEMENT	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828
SITE INDIRECTS	$4,609,669	$4,609,669	$4,934,869	$5,004,869	$6,235,699	$6,219,093	$6,414,025	$6,399,831
ENGINEERING & CONSTRUCTION MANAGEMENT	$5,659,689	$5,659,689	$6,144,820	$6,248.308	$7,971,076	$7,946,614	$8,229,042	$8,210,270
TOTAL COST ESTIMATE (U.S. DOLLARS)	$51,644,386	$51,644,386	$61,695,304	$63,839,992	$78,512,986	$78,005,978	$83,862,916	$83,472,394
COST/NET KW (U.S. DOLLARS)	$393	$277	$472	$345	$430	$422	$406	$400
$ VALUE OF UKRAINIAN LABOR, EQUIPMENT & MATERIAL	$28,087,483	$28,087,483	$27,809,834	$27,851,834	$40,038,473	$39,389,545	$46,086,608	$45,517,820
PERCENTAGE OF TOTAL PROJECT ESTIMATE	54%	54%	45%	44%	51%	50%	55%	55%

3. SUMMARY: REPLACEMENT OF BOILERS NOS. 13 AND 14, AND TURBINE NO.6

3.1 GENERAL

This section summarizes the results of the development of a new 125 MW unit including two 62.5 MW circulating fluidized bed (CFB) boilers with auxiliary equipment, a 125 MW steam turbine generator and necessary balance of plant equipment.

This new unit replaces decommissioned 50 MW Boilers Nos. 13 and 14 and 100 MW Turbine No. 6 in the Phase I area of the plant. This equipment had originally been on a headered arrangement with the Phase I boilers supplying steam to the header which supplied the turbines.

3.2 RECOMMENDED EQUIPMENT

3.2.1 CFB Boilers

Two half-capacity CFB boilers will be utilized. Each boiler is a single drum, natural circulation unit of the two stage solid collection design, with one forced draft fan and one induced draft fan. The two stage collection system includes an impact-type separator consisting of an array of suspended U-beams located at the inlet and outlet of the furnace gas exit. The second stage is a multicyclone dust collector located after the convection pass.

Coal transferred from the coal pile is conveyed to new hammer mill crushers, and then conveyed again to feed bunkers. It is then fed through volumetric feeders to screw feeders for discharging into the furnace.

Limestone is conveyed through a rotary dryer to an inplant storage bin. From the bin the limestone is fed into vertical spindle roller screen mills where it is crushed to its final feed size, and then supplied pneumatically to the furnace.

A fabric filter system will control particulate emissions consisting of ash, sulfated limestone, excess lime and a limited amount of unburned carbon.

3.2.2 Turbine

A new 125 MW turbine generator will be provided, suitable for installation on the pedestal of the original 100 MW turbine generator. The new turbine consists of a high pressure (HP) section and a double flow low pressure (LP) section. There are four extraction points on the HP section and two on the LP section. All auxiliary equipment for the turbine is provided.

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3.2.3 Turbine Balance of Plant

A complete new set of turbine balance of plant equipment and piping suitable for the 125 MW turbine will be provided.

New circulating water system equipment and piping will supply cooling water to the new condenser from a section of the existing Phase I pumphouse, which will be refurbished.

3.2.4 Electrical Systems and Equipment

The entire unit electrical system, including all equipment and cabling, will be replaced with modern equipment suitable for the higher unit capacity. The only equipment not being replaced are the reserve transformers and reserve buses, the cable tunnels and the steel structures for cable leads from generator to transformers.

3.2.5 Instrumentation and Controls Systems and Equipment

All instrumentation and controls systems and equipment will be replaced. The new equipment will include a state-of-the-art distributed type control system.

3.3 SUMMARY OF PERFORMANCE

Turbine gross output, MW	125
Turbine gross heat rate, Kcal/kWh	2042
Unit net output, MW	114.4
Unit net heat rate, Kcal/kWh	2595
Particulate emissions, mg/Nm^3	50*
SO_2 emissions, mg/ Nm^3	600*
NO_x emissions, mg/ Nm^3	200*
Total coal fired, Kg/hr	85.8
Total limestone consumption, Kg/hr	11.6

*At 6% oxygen in flue gas

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3.4 SUMMARY OF CAPITAL COST $105,376,386

The total project cost expressed in 1995 U.S. Dollars for the Replacement of Boiler No. 13 and No. 14 with new CFB Technology and Replacement of Turbine No. 6 with a new 125 MW Turbine is $105,376,386 and is broken down as follows:

Civil/Structural/Demolition Work	6,946,680
Boiler Replacement Cost	37,520,230
Turbine and Balance of Plant Equipment Upgrades	17,498,262
Instruments and Controls	1,442,410
Environmental Systems	4,539,920
Electrical Equipment Repair/Replacement	10,619,154
Site Construction Services	11,509,980
Engineering and Construction Management	15,299,749

Ukrainian labor, equipment manufacturers and material suppliers represent $60,470,127 or 57% of the total project costs shown above.

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4. REHABILITATION DETAILS - UNITS NOS. 10 & 13

4.1 PRESENT CONDITION

4.1.1 Boiler and Boiler Auxiliaries

4.1.1.1 Equipment Description:

The type TP-100 boilers of Unit Nos.10 & 13 were manufactured by Taganrog Boiler Manufacturing Plant and are nearly identical. Each boiler is of the natural circulation,drum type with a radiant,balanced draft,wet bottom furnace. The boilers are top supported,suspended from the steel structure, allowing for cubic thermal expansion. The boiler configuration is of the "T" type with symmetrical,double convective passes and a furnace division wall which is arranged at a right angle to the longitudinal steam/.water drum centerline.

The boilers were designed for base load operation, in an electric power plant, with a 15% to 85% bottom to flyash split fired with pulverized anthracite from the Donbas region of the Ukraine.Each of the boilers is capable of 100 % full load while firing natural gas fuel. Mazut is used as an auxiliary fuel for start-up and combustion stabilization,having 30% of full load heat input capacity.

A cross-section of the boiler is shown in Fig. 4.1.1-1. The furnace is rectangular,8128 mm deep and 18,560 mm wide and consists of fully water cooled carbon steel tubing, 60 mm OD by 6 mm thick,on 64 mm spacing,refractory backed. The furnace and horizontal convective passes rooftubes are steam cooled,38 mm ODx4 mm thick carbon steel tubes on 40 & 80 mm centers. The vertical furnace tubewalls as well as the horizontal furnace/symmetrical backpasses rooftubes have coldside refractory backing, insulation layer and wiremesh/cement liner casing. The lower furnace tubewalls have fireside refractory coverage sprayed onto studded tubing.

The boiler circulation system consists of small bore downcomers,supply tubes and risers back to the steam/water drum. The symmetrical, horizontal convective passes and top portion of the vertical backpasses are refractory brick lined. The lower portion of the vertical convective passes[four per boiler] are metal cased.

The furnace of Boiler No. 13 is horizontal wall fired,producing multi-flame envelops. The circular swirl burners of the indirect [pulverized anthracite storage]type firing system are positioned in the furnace front and rear walls. Each of the two walls has eight pulverized anthracite/natural gas burners with mazut guns positioned in the center of each burner. The original swirl burners of Boiler No.10 have been removed and replaced by a total of eight fuel/combustion air injectors designed by Professor Shatil of Leningrad Technical Institute. There are four in the front wall and four in the rear wall. The redesigned firing system produces multi-flame envelops.

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The superheated steam progression starts with saturated steam piping to the pendant platens positioned above the furnace arches,then to the furnace and convective pass rooftubes, and then to the pendant convective superheaters in the horizontal gas passes. From there the original steam progression was to radiant wall type tubepanels situated in the upper furnace and supported on all four tubewalls. These tubepanels have been dismantled, however. The steam progression is now direct to the pendant tubebanks of the finishing superheater,situated in the horizontal convective passes. The reheated steam progression starts with the cold reheat piping to the horizontal low steam temperature tubebanks in the vertical convective passes and from there to the pendant tubebanks situated in the horizontal convective gas passes.

Superheated steam final temperature control is by spray attemperation. Drum saturated steam is condensed by feedwater in coil type condensers and then injected into spray nozzles of the attemperator stages. Boiler No. 10 has a total of eight main steam attemperators. Boiler No. 13 has a total of twelve main steam attemperators. Both boilers have a total of four each, emergency reheat attemperators. Reheated steam final temperature control is by cold reheat steam injection into the second stage reheater inlet header by means of a bypass of the primary reheater. (Refer to Figure 4.1.1-2).

The four economizer tube banks, are situated in the vertical convective gas passes and are of fully drainable horizontal, bare, in-line tubes, with water upflow, fluegas downflow.

There are four second stage tubular airheaters. They are also situated in the vertical convective fluegas passes, with fluegas in tubes in downflow, combustion air in upflow across the tubes. The secondary airheaters have staggered tube arrangement. There are four primary airheaters of the rotary, regenerative, bisector type, with vertical shaft arrangement. Cold end corrosion protection of the regenerative airheaters is by hot air recirculation into the FD fan suction. (Refer to Figure 4.1.1-3)

Heating surfaces cleaning equipment consists of steam operated furnace wall blowers [no longer operational], also retractable sootlances together with a pulse/vibratory sootclean system for the pendant heating surfaces in the horizontal convective passes. Shot-cleaning equipment was installed for the heating surfaces situated in the vertical convective passes. The shotclean equipment is also non-operational. The rotary regenerative airheaters have no sootblowers installed. Water wash with the boiler shut down is the only means of cleaning the heating surfaces of both the tubular and the regenerative airheaters.

The bottom molten ash handling system consists of refractory plugs situated in the furnace tube hoppers, together with lined molten slag receivers supported on the basement floor. Sealing ,to prevent unmeasured air ingress into the bottom of the furnace is provided by a chute supported on the furnace tubes, that dips into the molten slag bed.

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The draft plant consists of two [2] forced draft and two [2] induced draft fans per boiler, with electric motor drives and radial inlet vane control. All draft plant fans are radial flow, centrifugal type.

Each boiler is supplied with raw coal from two [2] silos through two [2] volumetric feeders. The coal milling plant for each boiler consists of two tumbling ball mills, Type SBM 370/850, manufactured by the Syzran Machinery Works. The mills operate with negative pressure and closed circuit grinding. The two stationary centrifugal classifiers, per boiler are installed on the discharge side of the ball mills. Each ball mill nominal coal throughput capacity is 50 te/h, requiring 1600 kWe electric motor power input. The flash-drying and conveying hot primary air circuit for each boiler consists of two circulating air fans, two separating cyclones which discharge the separated pulverized anthracite into a single storage hopper,primary air/pulverized anthracite conduits, supports, control and isolating dampers, ventlines into the lower furnace.

The pulverized anthracite/primary air (PA) mixture is conveyed from the single storage bunker to the burners of each boiler by two centrifugal hot PA fans. One of the ball mills of each boiler has a mazut fired duct burner installed at the raw coal inlet into the ball mill, for the temperature boost of PA, in case of increased moisture content in the anthracite being fired. It is understood that plant personnel are presently experimenting with high density pulverized anthracite conveying to the burners, so as to improve the ignitability and combustion of the low reactivity Donbas anthracite. Results of these experiments are inconclusive at this time. (Refer to Figure 4.1.1-4)

4.1.1.2 Performance: Design vs Current

Parameter	Units	Design	Current	
			#10 Boiler	#13 Boiler
Main steam flow @BMCR	te/h	640	389	404
Superheated steam pressure	bar g.	139	139	139
Superheated steam temperature	deg. C	[derated to 545]	509	521
Feedwater Temp. To Economizer	deg. C	235	201	202
Combustion air temp. To airhtr.	Deg. C	35	31	33
Combustion air temp. Lvg. airhtr.	Deg C	398	340	340
Fluegas temperature lvg. airhtr.	Deg. C	125	160	155
XS air in fluegas @ furnace exit	%	20	30	23

XS air in fluegas @ airhtr. exit	%		77	66
XS air in fluegas @ ID fan exit	%		205	200
Boiler efficiency LHV basis	%	90.8	79.96	78.21
Number of operating hours as of Jan. 1, 1995			224,267	189,287

4.1.1.3 Condition Assessment

Thick-walled pressure parts such as the steam/water drums,high operating metal temperature superheater and reheater headers, economizer inlet headers,superheat and reheat attemperators,boiler integral piping and circulating system piping components and headers are regularly inspected by the plant metallurgy lab personnel. Low cycle fatigue and or creep damaged thick walled pressure parts will be repaired/replaced as required.

Other [thin-walled] pressure parts:

Furnace waterwall tubing replacement is required and recommended, partly due to hydrogen embrittlement,partly due to high temperature corrosion thinning, partly due to steam blanketing oxidation metal loss. Superheater and reheater high operating metal temperature tubing replacement is required due to combined low cycle fatigue and creep damage. Flyash erosion of low operating metal temperature (steam or water cooled) heating surfaces tubebanks in the vertical convective pass is a serious maintenance problem.

Recuperative tubular and regenerative rotary airheaters:

Increased fluegas velocities and increased flyash quantities, due to deteriorating quality of the anthracite being fired, are resulting in accelerated erosion damage. Heating surface cleaning equipment of the tubular airheaters is inoperational, and it was not installed for the rotary airheaters. Water washing,with the boiler shut-down is the only means of cleaning these heating surfaces at this time. The rotary airheater vertical shafts are damaged due to metal embrittlement and the top support shaft bearings are a frequent maintenance item. The deteriorated condition of the radial and circumferential seals of the rotary airheaters is a very serious operating problem. This results in substantial amounts of combustion air leakage into the fluegas stream, increased draft plant auxiliary power consumption and decreased boiler efficiency.

Boiler/furnace casing,tube penetration seals,refractory brick lining of horizontal convective pass,metal casing of vertical convective pass:

The tubewalls refractory backing, insulation,wiremesh reinforced cement casing is in a seriously deteriorated condition,resulting in large amounts of false air ingress into the furnace. This type of casing is suitable for a base load operating mode boiler. The boilers in Lugansk GRES experience cyclic operation and also are frequently shut down and started up.

The false air ingress into the furance results in the following adverse effects:

- Lower combustion zone temperature
- Lower combustion efficiency and lower flame stability
- Less slag tap operating flexibility
- Increased quantities of continuous auxiliary natural gas fuel support firing
- Poorer thermal performance of air heaters, lower boiler efficiency
- Less operating safety of slag tap furnace
- Increased flue gas velocity through convective heating surfaces resulting in accelerated erosive metal loss

Another source of false air ingress into the furnace/boiler is the deteriorated condition of the furnace roof tubes and convective backpass metal casing tube penetration seals.

The refractory brick lining of the horizontal convective passes, the metal casing of the vertical convective passes are in need of repair/replacement on both boilers. The main reason for the damage is the highly erosive nature of the flyash as well as the substantially increased fluegas velocities.

Firing system:

The fuel/combustion air injectors of boiler No. 10 as well as the swirl burners of boiler No. 13 are suffering fireside oxidation type corrosion attack,distortion due to high metal temperatures, serious metal loss due to erosive wear. The refractory setting of the fuel injectors, the refractory quarls of the swirl burners are erosion damaged.

The most serious operating problem of the milling plant is erosive wear of all pulverized anthracite/PA conduits, classifiers, separating cyclones, control and isolating dampers, ball mill liners, ball mill trunnion seals circulating air fans housing and impellers. A result of this erosive metal loss of mill circuit components is substantial false air ingress into the pulverized anthracite flash-drying and grinding system, which badly affects their performance. The accelerated wear of the ball mill liners and ballcharge is partly due to the substantially increased raw coal mineral matter content and highly abrasive nature of the mineral matter, but also partly due to the low material quality of these components. The ball mills instrumentation and control devices are insufficient, e.g. neither mill coal level nor ball charge weight loading are controlled automatically.

The substantially higher raw coal mineral matter content results in a decreased anthracite calorific value thus increased coal throughput requirement on the ball mills. Both mills of a boiler must be operated continuously, the two mills cannot fill the pulverized anthracite bunker during the night shift. Even with continuous ball mill operation, the boiler steam output has to be derated..The reduced ball mill coal throughput capacity is also due to a very low coal grindability index[HGI=29].

Draft plant and air & fluegas duct systems:

The highly erosive fluegas flyash content has affected the integrity of the housing and impeller of both ID fans, the substantial metal loss due to erosion results in false air ingress into the fans,with increased auxiliary power consumption. The fluegas ducting metal loss due to erosive wear also gives increased amounts of unmeasured air ingress. Metallic expansion joints in both the air and fluegas duct systems are failing due to low cycle fatigue. Cracked expansion joints in the fluegas duct system are another source of unmeasured air ingress.

Heating surfaces cleaning equipment:

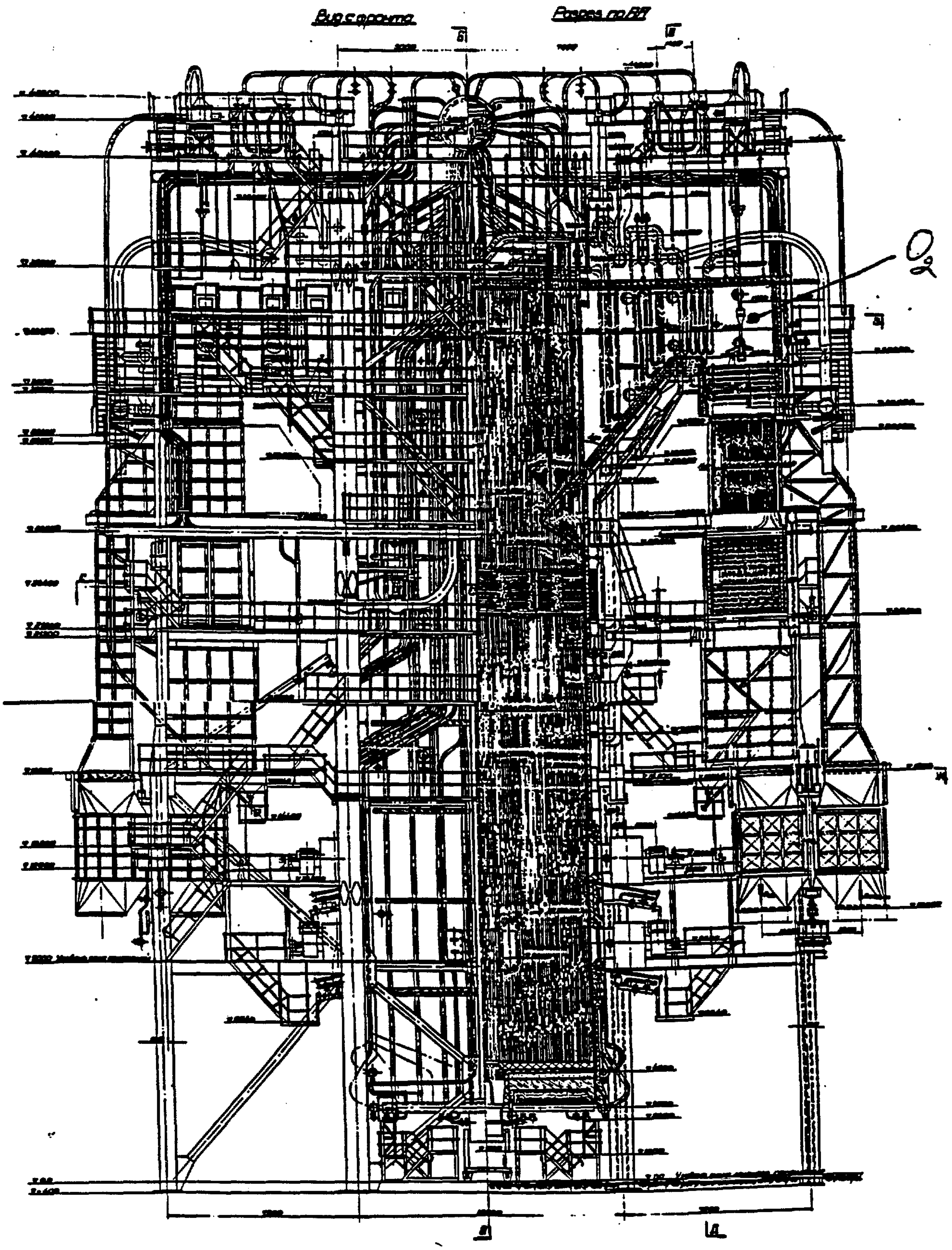
The furnace tubewall steam blowers are inoperative. The shot-cleaning system for the heating surfaces in the vertical convective passes is also inoperative. The rotary, regenerative airheaters have no steam sootblowers installed.

Bottom ash and molten slag removal equipment:

The refractory plugs [tap holes]of the furnace tube hopper are in a badly spalled condition,mainly due to high temperature oxidation attack. The tap holes are frequently blocked up, which results in large amounts of molten ash accumulation. Wet bottom, slag tap operation of the furnaces is only possible over a narrow high load range, the tap holes freeze up at loads below 80% of full load and then the boiler can only be operated for relatively short periods as a dry bottom furnace boiler. At low loads [below approx.40 % of full load] the boilers can only be operated with full NG firing .

Boiler suspension steel structure,galleries,stairs,pressure part hangers:

A visual, walkdown type inspection did not reveal any major maintenance problems. To be noted is, that the galleries[walkways] are much narrower, the stairs are much steeper than in US or European power plants, these constituting operational safety hazards.



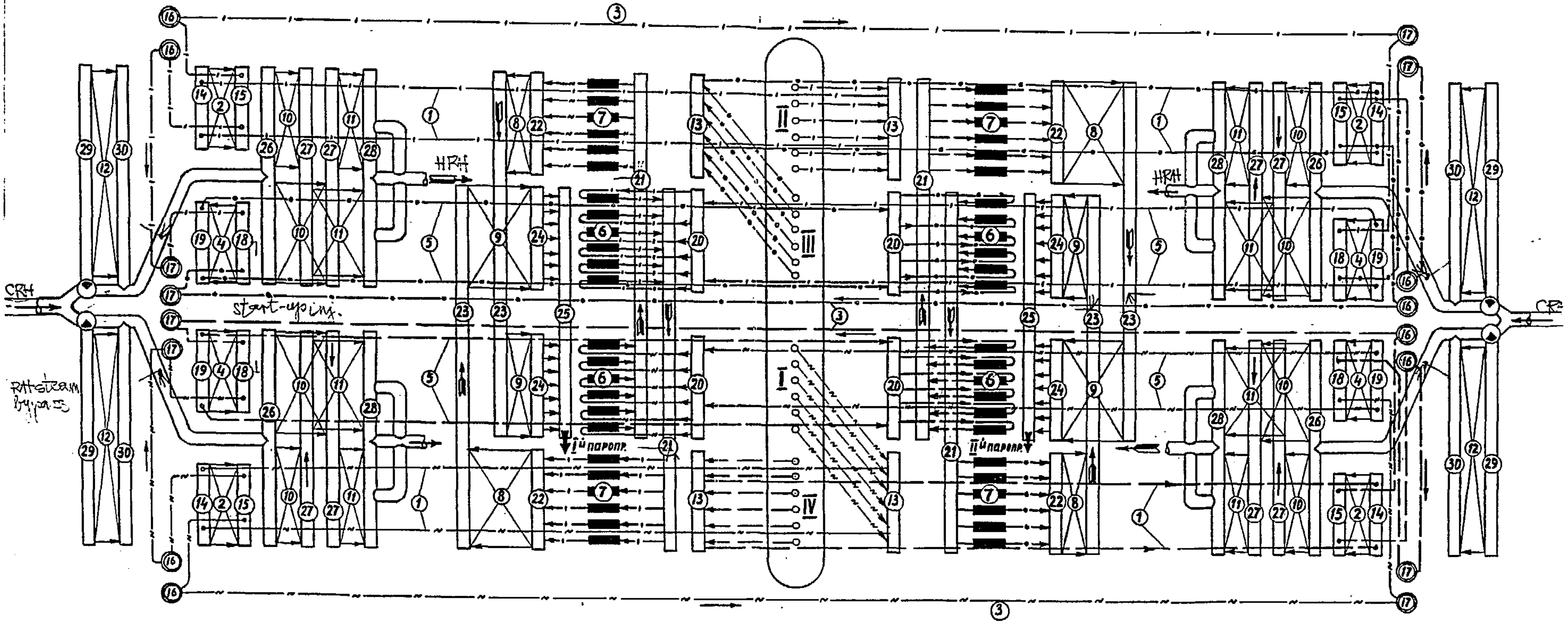
TP-100 BOILER SIDE ELEVATION AND SECTIONAL SIDE ELEVATION
FIGURE 4.1.1-1

TP-100 Boiler superheaters & reheaters schematic

Схема пароперегревателя
котла ТП-100

Flow Mixing After wall superheater

Перемешивание потоков после настен. п/пер.
1 основной + 4 дополнит. 4 MAIN + 4th Additional
2-й основной + 3 дополнит. 2nd MAIN + 3rd Additional
3-й основной + 2 дополнит. 3rd MAIN + 2nd Additional
4-й основной + 1 дополнит. 4th MAIN + 1st Additional



SUPERHEATED AND REHEATED STEAM PROGRESSION
DIAGRAM TOGETHER WITH STEAM-SIDE CROSSOVERS
FIGURE 4.1.1-2

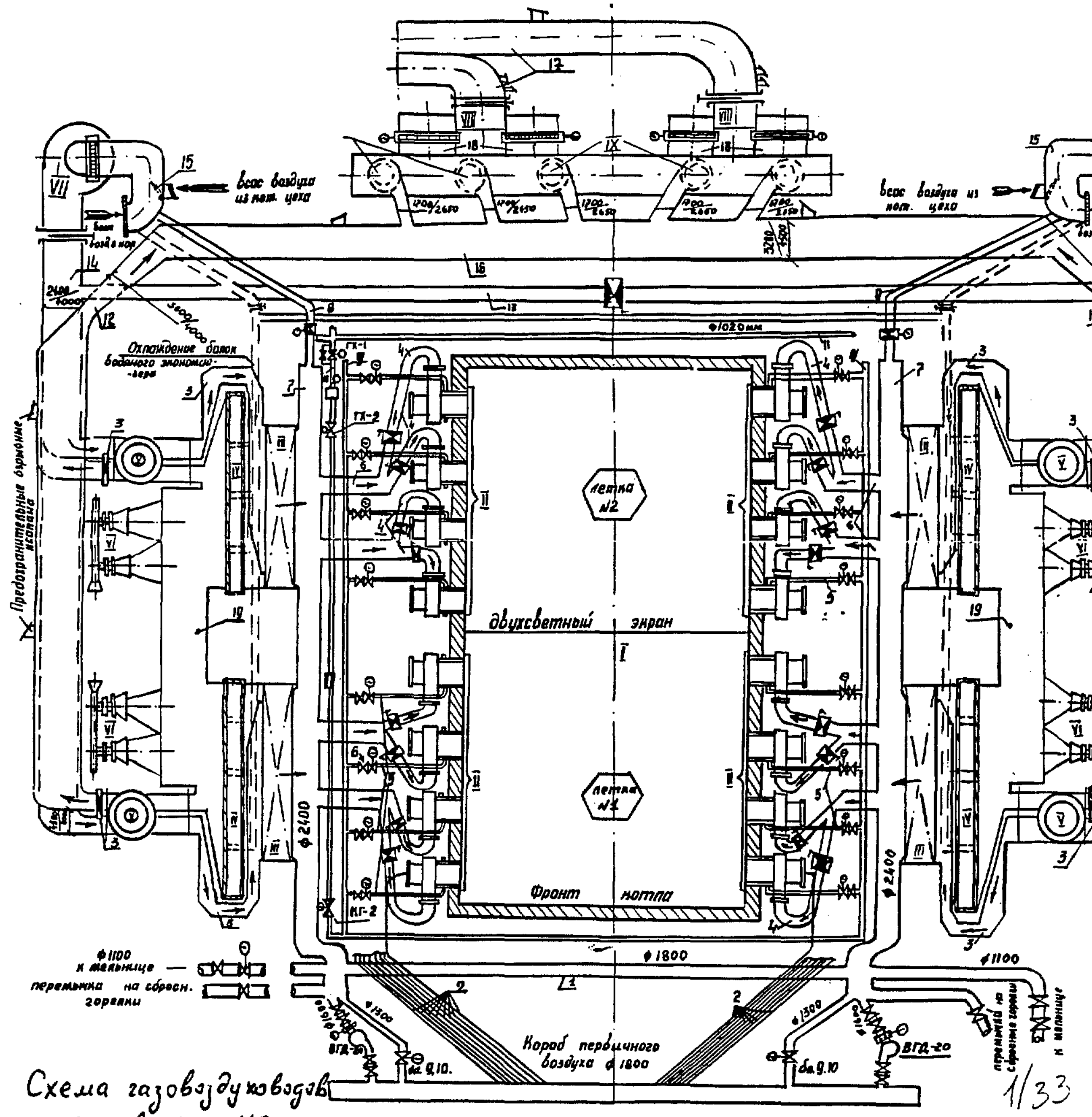


Схема газовоздуховодов блоков 200 МВт.

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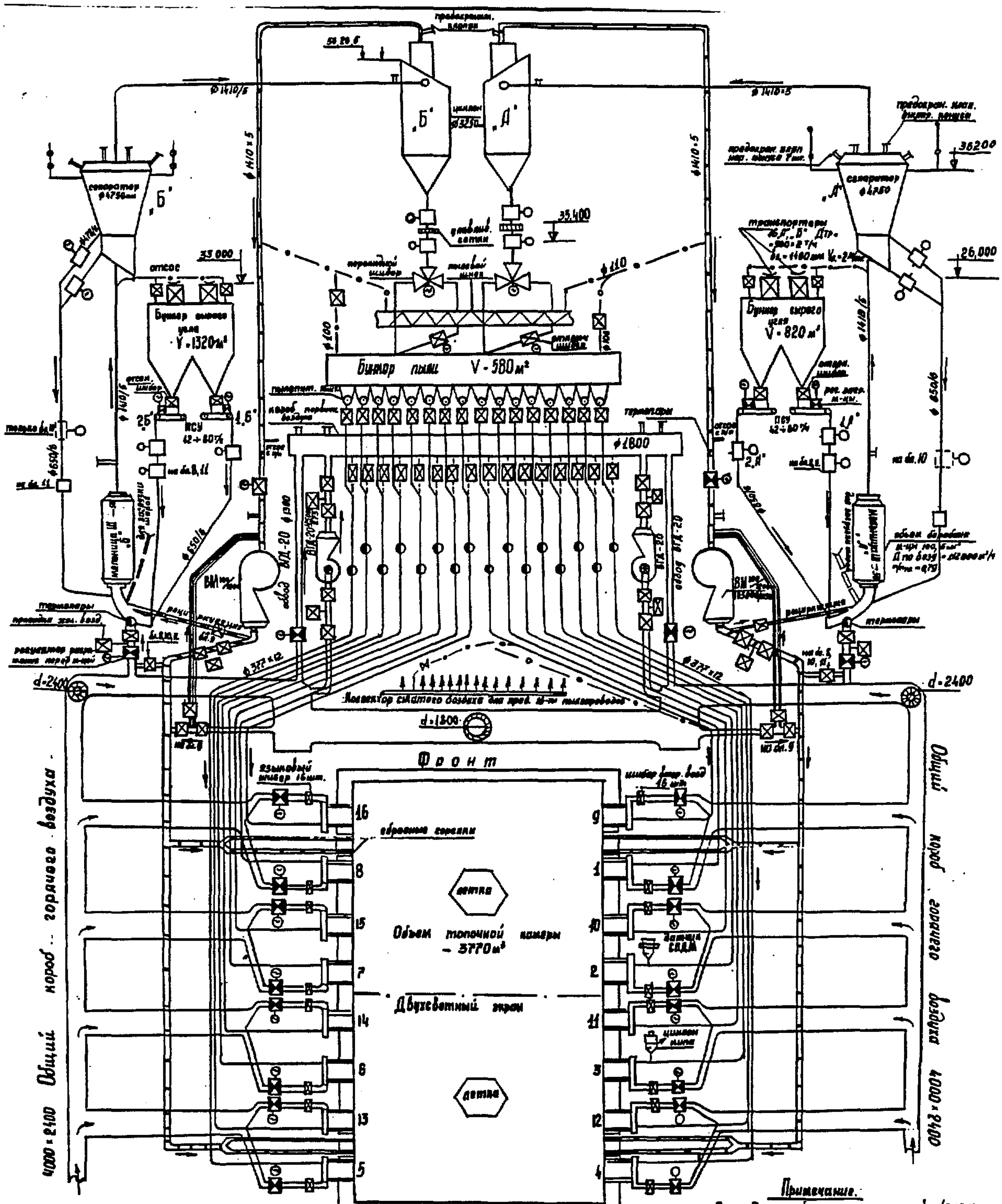
COMBUSTION AIR AND FLUE GAS
FLOW DIAGRAM
FIGURE 4.1.1-3



Примечания.

1. На бл. №8, 10, 11 рециркуляции с выдачи МВ на м-цы демонтированы
2. На бл. №8, 11 обводы ВГД А и Б отглушены
3. На бл. №8 пылепроводов, как и основных горелок – 8 шт.
4. Управление шибером на выдаче МВ А и Б на бл. 8 производится под ∇ 9.0м
5. Шибера на выдаче МВ А Б на бл. 11 установлены сразу непосредственно у м-ных бент. на ∇ 0.0м

Схема топливоприготовления котла ТП-100

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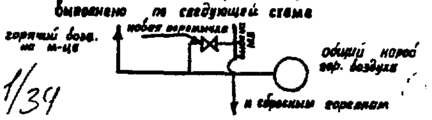
Примечание.

Охлаждение сбросных горелок на бл. №8,10,11 выполнено по следующей схеме



PULVERIZED ANTHRACITE
FIRING SYSTEM LINE DIAGRAM
FIGURE 4.1.1-4

4.1.2 Emission Controls

4.1.2.1 Unit 10

Particulate Emissions

Unit 10 is equipped with a wet ash collection (scrubbing) system. Flue gas from the boiler is ducted to a manifold feeding five (5), 4,600 mm diameter scrubbers. Flue gas enters the scrubber tangentially where it is contacted with a spray of water. Coagulated ash particles accumulate at the scrubber vessel wall and are carried out by a continuous film of water.

Design flue gas pressure drop for the scrubber is about 125 mm water and design efficiency has been stated to have been only about 95% which would result in an estimated particulate emission of 1,500 to 2,000 mg/Nm^3 (at 40% excess air) when firing the uncleaned coal.

NOx Emissions

Unit 10 is not equipped with any NOx reduction equipment. NOx emissions have been estimated at 1600 mg/Nm^3 when firing the uncleaned coal.

Sulfur Dioxide Emissions

Unit 10 is not equipped with any SO_2 reduction equipment. SO_2 emissions have been estimated at 6,660 mg/Nm^3 when firing the uncleaned coal.

4.1.2.2 Unit 13

Particulate Emissions

Unit 13 is equipped with a Model 4G-4-50 electrostatic precipitator (ESP), installed after the air heater, designed to capture fly ash from the flue gas prior to release to the stack. The ESP consists of three (3) parallel sections. Each section consists of four (4) fields with each field consisting of 2 half fields.

Overall dimensions of each ESP are 19.25 meters long, 9.5 meters wide and 15.45 meters high. Specific characteristics of the ESP are as follows:

Model	4-50
Number of ESP's	3
Plate Height, m	8.11
Plate Length, m	11.08
ESP Width, m	9.40

Active Section Area (each), m^2	76.23
Active Section Area (total), m^2	228.70
Estimated Gas Passages/ESP	27
Estimated Plate Spacing, mm	340.0
Estimated Plate Area/ESP, m^2	4673
Plate Area (Total), m^2	14018
Aspect Ratio (h/l)	0.73

Design efficiency of the ESP has been stated to have been 96%-98%. Efficiency is determined in part by the ratio of plate area to flue gas volume and the volume of flue gas has been estimated for operating conditions which reflect firing uncleaned coal in the boilers. (Note that firing of some natural gas is required to sustain combustion).

Based on the estimated flue gas flow of 933,000 Am^3/hr generated by the boiler when producing 400 tonnes/hr of steam, the calculated SCA for the ESP is 275 ft^2/1000 ACFM. The anticipated particulate collection efficiency for this design is about 96%-97% when firing the uncleaned coal at the reduced boiler steam production rate. Estimated particulate emissions would be expected to be about 1300 mg/Nm^3 (at 40% excess air) from the existing ESP.

NOx Emissions

Unit 13 is not equipped with any NOx reduction equipment. NOx emissions have been estimated at 1600 mg/Nm^3 when firing the uncleaned coal.

Sulfur Dioxide Emissions

Unit 13 is not equipped with any SO_2 reduction equipment. SO_2 emissions have been estimated at 6,660 mg/Nm^3 when firing the uncleaned coal.

4.1.3 Turbine-Generator

4.1.3.1 Technical Description of Steam Turbine

The existing steam turbine is a type K-200-130 reheat unit manufactured by the Leningrad Metal Works. It is a nominal 200 MW capacity unit with seven stages of feedwater heating steam extractions. The turbine is a single shaft machine and has separate High Pressure (HP), Intermediate Pressure (IP) and a two-flow Low Pressure (LP) sections. The direction of the steam flows in the HP and IP section is countercurrent. The single thrust bearing is located between the HP and IP turbines. The cross sectional drawing of the turbine is shown in Figure 4.1.3-1.

The HP section of the turbine is of single casing design made of alloy steel (15XIHIFL) and is made with a horizontal casing joint. The steam path consists of 12 pressure stages including the control stage. The HP rotor is made of steel R2. The rotor discs are forged together with the rotor. The critical speed of the HP rotor is 1750 rpm. The diaphragms of the HP section are located in blade carriers in a 3-5-3 configuration.

The IP cylinder is also of the single shell design, and it consists of two parts: the front part is cast alloy steel (type 15XIHIFL) and the exhaust part which is welded from carbon steel. The steam path consists of 11 pressure stages, 7 in the front part and 4 in the exhaust part. The IP rotor is made of steel R2. The first 7 discs are forged together with the rotor, the last 4 discs are fitted on the shaft. The HP and IP rotors are connected with a rigid coupling and have a joint support-thrust bearing.

The two flow LP cylinder consists of three parts: one cast intermediate (center) part, and two exhaust parts which are fabricated and welded carbon steel. The LP rotor consists of a shaft and 8 fitted discs, and the LP section utilizes the Baumann exhaust arrangement. The stages in the LP section are counted along the steam path - toward the generator (24-27) and toward the IP section (28-31). The Baumann stages are used as two stages before the last ones (26 and 30). These stages have two-tier blades.

Main steam to the steam turbine is provided from the steam generator through two stop valves and four control valves. Hot reheat steam from the steam generator to the IP turbine is routed through reheat stop and intercept valves. The 4 control valves and 4 intercept valves are located directly on the HP and IP cylinders, respectively.

The turbine is equipped with devices to control axial expansion and relative displacement of rotors of all cylinders. In addition, the turbine is also equipped with a turning gear to help prevent turbine shaft bending during cooldown.

The turbine control system is mechanical hydraulic. The set of turbine oil pumps consists of a main oil pump of the centrifugal type which is driven by the turbine shaft, a high pressure startup pump, and a reserve oil pump with two electric (AC and DC) motors. The oil to the control system is supplied at a pressure of 21 atmosphere, the oil to the bearing lubrication system is supplied at 1 atmosphere pressure.

The oil purification system consists of a pressure filter, and a cotton filter and an adsorber for mechanical cleaning of the turbine oil. In addition a centrifugal oil purification machine is provided to remove water from the turbine lube oil.

The electric generator is a type TGV-200 operating with a stator current of 8630A and a rotor current of 1750A. The generator is cooled by hydrogen with pressure of 4 kg/cm^2. The working exciter is of the thyristor type with a nominal current of 2000A.

The original design technical parameters of the turbine are shown in Table 4.1.3-1.

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Table 4.1.3-1

ORIGINAL DESIGN TECHNICAL PARAMETERS

OF THE K-200-130 TURBINE

Nominal Capacity (Gross Output)	200 MW
RPM	3000 rpm
Fresh steam pressure before stop valves	130 ata
Fresh steam temperature before stop valves	565°C
Steam flow to turbine	560 t/h
Steam pressure at exit of HP section	23.2 ata
Steam temperature at the exit of HP section	345°C
Steam pressure before IP section	21.3 ata
Steam temperature before IP section	565°C
Steam pressure at the regulating stage	96 ata
Steam pressure in the condenser at design cooling water temperature of +10°C and design cooling water flow of 25000 m^3/h	0.035 ata
Steam flow to the condenser	392 t/h
Number of extractions	7
Final feedwater temperature	235°C

4.1.3.2 Performance: Design vs Current

The technical parameters shown in Table 4.1.3-1 above indicate that the K-200-130 steam turbine was originally designed to operate with main and reheat steam temperatures of 565°C. After operating these types of units for a number of years with these parameters, the then Soviet regulatory organization decided to officially lower the steam parameters for both the steam generators and steam turbines because of failures in high temperature components in the steam

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generators. This resulted in the new design temperatures of 545°C for the steam generators lowered from 570°C, and 540°C for the main and reheat steam inlet conditions for the K-200-130 steam turbines. The design heat balance diagram indicating the new design main steam parameters is shown in Figure 4.1.3-2.

The reduced steam temperatures resulted in a slightly modified steam flow, output and final feedwater temperature. The new design performance of the steam turbine for various load points between 100% and 30% is shown in Table 4.1.3.2.

Table 4.1.3-2

DESIGN PERFORMANCE OF K-200-130 TURBINE

With 540°C Steam Temperature

Electrical Load (~%)	100	75	50	30
Main steam flow, t/h	566	420	283	188
Main steam pressure, ata	130	130	130	130
Main steam temperature, °C	540	540	540	540
Reheat steam pressure, ata	22.3	16.7	11.3	7.6
Reheat steam temperature, °C	540	540	540	540
Condenser pressure, ata	0.035	0.035	0.035	0.035
Final feedwater temperature, °C	231.3	215.5	195.6	177.3
Turbine gross output, MW	197.06	148.8	95.7	61.1
Turbine gross heat rate, kcal/kWh	1989	2020	2185	2335

It should be noted, however, that the above performance cannot be obtained from either the Unit 10 or the Unit 13 turbines at the present time. In fact, all the 200 MW units are currently derated to 175 MW gross output due to the degradation of boiler fuel which, with excessive air inleakage into the boilers, severely reduces actual steam generating capacity. Steam generator operating capacity and efficiency data obtained during plant inspection indicated the following actual operating parameters:

	Unit #10	Unit #13
Steam Generator Operating Capacity, t/h	389	404
Superheated Steam Temperature, °C	508.8	521.3
Final Feedwater Temperature, °C	201.2	201.5
Boiler Gross Efficiency, %	79.96	78.21

As can be seen, the main steam flow, and correspondingly the reheat flow, available from the steam generators are only about 71% of the design turbine steam flows. In addition, the units are usually operated with one or two evaporators in the extraction steam system to produce make-up water for the steam generators. Depending whether the upper or lower or both extractions (Extraction No. 5 or No. 6) are utilized, steam turbine output is reduced between about 4.2 and 2.8 MW. Of course this reduction of output can be eliminated by increasing the turbine steam flow if the steam generators allowed the production of additional flow which, in turn, also requires an additional fuel input.

Discussions with plant personnel and reviewing the operating data indicated that Unit 10 can generate between about 140-145 MW and Unit 13 between about 145-153 MW with most other units generating about 143 MW. Considering the above reduction of turbine output associated with the use of the evaporators, the resulting average outputs fit very well with the steam flows available from the steam generators shown above. Based on the design auxiliary power consumption of 7.8% given for the units at 200 MW, an auxiliary power consumption curve for partial loads was generated. The use of this curve in connection with the turbine outputs and steam generator data (steam flow, temperature, efficiency and feedwater temperature) allowed the determination of the current actual gross and net heat rates and electric outputs for the two units. These figures can be used as the "base line" performance from which the various efficiency improvements associated with proposed modifications can be measured. The base line (present) performance of Unit 10 and Unit 13 are shown below

CURRENT UNIT PERFORMANCE

	Unit #10	Unit #13
Main Steam Flow, t/h	389	404
Gross Turbine Output, MW	139	145.5
Gross Turbine Heat Rate, kcal/kWh	2042	2032
Net Unit Output, MW	126.5	132.6
Net Unit Heat Rate, kcal/kWh	2805	2852
Overall Unit Efficiency, %	30.6	30.1

4.1.3.3 Condition Assessment

General Assessment and Plant Operation

The project team visited and inspected the plant, held discussions with cognizant operating and management personnel and reviewed the maintenance procedures and records as well as the findings of the plant metal control laboratory.

It was confirmed that the turbine governor parts have experienced significant wear, the turbine casings have developed cracks which have been repaired, and that continuous operation of the turbines in the non-stationary load regimes led, in some cases, to unacceptable deformation and erosion wear in the turbine steam path. The list of items most frequently requiring maintenance in the turbine plant includes:

- the turbine governing valve rods
- intercept valve guide piston
- HP and IP cylinder diaphragms
- Last stage blading in the LP cylinder

In addition, it is difficult to maintain vacuum in the condenser at the normal level. The causes of this are discussed in Section 4.1.4.

Both units have accumulated significant number of operating hours, exceeding their original design life by about a factor of 2. While the main steam/reheat steam temperatures have been

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lowered to 540°C as mentioned above in an effort to extend the life of the steam generator superheaters, the individual units at the plant no longer operate in the baseload mode. In fact, the units currently operate on a 2-shift regime.

The operable units at Lugansk GRES are loaded to their present capability during the hours of about 7:00 AM to 11:00 PM and held at a constant load. Between the hours of 11:00 PM and 7:00 AM the load is reduced either to the technical minimum or to 0 gross turbine load (such as can happen during weekends). The typical shape of the plant loading observed for June 27,1995, is shown in Figure 4.1.3-3.

Gross turbine loads of various units observed during the daytime on some of the days of the plant inspection visit are shown in Table 4.1.3-3.

TABLE 4.1.3-3

GROSS TURBINE LOADS OBSERVED

[MW]

Unit/ Date	#8	#9	#10	#11	#12	#13	#14	#15	TOTAL
6/22/95	0	137	0	0	0	90	130	125	482
6/26/95	0	121	144	0	0	0	135	153	553
6/27/95	0	141	142	0	0	0	140	150	573
6/28/95	0	149	142	0	0	0	140	129	560
6/29/95	0	142	150	0	0	0	146	158	596

During most of the time the plant operates at constant output; however, the individual units experience the effects of cycling. While the somewhat reduced main steam parameters tend to lessen the severity of the operating conditions for the turbine components, the frequent transients associated with the start-up and shutdowns or load changes of the various units will contribute to accelerated life consumption of critical parts. Some of the transients as well as the simple wearout of the parts operating for an extended amount of time have caused forced shutdowns of the various units. The number of planned and forced shutdowns for Units 10 and Unit 13 during the previous three years are shown in Table 4.1.3-4.

Table 4.1.3-4

PLANNED AND FORCED SHUTDOWNS OF UNITS 10 AND 13

BLOCK	UNIT 10			UNIT 13		
YEAR	PLANNED	FORCED	TOTAL	PLANNED	FORCED	TOTAL
1992	15	4	19	12	16	28
1993	34	14	48	12	3	15
1994	24	12	36	17	11	28

The allowable number of turbine starts originally specified for the 200 MW turbines are as follows:

Cold Start : 100

Warm Start : 1000

Hot Start : 900

However, the actual number of cold starts for both units are about 4-5 times greater than the allowable. The warm and hot starts are within the allowable range. This is shown in Table 4.1.3-5, where other relevant information is also shown for the two selected units.

Table X-4.1.3-5

TURBINE OPERATIONAL DATA

Unit No..	UNIT #10	UNIT #13
Commissioning date	12/30/62	8/29/68
Design electric generating capacity, MW	200	200
Cumulative hours of operation, hrs	224,442	191,841
Derating, —ΔMW	25	25
Official derated capacity, MW	175	175
Cause of Derating	Steam Generator	Steam Generator
Design/Actual Cond. Air inleakage, kg/h	20/35	20/70
Turbine maintenance schedules		
Preventive (minor)	1 per year	1 per year
Intermediate repairs	1 per 2 years	1 per 2 years
Overhaul	1 per 4 years	1 per 4 years
Last major overhaul completion date	12/31/91	8/2/93
Actual number of		
Planned shutdowns	440	329
Unplanned shutdowns	277	255
Actual number of starts		
Cold	550	460
Warm	102	81
Hot	65	43

The advanced age of these units especially that of the 1962 vintage coupled with the operating mode adapted at the plant requires the performance of extensive maintenance. There are three types of scheduled maintenance performed for the turbines:

- Preventive maintenance covering minor repairs, performed once a year. This maintenance takes about 13 days per year.
- Intermediate repairs which is performed once in 2 years. This maintenance takes about 25 calendar days.
- Major overhaul which is performed every 4 years and is scheduled to take about 100-120 calendar days.

Plant personnel are performing well in keeping the plant in operation. However, spare parts are not always available and plant personnel must sometimes machine spare parts or use parts from other non-operating units to complete repairs. Thus actual maintenance periods often extends beyond the above figures. For instance the last major overhaul for Unit 13 took more than 5 months to complete.

Unit 10 Assessment

The Unit 10 steam turbine is one of the oldest units commissioned during the second phase expansion of the Lugansk GRES between 1961 and 1963. By the first half of 1995 this turbine has accumulated a total of 224442 operating hours since its commissioning in 1962.

Only a few modifications were done to this machine such as the replacement of the turbine stages Nos. 24 to 31 with more modern blading profile in 1982, and the installation of an alternative seal arrangement at the casing and top of the regulating stage of the HP section in 1987. Both of these modifications were done in an effort to improve efficiency.

The past history of the forced shutdowns on this turbine includes the destruction of the trigger mechanism of the automatic safety device because of metal fatigue in 1988. The part failed because of metal fatigue and because there was not sufficient curvature in the transition radii of the upper and lower reinforcing flanges. Cracks have also been found in the HP cylinder. One of these was the result of the modification to carry the Curtiss wheel radial seals where the cracks occurred in the groove corners. Other cracks were found in 1982 in both the upper and lower parts of the HP cylinder on the inside walls in the nozzle block area. These cracks were repaired by further opening them up by drilling to a depth of 25 mm in accordance with LMZ technology.

In 1987 cracks were found on all surfaces of the stop valves (both left and right) so these valves had to be replaced with new ones. During the same year, cracks of 2 mm depths were found in the seat areas of the intercept valves. These defects were corrected by installing new valves. In

1991, at an accumulated total operating hours of 203830, two cracks of 300 mm length were discovered at the inside of the nozzle box of the HP cylinder. Since the geometry of the area at this location is complex, repair by grinding is not possible; therefore the defects were repaired by drilling, and the crack depths were opened up to 20 mm.

The most serious looking cracks were found in 1991 on the IP cylinder. Two cracks were discovered on the inside of the lower part of the casing in close proximity to each other: one is a crack with dimensions of 300 mm by 20 mm by 50 mm, while the other has a length of 800 mm with width and depth dimensions of 10 mm. Prior to this, another crack with dimensions of 250 mm by 120 mm by 45 mm was also found in this area (in 1973). All these defects have been repaired by a welding method according to LMZ technology.

In addition to the cracks, one of the major problems with the IP section is the distortion of the flow path, especially in the area of the 14th stage diaphragm, which has a very slight elliptical shape but enough to influence clearances along the rotating components. Similar problems apply to the fourth stage of the HP cylinder. This condition was found during the last overhaul when the turbine casing was opened. So far the normal maintenance procedures are sufficient to temporarily correct for this defect.

The rotors of this unit have operated satisfactorily so far, except that various blade replacements had to be performed during 1987 and 1991. In addition, the plant has reported increased vibration levels at the turbogenerator supports. The plant is also not totally satisfied with the existing turbine supports and alignment in regard to the uniform thermal expansion of the unit.

The vibration levels at low loads are mostly due to the relatively frequent wearout of the last stage blades in the LP cylinder. According to plant records the Unit 10 had forced outages in 1993 and 1994 due to destruction of blades in the last two stages of the LP rotor because of erosion. The last event, destruction of one blade on stage 31 caused an increased vibration level of up to 92 microns.

The main steam and reheat stop valves and the control valves and intercept valves had experienced cracking and valve spindle hang-up. Turbines at the Lugansk plant often have breakage of a rod at the upper part of the HP regulating valves, and sticking of intercept valves at the IP cylinder because of the formation and buildup of black carbon in the guide piston column. As it was noted the main stop valves and the intercept valves on Unit 10 were already replaced once in 1987.

Some distortion of the gland steam seal components have been reported and may be attributed to the problems with vibration and the effort to achieve correct alignment. The seals are replaced as necessary during scheduled maintenance. The gland steam leakage increases between the maintenance periods and the high gland leakage could be responsible for the emulsified condition of the turbine generator lubricating oil. The plant indicated no problems with the oil cleaning system and the centrifuge is said to get rid of any water in the lube oil. However, the existing lube

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oil cooler was reported to have leaks and caused some concern with small traces of oil leaking into the cooling lakes. This can happen because the GRES at Lugansk does not have a dedicated secondary service water system.

No major problems have been reported for the turbine turning gear. It is maintained as necessary and operation is satisfactory.

The condition of bearings are generally acceptable, except for the thrust bearing pads some of which are operating at an elevated temperature at stable operating conditions. These pads are usually changed at each overhaul. Procurement of the Babbitt metal is sometimes difficult because it is obtained from Russia.

One of the most annoying problems is that the turbine regulating system is unreliable due to the wearout of the components and sometimes the lack of spare parts. Because of this the turbine operation and control is unstable. The coupling of the main oil pump which is driven by the main turbine shaft wears out every year. There is also a valve sticking problem on the intercept valves on the IP cylinder due to creep of cast iron components of the guide piston box, despite the replacement of the valve internals in 1987. In addition the plant is not satisfied with the monitoring and transmitting instruments used to measure vibration of bearing supports of the turbogenerator shaft. Because of the wearout of the components of the mechanical-hydraulic control system the turbine control system is in need of upgrading.

The condition of the electric generator is assessed in section 4.1.4 of this report in more detail.

Unit 13 Assessment

The Unit 13 turbine is currently one of the younger units which were commissioned during the last (the 3rd) phase of plant expansion at Lugansk during the period 1967-1969. By early 1995 Unit 13 has accumulated 191841 operating hours during its 27 years of operation since its startup on 8/29/1968. In addition to the capability of providing steam for using the evaporators, the extraction steam piping of this turbine also has the capability to provide extraction steam for local hot water generation for plant heating needs.

The modifications done to this unit were the modernization of the 24 to 31 stages to change the blade profiles for better efficiency in 1979 and in 1984, and some reconstruction of internal seals in the HP and IP cylinders in an effort to decrease leakages between the turbine stages, in 1989.

The list of forced shutdowns of this turbine includes problems with the control and regulating components, such as fatigue damage of cotter pin for the governor spring, fatigue damage of regulating stage support, and the destruction of the support of governor spring due to the exhaustion of the material. All the above occurred in 1988. In 1990 the end part of two turbine blades broke off which increased the shaft vibration to 68 microns. In 1991 a forced shutdown occurred because of damage to blades at the 27th and 31st stages in the LP section due to excessive erosion.

The number of cracks found on this turbine are less than those on Unit 10, probably due to the relatively lower operating hours accumulated on Unit 13. During the last 10 years only 2 cracks were found (in 1993). These cracks with lengths of 105 and 110 mm and depths between 5 and 7 mm were discovered during the last overhaul when the turbine casings were opened. The cracks occurred on the lower part of the IP cylinder in the area of the nozzle boxes on the left and right sides. The turbine had accumulated 179071 operating hours when these cracks were discovered. Both cracks were repaired by grinding them out to dimensions with 120 x 50 x 60 mm and 130 x 70 x 30 mm and subsequent welding according to LMZ technology.

There have been no other cracks reported on the turbine shells, however, the stop valves started to show fatigue damage lately and they are in need of replacement. These valves have already been replaced on Unit 10. In addition, the governor parts and control components on the turbine also have significant wear, similar types to those listed for Unit 10, and spare parts on these components are not readily available. Because of this the turbine control is unstable and the turbine control system needs upgrading.

Generally, the steam pass including the stationary and rotating parts (diaphragms, nozzles, blading etc.) is approaching twice the original design life of this unit and the shells and valves and other high temperature components requires careful monitoring for cracks and creep damage as a minimum. Except for various blade replacements the turbine rotors have operated satisfactorily so far. With the type of plant operation described, accelerated exhaustion of the turbine materials and components can be expected.

4.1.3.4 Assessment of Plant's Metal Control Laboratory

The metal control laboratory personnel has been interviewed to assess the procedures and equipment the plant has to control metal conditions. In general the plant has quite a large array of non-destructive examination (NDE) equipment for the testing and inspection of the turbine, steam generator, and main steam piping components. These equipment include the following:

UD-2-12 Echo-impulse inspection instrument

UT-93P Ultrasonic thickness gage

GAMMARID-192/120 Gamma-ray flaw detector

MIRA-2D X-ray impulse instrument

ARINA-02 X-ray impulse instrument

PMD-70 Magnetic particle defectoscopy instrument

RVP-456 Boroscope

SLP-I Transportable steeloscope

VPI-3k Hardness meter

TEMP-I Electronic, compact, transportable hardness meter

ITV-02 Eddy current crack indicator

In addition the plant is also equipped with testing devices that can be used with destructive control methods. These devices include:

UMM-4	Universal unit for static testing of metals. Maximum load 5 tons
UMM-50	Universal unit for static testing of metals. Maximum load 50 tons
MK-30A	Pendulum impact testing machine
TK-2	Table instrument for Rockwell hardness measurement
TSCHA-2	Hardness measuring instrument

In addition to these, the laboratory also has a metallographic microscope and a gas analyzer.

As far as the steam turbines are concerned the plant personnel indicated that visual and magnetic particle testing are carried out on the main castings and steam pipes and valves. This usually occurs every 4 years during the turbine overhaul periods. These tests are done on the turbine shells to detect and/or observe cracks and cavities. In addition, ultrasonic testing of the turbine blades are carried out. The turbine nozzle boxes are examined visually. Sometimes boroscopic and visual inspections of these areas are also performed during intermediate repairs.

Stud bolt measurements of elongations are performed during capital repairs only. There is only ultrasonic testing done between capital repairs.

There is currently no replication type creep testing capability at this plant. As the plant is getting older such testing capability would be highly desirable to monitor potential creep cavitation of critical components and to be able to better predict potential failures or to perform predictive maintenance operations. This is particularly applicable to a plant in which turbines are operated with frequent cycling.

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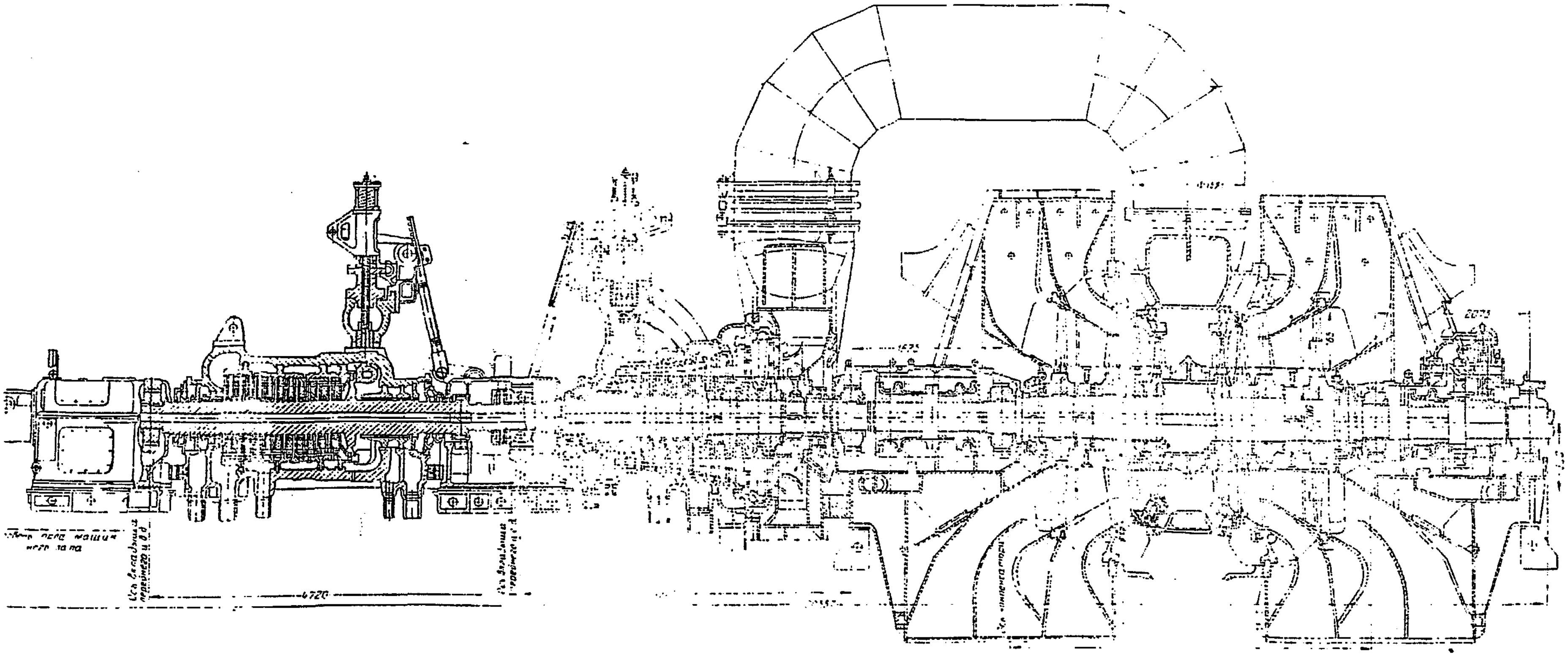

Figure 4.1.3-1 Cross Sectional Drawing of the 200 MW Turbine

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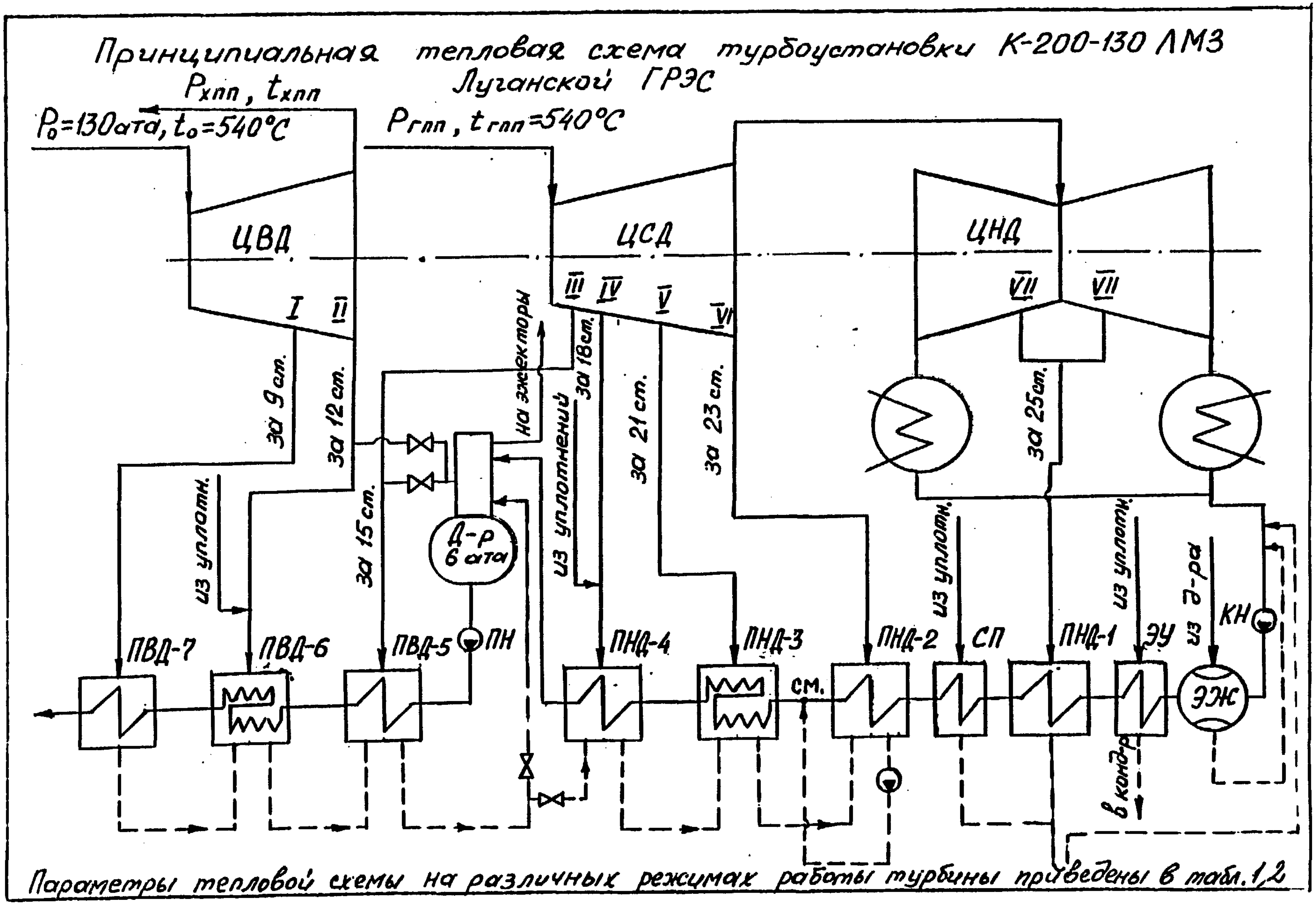
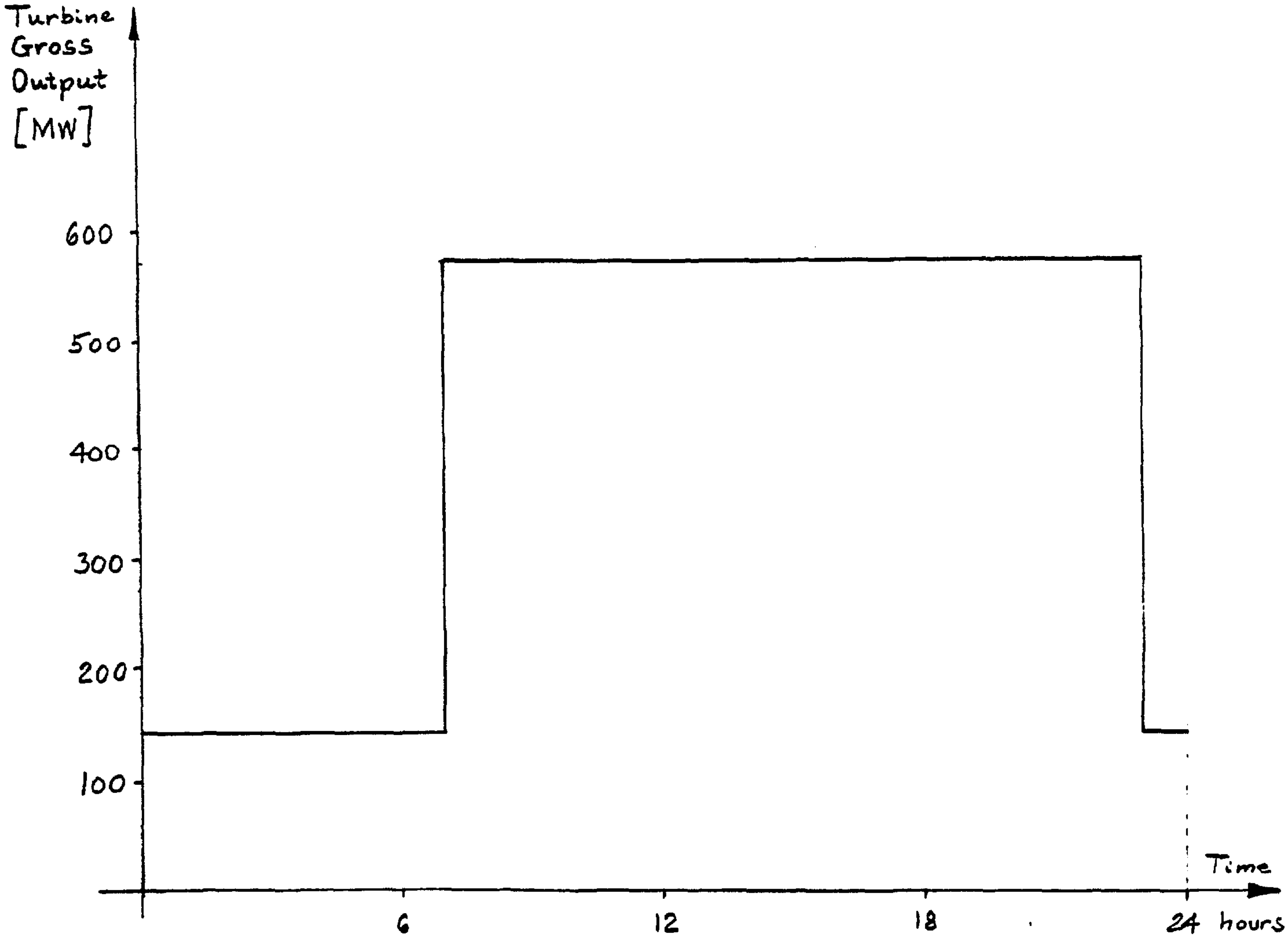


Figure 4.1.3-2 Design Heat Balance Diagram



(Data based on June 27, 1995)

Figure 4.1.3-3 Typical Load Shape for Lugansk GRES

4.1.4 Mechanical Systems and Equipment

This section contains a brief description of the major mechanical fluid systems which support the existing 200 MWe turbine generator units. Unless noted otherwise, the description applies to both **Units No. 10** and **No. 13.** Drawing No. SM200, "Site Plan, Main Power Plant Buildings," is included as a reference in Appendix D.

Main and Reheat Steam System

The two 325 mm main steam pipelines were designed to convey 620 t/h of 130 atm steam to the K-200 turbine unit but are presently carrying only 566 t/h due to the current derated mode of operation. Isolation from the boiler is provided by 250 mm main steam stop valves. The stop valves are provided with 100 mm bypass valves for use during turbine start-up. At the High Pressure (H.P.) turbine casing inlet, steam is admitted through 200 mm turbine stop valves which are crossconnected in case either one becomes inoperative. The valves have developed fatigue cracks in their body material. The turbine stop valves on Unit 10 have already been replaced. Downstream of the turbine stop valves steam enters the turbine through four governor valves by way of four 225 mm crossover lines. Exhaust steam from the H.P. turbine is directed, via 426 mm cold reheat piping, to the boiler reheat section. Reheated steam is directed to the Intermediate Pressure (I.P.) turbine casing via 426 mm hot reheat lines and admitted through two 420 mm reheat stop valves. From the reheat stop valves steam is admitted to the I.P. casing through four governor valves. Pressure relief valves are located on each of the main (quantity of two) and reheat (quantity of four) steam lines. These relief valves have exceeded their useful life and have required excessive maintenance.

All main and reheat steam piping is made of stainless steel, grade 12XIMF. Bolts and nuts are stainless steel, grades EI-723 and 20XMFL, respectively. Valve bodies are stainless steel, grades 15XIMI and 20XMFL. Current conditions of steam piping, as determined during capital repair maintenance outage, indicates an average creep of 1% and a degradation of metal structure.

Extraction Steam

As currently designed, the extraction steam system is supplied from two H.P., four I.P., and one Low Pressure (L.P.) extraction points and provides steam to feedwater heaters, make-up water evaporators, and district heating heat exchangers. H.P. extractions No. 1 and 2 supply feedwater heaters No. 7 and 6, respectively. I.P. extraction No. 3 supplies feedwater heater No. 5. and I.P. extractions No. 4, 5, and 6 supply steam to feedwater heaters No. 4, 5, and 6, respectively. IP extractions No. 4 and 5 also supply steam to evaporators No. 1 & 2 and the district heating heat exchangers. Discussions with plant personnel indicated that there have been no problems with the extraction piping.

Current extraction steam conditions are as follows:

Extraction No.	**Turbine Stage Before Extraction**	**Heater Name and Number**	**Extraction Pressure** (atm)	**Extraction Temp.** (°C)	**Steam Flow to Heater** (t/h)	**Condensate Temp. After Heater** (°C)
1	9 (HP cyl)	HP heater No. 7	37.3	397	26	235
2	12 (HP cyl)	HP heater No. 6 + Deaerator	23.2	340	35	215 158
3	15 (IP cyl)	HP heater No. 5 + Deaerator	11.5	478	16.3	180.6 158
4	18 (IP cyl)	LP heater No.4	6.06	391	18.0	153
5	21 (IP cyl)	LP heater No.3	2.64	290	19.0	125.5
6	23 (IP cyl)	LP heater No.2	1.23	207	24.0	99.7
7	25, 27 (LP cyl) Bauman stage	LP heater No. 1	0.25	77	210	59

Condensate System - Condensate is pumped from each of the two main condenser hotwells via two operating and one spare condensate pumps. Design conditions are as follows:

	Unit #10	**Unit #13**
Quantity, Operating/Standby	2/1	2/1
Model No.	12KCB 9x4	12KCB 9x4
Design Flow & Head, m^3/hr / kg/m^2	300 / 16	300 / 16
Operating Flow & Head, m^3/hr / kg/m^2	**320** / 10	**390** / 11
Design Bhp	210	210
Motor Size, volts	6000	6000

Must be
atm or
kg/cm²

Condensate passes through the main air ejector condenser, the gland seal steam condensers, and L.P. feedwater heaters No. 1, 2, 3, and 4 and is admitted to the two 6 atm deaerators. L.P. feedwater heater No. 1 is mounted inside the condenser shell. Condensate drains from heaters No. 4 & 3 cascade to heater No. 2 and are then pumped to the main condensate effluent line leaving heater No. 2. The casing of heater No. 4, of Unit No. 10, has become deformed and cracks and erosion wear have developed.

Design data for the L.P. feedwater heaters is as follows:

Unit #10 & #13

Heater No.	Type	Pressure Water/Steam, (atm)	Flow Water/Steam (t/h)
LP #4	PN-300-16-7-1	15/5.6	520/25.5
LP #3	PN-300-16-7-2	15/2.5	520/18.0

LP #2	PN-300-16-7-2	15/1.15	520/30.0
LP #1	Horizontal, Internal (2x145 m^2)	15/0.25	520/21.0

Cycle make-up water is provided by a double-effect evaporator system associated with each turbine unit. Water is received from the plant-wide raw water supply, originating in the Water Treatment Building, and enters a 1.2 atm deaerator. From this deaerator water is pumped to each of two evaporators (ISV-350) where it is boiled and condensed in the evaporator condensers (PN-250-3N)which are cooled by the main condensate flow. Distillate pumps (2 x 50% capacity, Model 4MS-10) transfer the distilled water to the main deaerators as cycle make-up. The plant staff have described the evaporator systems as an unreliable source of proper quality make-up water.

The main condensers of each unit (Model 200 KCS-2) consist of two sections each with a total design circulating water flow of 25,000 m^3/h per unit and a condensing pressure of 0.035 atm. Tube material is alloy MNZH 5-1. Vacuum is maintained on Unit No. 10 by two main air ejectors (Model EP-3-600-4/M/) and on Unit No. 13 by three main ejectors and a start-up ejector. Difficulties have been experienced in maintaining condenser vacuum due to excessive air inleakage. Differences of approximately 0.6 % from normal vacuum have occurred as a result of air inleakage rates of 35.4 kg/h and 70 kg/h in Units No. 10 and 13, respectively. The main leaks have occurred through valve packing seals of valving on the condensers along with perforations and cracks in turbine exhaust expansion joints. Leakage has resulted in the need to have all three main ejectors in operation simultaneously.

In addition to air inleakage problems, the condensers have experienced metal corrosion of the separating wall between the steam and cooling water.

Feedwater System - Feedwater is pumped from the two 6 atm. deaerators (400 t/h design capacity each) by electric motor driven feedwater pumps. Unit No. 10 has one main 100% capacity and two standby 67% capacity pumps. Unit No. 13 has one main and one standby pump, 100% capacity pumps. The following is a summary of design data for the Units No. 10 & 13 feedwater pumps:

	Unit #10		**Unit #13**
	Operating	Standby	Oper. / Stby.
Quantity	1	2	1/1
Model No.	PE-640-180	PE-430-200	PE-720-185
Flow, m^3/hr	640	430	720
Head, kg/m^2	193	188	185
Pump Eff., %	72 -77	70 - 71	82
Pump bhp	5691	3831	5389
Motor Eff., %	96.5	96.5	96.5
Running Load, kW	4397	2960	4164
Motor Size	5000	3800	5000

The models of feedwater pumps currently in use are no longer manufactured. Spare parts have been difficult to obtain necessitating the use of parts from the pumps on Unit No. 11. Additionally, due to the age of the pumps, their efficiencies are low compared to new versions of the same pump line.

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The feedwater pumps discharge through H.P. feedwater heaters No. 5,6, & 7 with provision for bypassing the heaters as a group. Design data for the H.P. heaters is as follows:

	Unit #10			Unit #13		
Heater No.	Type	Pressure (atm) Water/Steam	Flow (t/h) Water/Steam	Type	Pressure (atm) Water/Steam	Flow (t/h) Water/Steam
HP #7	PV-480/230	230/37	640/26.0	PV-500-230-44	230/43	640/26
HP #6	PV-480/230	230/25	640/35	PV-500-230-30	230/29	640/35
HP #5	PV-480/230	230/11	640/16.3	PV-500-230-14	230/13	640/16.3

The H.P. feedwater heater shells are in good condition. The heaters have been operated continuously with only partial replacement of the heating surfaces having been performed on certain heaters. Frequent shutdown of the heaters has caused damage to the coils and resulted in unsatisfactory operation of the heater drain level control valves and loss of sealing pressure at valve packing contributing to air inleakage into the system.

Excessive maintenance has been required on feedwater and attemperator control valves due to the high differential pressure under which they operate due the high feedwater pump discharge pressures resulting from operation at reduced loads.

Circulating Water System - The circulating water system for the Phase 2 and 3 plant areas is supplied from Pumphouses No. 2 and 3 located at the Donets Riverfront. Units No. 8 to 11 are served by Pumphouse No. 2 via headers #3 & #4 and Units No. 12 to 15 are served by Pumphouse No. 3 via headers #5 & #6. These headers are cross-connected, along with headers #1 and #2 from Pumphouse No.1, via electric operated isolation valves. These cross-connections provide maximum flexibility in supplying all units when any pumping system is out of service.

Pumphouse No. 2 contains six pumps and Pumphouse No.3 contains four pumps. Unlike the pumps at Pumphouse No. 1, these pumps do not have capacity control. The pump design data for these pumps is as follows:

	Pumphouse No. 2	Pumphouse No. 3
Quantity	6	4
Model	OP-2-145	OP-10-145
Flow, m^3/hr	28,000	36,000
Head, m (w/c)	18.5	17.5
Power, kW	1600	2150

Circulating water is returned to the river, via concrete conduits and Cooling Ponds # 2 and #3. Only Pond #3 is in operation during summer months.

Although very few condenser tubes have been plugged, there is a constant problem of condenser tube fouling due to sludge deposits. The existing tube cleaning system uses hard rubber balls which are smaller in diameter than the tubes and are designed to contact the tube walls intermittently rather than to continually "wipe" the tube surfaces. Additionally, replacement balls have been unavailable thus preventing use of the system at all. In the absence of the ball cleaning system, the current method of condenser tube cleaning has been to blow air through the tubes to cause deposits to dry out and flake off the tube walls.

Boiler Water Blowdown System - The Blowdown System consists of Continuous and Intermittent Systems. The Continuous system controls a small quantity of boiler drum water through two lines (32 mm) to a blowdown flash tank . In the flash tank the liquid Stage is directed either to a bubbler or to a condensate collection tank. The flashed vapor is vented to the main (6 atm) deaerators.

Intermittent blowdown is collected from the lower headers of all 30 boiler waterwall panels and is directed into a common collection header and to the bubbler. It is possible to blowdown sections separately or by groups.

Plant staff have reported no problems with the Boiler Blowdown Systems.

4.1.5 Electrical Systems and Equipment

The following is an assessment of the physical condition of major electrical equipment and systems as determined during the plant inspection and through discussion with senior plant management and operating and maintenance personnel:

220 kV Circuit Breakers

The existing 220 kV circuit breakers located in the switchyard are of the obsolete air-blast type design. They are in a deteriorated condition. The utility high voltage distribution system has undergone many changes during the last 20 years of power plant operation. New power sources have been added to the system. These additional power sources, connected through 220 kV transmission lines to the 220 kV switchyard, have increased the short circuit current on the 220 kV buses. The existing interrupting capacity of 220 kV circuit breakers are rated 25 kA or 31 kA. The breakers may not be able to open the circuit under the short circuit fault condition. This would cause a severe damage to the switchyard equipment.

220 kV Disconnect Switches

Existing 220 kV disconnect switches located in the switchyard are in deteriorated condition. They are installed to disconnect the high voltage circuit breaker during repair and maintenance and for the grounding of the disconnected high voltage equipment. Because these types of disconnect switches do not have any provision for the remote control (the remote control is required by present Russian Safety Code) it is dangerous for the power plant personnel to operate these switches.

220 kV Potential Transformers and Lightning Arrestors

The existing potential transformers and lightning arrestors located in the switchyard are of older design. These high voltage devices have old insulation and are subject to failures. They should have been replaced many years ago. The potential transformers would not have adequate capacity and accuracy for the proposed new synchronizing, metering, protection and control systems.

6.3 kV Switchgear

The existing 6.3 kV switchgear are equipped with oil-filled circuit breakers. These 6.3 kV circuit breakers are solenoid operated. The overvoltage, undervoltage, overcurrent and ground fault protection is provided by the obsolete electromechanical relays which do not operate properly to protect the switchgear equipment. The switchgear design is also based on the obsolete control concept. The installation of new DCS System would require a significant modification of the switchgear equipment and wiring, and installation of additional current transformers and transducers. The switchgear have a very high rate of ground and phase to phase faults. During the ground fault on one phase, the voltage of the other phases is raised to a very high value. This increased voltage causes the damage to 6 kV motors and other equipment connected to the 6 kV distribution system.. The switchgear is also susceptible to fire hazard becuase of oil used in the circuit breakers.

400 V Switchgear

The existing 400V switchgear are equipped with oil circuit breakers and have high contact wear. The overvoltage, undervoltage, overcurrent and ground fault protection is provided by the obsolete electromechanical relays and circuit breakers which do not operate properly to protect the switchgear equipment. The 400V switchgear design is based on the obsolete control concept. The installation of new DCS System would require a significant modification of the switchgear equipment and wiring, and installation of additional current transformers and transducers. The switchgear buses are not rated to accept the additional load that would be added due to refurbishment of other systems. The switchgear is also susceptible to fire hazards because of oil used in the 400V circuit breakers.

400 V Switchgear Transformers

The existing 400V switchgear transformers are old and do not have spare capacity to supply additional loads that would be added due to refurbishment of other systems.

Motor Control Centers

The existing motor control centers are obsolete and are located locally throughout the plant areas. MCC's are generally installed near load centers. The motor control center design is based on the obsolete control concept. The installation of new DCS System would require a significant modification of the motor control center equipment and wiring. The short circuit interrupting rating of the motor control center buses and equipment will not be adequate to match the system short circuit current of the refurbished plant..

6.3 kV Non-Segregated Phase Bus

The existing 6.3 kV non-segregated buses between unit auxiliary transformers and 6.3 kV switchgear are old. Due to the old design and the construction features, it would be very difficult to connect the buses to the new 6.3V switchgears.

220V DC Battery Chargers and Batteries

The existing battery chargers and batteries are of obsolete open type design and generate a large quantity of hydrogen during operation. The battery cell consists of an open type glass jar, plates and electrolyte. The glass jar are not explosion proof. The plate system was replaced a few years back. A built-up of sludge was observed at the bottom of the existing cells. The cell plates are not available for replacement anymore. Instead of insulated cables, the bare copper flat bars are used for the interrow connection of the batteries. The batteries require significant maintenance. The existing 220 V DC batteries and chargers have inadequate capacity to supply additional DC loads that would be added as a result of plant upgrade.

220V DC Switchboard

The existing 220V DC switchboards are of obsolete design. Flat copper leads from the battery cells are currently mounted on the wall in open air. The 220 V DC buses do not have sufficient ampacity to accommodate the required additional loads. Additional feeder circuits will be required to feed new loads. The replacement of the batteries and battery chargers will provide required ampere rating for the 220 V DC distribution system.

Electric Motors for Auxiliary Equipment

Electrical motors associated with driven equipment are generally designed for a service life of about 20 - 25 years. The motors are approaching their service life. The windings and terminal insulation of the electric motors might not be able to sustain stresses due to short circuit faults in the future.

Power, Control and Instrument Cables

All power , control and instrumentation cable are very old and are in degraded condition. Many of the cables are paper insulated and are susceptible to fire hazards. The cables are subject to the frequent short circuit faults due to the poor cable insulation. The modification of AC and DC power distribution systems would increase the value of the fault current and, therefore, the damage from the fault to the power cables would be more severe. The existing control system is rated 220 V AC and 220 V DC. The control and instrumentation cables of this system are unsuitable for the new DCS system, which requires shielded and twisted pairs cables for operation.

Cable Trays and Conduits

Currently the plant utilizes cable racks located in the cable tunnels for routing cables. The cables are run in a haphazard fashion. This method of cable support is not considered suitable for the large number of cables used in the plant. Exposed conduits are rusted at a number of locations. The existing cable trays and conduits do not have spare capacity to accommodate additional cables that would be added due to boiler refurbishment.

Protective Relay Board

The existing protective relay boards, both for the plant and the switchyard, contain electromechanical protective relays of obsolete design. The spare parts or replacement relays may be difficult to find. It might be impossible to coordinate many of these obsolete type protective relays with the new solid state protective relays. The existing protective relays require extensive maintenance. Because the relays have many moving parts, they require periodical cleaning , adjustment and setting verification. The existing relays should be replaced.

Electrical Control Board

The control devices on the existing electrical control board are of obsolete design. The Russian control and alarm systems concept is not compatible with DCS system. A number of control switches, meters and other devices may not be required with the new DCS system recommended for the plant.

Electrically Operated Valves

A number of electrically operated valves have not been working properly. Their actuators are relatively slow and are not compatible with DCS system. Repair of these electrically operated valves on piece meal basis affects plant operation.

Lighting System

The lighting system is inadequate. Certain areas of plant remain complete dark even during the day time. The lighting fixtures are of obsolete design. They have low efficiency and require frequent cleaning.

Emergency Lighting System

The existing emergency lighting system is inadequate and does not meet minimum requirements for safe egress.

Fire Detection System

The existing fire detection system is inadequate. The fire detection system is of obsolete design. It creates many false alarms and is not reliable. Fire detectors are of obsolete type. They require frequent cleaning and maintenance to keep them operable. Fire detectors are not installed in a number of plant areas.

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Main Generators

Excessive leakage of hydrogen gas from the main generator casing was reported by the operation staff of the power plant. The hydrogen gas is used as the cooling medium inside the generator casing. The hydrogen gas leakage is through the generator seal oil system. Figure 4.1.5-1 shows a typical seal ring in a hydrogen cooled machine. The hydrogen gas leakage is a safety concern in addition to increased operation and maintenance cost.

4.1.6 Instrumentation and Controls Systems and Equipment

Instrumentation and control systems utilized at Lugansk for process monitoring and controls are considered outdated by international standards. The control systems are obsolete; supervisory and protection systems are minimal; event recording and operator information systems are unreliable. The instrumentation does not lend itself to remote monitoring of plant status and performance.

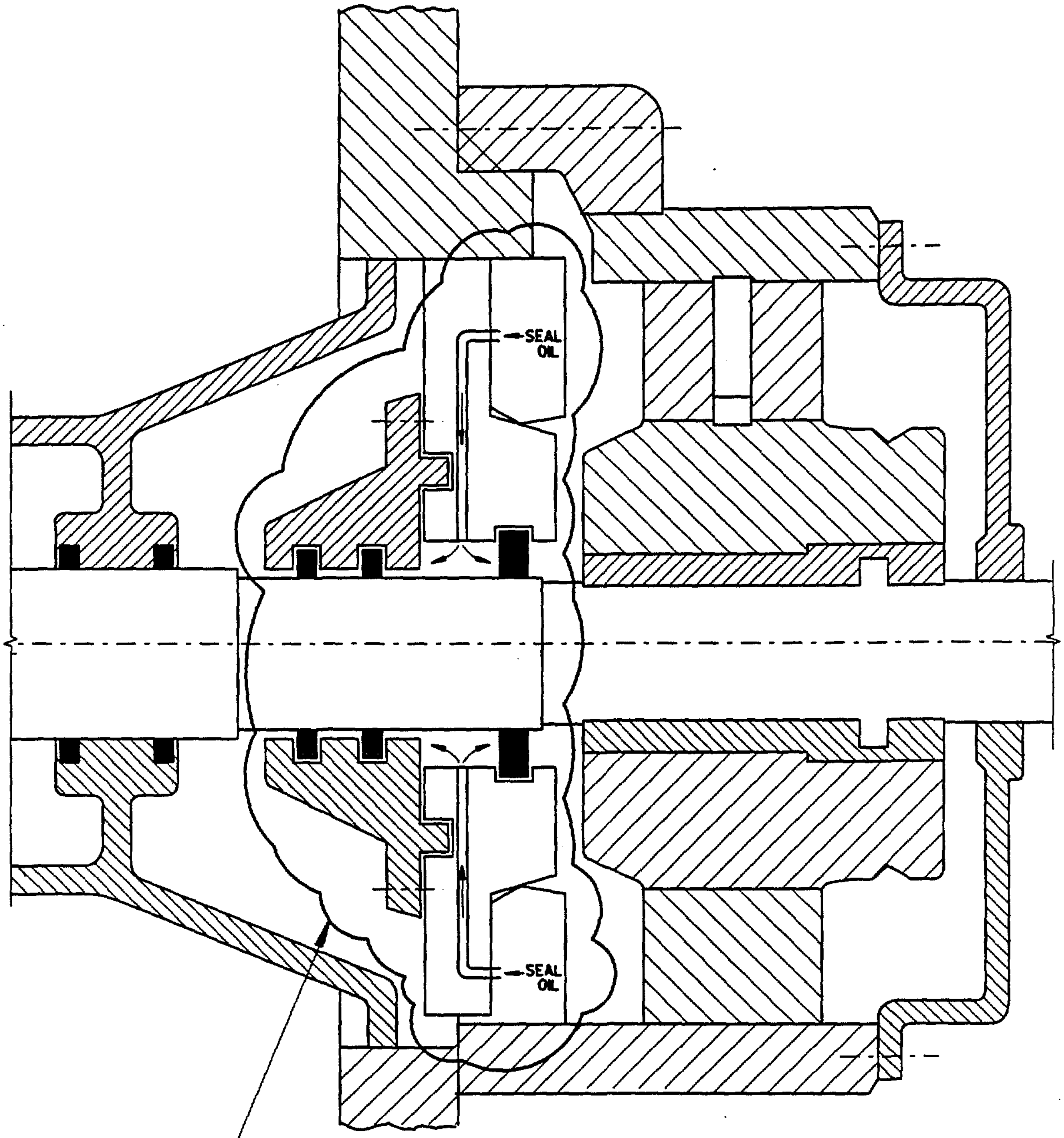
Since the commissioning of the plant in the 1960's there has been no general upgrade of plant instrumentation and controls. The existing systems are not maintained and are deteriorating. Visual examination of the control room instruments indicates that many indicating and recording instruments are performing poorly. This is due to unavailability of replacement parts. The field transmitters for process variables such as pressure, temperature, flow and level are not accurate.

The combustion control is actually a manual operation. Coal is usually fed to the boilers at maximum coal feeder speed, with co-firing of mazut or natural gas used to bring the boiler to the required load. The forced draft fan air damper positions are adjusted manually based upon a chart displayed on the control room wall, which is a function of the amount of coal and mazut or natural gas being fired and the load. Final air damper position adjustment is made based upon O_2 analyzer indications. Thus the control of fuel and combustion air ratio is essentially a manual operation based upon maintaining a certain unit load, under constant boiler outlet steam pressure and temperature.

The existing O_2 analyzers of Russian design and manufacturer require frequent maintenance and calibration. The steam boilers flue gas samples are drawn from the backpass after the superheater and before the first stage reheater. Although these analyzers are functional, they are subject to drift and significant lag time as well as inaccurate readings due to air in-leakage. This results in less than optimum control of excess air for efficient combustion which results in waste of fuel.

Currently coal flow to the coal mills is measured and controlled volumetrically, that is by controlling coal feeder speed. This method does not allow for voids in the coal flow, or for erratic operation of the feeders.

The coal delivered to the plant does not match original boiler design requirements, thus reducing boiler efficiency and increasing maintenance requirements. In addition, the poor quality of coal increases the air pollution and causes reduction in MW output of the boilers. Mazut or gas is



EXPANDED VIEW OF A TYPICAL
SEAL OIL RINGS IN A HYDROGEN
COOLED GENERATOR

FIGURE 4.1.5-1

cofired almost all the time in order to deliver the MW output required by the system and maintain stable operation of the boilers.

Coal is currently analyzed in the laboratory by taking samples from the conveyors periodically. This method takes several days to do a complete analysis.

The boilers have no burner management system and all interlocks are of a very basic design offering limited protection.

The units do not have low No_x pollution control system.

The units are operating with the original Mechanical Hydraulic Turbine Control (MHC) system. The system does not respond properly to load changes and is deteriorating due to lack of spare parts.

4.1.7 Structural Systems

The primary structures of the Power Plant include the Main Building, the Water Treatment Plant, Coal Handling Structures, Circulating Water Structures and the Switchyard Structures.

The Main Building is a steel formed structure with a combined coal bunker/deaerator bay located between the Turbine Hall and Boiler Room. The walls of this building are constructed of precast reinforced concrete panels. The roof of the building is constructed of concrete roof planking supported by metal trusses.

The lower level of the Boiler Area Houses the Ball Mills, Ash Removal Equipment and Boiler Foundations. Access to the various levels of the Boiler (i.e. sootblowers steam drums etc.) is provided through a series of structural steel stairways and platforms. The lower level of the Turbine Hall is a poured concrete slab and houses the Boiler Feedwater/Condensate Systems and Equipment. Below grade are the circulating water supply and return piping systems for the condenser. A concrete pedestal supports the Turbine Generator at the mezzanine level, which through a series of elevated walkways, provides access to the Control Room and Boiler Area.

The Water Treatment Plant is located in a separate building adjacent to the main building and is a masonry block and brick structure.

The Circulating Water Structures are constructed of masonry block and are located approximately one mile from the Power Plant on the river.

During inspections of the Facility it was observed that overall, the structural integrity of the plant appeared to be in satisfactory condition considering the age of the structures (30 plus years).

The Boiler Foundations were inspected and had some minor spalling but appeared to be in acceptable condition. The structural supports for the Boilers will require some rehabilitation work. Specifically, access platforms and stairways to the various boiler levels will require significant replacement as the existing structures are missing stairs, handrails and are generally in an unsafe condition.

The coal conveyor, coal sizing and coal storage bunker areas of the main building were inspected and are in good condition. Modifications will be required to winterize the area and to accommodate new dynamic classifiers.

The Turbine Hall and the operating floor areas surrounding the turbines of Units 10 and 13 appeared to be in good condition and will require no rehabilitation work. The Overhead Crane is operable and looked to be in excellent condition.

The Switchyard is in acceptable condition except for the areas surrounding the Unit Transformers which will require some rehabilitation work to assure the containment of any future oil leaks.

The Circulating Water Buildings for Phase 2 and 3 of the Facility are structurally in satisfactory condition.

The Circulating Water Discharge Canal is in excellent condition and will require no rehabilitation work.

The foundations supporting the particulate control devices will require complete replacement to accommodate the new technology employed in each of the previously discussed options.

The stack and foundation appeared in good condition and will not require replacement based on our discussions with the plant operating and engineering personnel.

4.1.8 Demolition Requirements

The demolition required for this portion of the project will involve different levels of effort depending on the option selected. In some areas, demolition activities will require the handling of asbestos containing material and waste oils. Handling of these types of materials is discussed in Section 7.

Major demolition is required in the area of the existing cyclones and precipitators. In this area, the existing equipment foundations, and ductwork to the stack will require complete demolition and replacement.

In some options only selected portions of the boiler will be dismantled and replaced while in other options the entire boiler is removed (except for the drum and pressure parts) and replaced. Also, a majority of the coal mill circuit is dismantled and replaced in all options.

In all options, the existing wiring for Units Nos. 10 and 13 will require complete replacement.

The control system will be completely replaced and will require the removal of the existing system.

The existing Turbine Generator is completely replaced only in extensive refurbishment Options 7 and 8 and will not require a new pedestal so only minor demolition work is required in this area.

4.2 BOILER AND BOILER AUXILIARIES - REHABILITATION DETAILS

4.2.1 Minimal Refurbishment - Minimal Emission Control

4.2.1.1 Systems and Equipment Considered for Refurbishment

Minimal Emission Control - as it was shown in Section 4.1.1.2, the effect of deteriorated fuel quality on the load carrying capability of boiler Nos. 10 and 13 is restricting turbine/generator output capability. However due to the age of the subject boilers, reliable long term operation can be ensured only if significant boiler refurbishment is done. This refurbishment will be addressed with clean coal or uncleaned coal. In addition, the boiler capacity can be restored to the original main steam flow rating of 640 tonnes per hour with the use of clean coal, as agreed in the Lugansk meetings, between the power plant personnel and the BRC team.

As indicated in the condition assessment Section 4.1.1.3, these boilers have major ambient air ingress in the refractory, insulation, lagging and casing [RILC] covering the furnace tubes. The convective back pass refractory and metal casing are deteriorated. Burns and Roe estimated the amount of area for RILC and furnace water wall and other tubes to be replaced for each boiler. This was based on conversations with GRES plant personnel and our engineering judgment.

Furnace wall tubes are experiencing high temperature corrosion attack and wall thinning due to steam blanketing. These tubes will be replaced or repaired as necessary.

Superheater and reheater pendant tube banks including inlet and outlet headers have low cycle fatigue and/or creep damage. The low steam temperature horizontal reheater and economizer tubes are experiencing erosion damage which will be replaced or repaired as necessary. The furnace roof tube penetration seals are deteriorated which will be replaced.

The superheater and reheater steam attemperator piping, thermal sleeves, spray water nozzles, flow control and isolating valves for both boiler Nos. 10 and 13 need to be inspected.

The superheater and reheater spray attemperators operate by adding high purity water through spray nozzles into the superheated steam integral pipeline. The spray water then vaporizes and mixes with the superheated steam, thus cooling it and controlling the superheated steam temperature. Due to the large temperature difference between the spray water and superheated steam (up to 250°C), the spray nozzle heads and pipeline thermal liners receive a large thermal shock each time the attemperator is used. Over the course of extended operating periods, the effect of the accumulated thermal shocks are substantial, causing attemperator failures due to thermal fatigue. Each year, spray water attemperator failures are one of the three (3) main causes of major extended forced outages in the US electric utility industry. Such forced outages can be dramatically reduced by employing a regularly scheduled inspection/replacement program for

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spray attemperators. Metallurgy lab personnel need to carry out regular checks of the attemperators.

The superheater and reheater steam attemperators piping, thermal sleeves, spraywater nozzles, flow control and isolating valves will be inspected by qualified metallurgy lab personnel and items be repaired or replaced as necessary. No. 10 boiler has a total of eight (8) attemperators and No. 13 boiler has a total of twelve (12) attemperators.

The rotary regenerative air preheaters have higher than design cold air to flue gas side leakage and the baskets are experiencing fouling. The cold air to flue gas leakage for each regenerative air preheater will be reduced to original design value by complete replacement of axial and circumferential seals. Also a soot blower will be added to each regenerative air preheater. It is current practice in the United States and abroad to have a sootblower for each regenerative air preheater. This is to enable on-line cleaning of the rotating heating surfaces. The flue gas ducting from rotary air preheater to particulate emission control equipment and from particulate emission control equipment to stack has corrosion damage which will be refurbished, the expansion joints for the cold end of rotary air preheater are deteriorated. This deteriorated condition of the expansion joints is caused partly by the formation of sulfuric acid in flue gas due to the sulfur content in the fuel and the presence of moisture in the flue gas. Additional moisture can be added to the flue gas stream due to economizer tube leaks, incomplete water washing and unprotected FD fan inlets. The presence of sulfuric acid and presence of moisture in the flue gas cause dewpoint corrosion, particularly of the cold end metallic expansion joints for the rotary air preheater. Acid resistant non-metallic (fabric) expansion joints will be used for this replacement. These fabric expansion joint will have a longer service life.

The induced draft fans are experiencing erosion damage of housing and fan impeller. The ID fan housings will be repaired as necessary and lined with a ceramic material. The ID fan impellers will be replaced or repaired as necessary. Each impeller will be balanced in the field.

Firing system for each boiler has abrasion and erosion damage in the circulating air centrifugal separating cyclones, primary air/pulverized coal (PA/PC) ducting, raw coal conduits, vent conduits, ball mill liners and PA/PC coal conduits. In conjunction with the upgrade of the ball mills, the existing static classifier will be replaced by a dynamic classifier. This dynamic classifier for each ball mill will increase the pulverized coal fineness. This will result in a more stable flame with reduced amounts of natural gas auxiliary fuel support required and reduced unburnt carbon in flyash efficiency loss.

A Dynamic Classifier provides effective particle separation through the application of the following theoretical principles:

Coal particles of varying size are transported pneumatically by the PA flow into the classifier where they impinge against the rotating separator vanes. At this point the coal particles are under the influence of a centripetal force ® due to the radial air flow, as well as centrifugal force (F_c)

resulting from the rotating vanes. When the centrifugal force acting on a particle is greater than the centripetal force, the particle is ejected out of the separator. The centripetal force magnitude is related to the particle size as well as air flow velocity, while the centrifugal force is related to particle size and the separator radius and RPM as described below. Thus, at a fixed PA flow the separator RPM can be adjusted to eject particles of a given size or larger while permitting the smaller particles to pass through. Once an operating curve is created, the separator RPM can be automatically adjusted according to PA flow for optimum performance (See Figure 4.2-1).

The hot PA circuit control and isolating dampers are operating poorly which will be refurbished. The fuel injectors of boiler #10 and swirl burners of boiler #13 are experiencing metal loss due to oxidation, distortion, due to high metal temperatures. These parts will be replaced or refurbished as necessary.

The wet bottom furnace slag tap refractory lining is worn, exposing water wall tubing. Excessive tube repair is being experienced in this area. This lining will be replaced.

The sootlances for pendant superheater and reheater and pulse/vibratory sootcleaning system is not operating properly. This is resulting in higher flue gas side pressure loss and increased heating surface fouling. These soot cleaning systems will be repaired as necessary.

A burner management system including flame scanners will be added for pulverized coal, natural gas and mazut fires. This will greatly improve plant safety.

There is no continuous emission monitoring system (CEM) for NO_x, SO_x, CO and particulates for both boiler Nos. 10 and 13. A CEM will be added for each boiler.

The load capability of the boiler is limited during wet coal conditions because only one (1) mill per boiler has a mazut duct burner for primary air temperature boosting. A new mazut duct burner will be added for each boiler and the existing mazut fired duct burner will be refurbished.

In general, the modifications are considered as minimal and their purpose is to increase boiler availability and reliability and reduce maintenance costs. If uncleaned coal is used with these minimal modifications the derated steam flow of 400 tonnes per hour will remain at the present level with an estimated 30% natural gas boiler auxiliary fuel support firing. But if cleaned coal is used with these minimal modifications, the boiler steam flow will be restored to the original level of 640 tonnes per hour with the use of natural gas auxiliary fuel support firing estimated of 15%.

The plant personnel at Lugansk GRES stated that the original boiler with the design coal (similar in characteristics to clean coal) did not require auxiliary natural gas fuel support firing. However Burns and Roe considers it necessary to take into account other operating variables and predicts 15% of natural gas support firing with clean coal.

The list of minimal upgrades for the TP-100 type boilers of the 200 MW units includes the following:

- Replace localized areas at RILC covering furnace tubes
- Partial replacement of furnace wall tubes
- Partial replacement of superheater and reheater pendant tube banks including headers
- Repair of furnace roof tube penetration seals
- Complete replacement of air preheater seals
- Add sootblower cleaning system to each air preheater
- Inspect superheater and reheater attemperators
- Replace flue gas ducting
- Repair ID fan casing and coat with ceramic lining
- Replace or repair ID fan impellers as required. Balanced each impeller in the field.
- Replace air preheater expansion joints
- Repair/refurbish ball mills including dedicated seal air fans, mill coal level and powersonic or similar ball charge automatic control/monitoring system
- Repair/refurbish fuel injectors no. 10 boiler and swirl type burners no. 13 boiler.
- Refurbish wet bottom furnace slag tap refractory lining as required
- Repair sootlances and pulse/vibratory sootcleaning systems
- Add burner management system to monitor pulverized coal, natural gas and mazut firing
- Add continuous emission monitoring system CEM for boiler No. 10 and 13
- Add a mazut fired duct burner for ball mill PA temperature boost on each boiler. Also refurbish each existing mazut fired duct burner on each boiler.

In summary, the minimal modifications and upgrades for boiler Nos. 10 and 13 together with their benefits are shown in Table 4.2.1.

Table 4.2.1

Minimal Modifications and Upgrades

For Boiler Nos. 10 and 13

ITEM NO.	ITEM DESCRIPTION	BENEFIT	IMPROVEMENT
1	Replace RILC in furnace area	R, M	A
2	Repair convective back pass refractory and casing	R, M	A
3	Replace furnace wall tubing	R, M	A
4	Replace/repair superheater and reheater pendant tube bands with inlet and outlet headers (This item will be done by Lugansk GRES).	R, M	
5	Repair/replace low temperature reheater tubes	R, M	
6	Repair/replace economizer tubes	R, M	
7	Inspect superheater and reheater attemperator components	R, M	
8	Install erosion shield for superheater, reheater and economizer tubes	R, M	
9	Replace furnace roof tube penetration seals	R, M	A
10	Replace air preheater radial and circumferential seals. Add swinging arm sootblower for each air preheater	R, M	A
11	Repair ID fan casing and install ceramic liner. Repair/replace ID fan impellers as necessary	R, M	A
12	Refurbish flue gas ducting from rotary air preheater to particulate emission control equipment and from emission control equipment to stack. Replace metallic expansion joints at the cold end of rotary air preheater with new upgraded fabric type expansion joint.	R, M	A
13	Repair/refurbish grinding circuits, two per boiler, including circulating air centrifugal fans, separating cyclones, PA/PC ducting, raw coal conduits, vent conduits. Retro-fit abrasion resistant ceramic tiling in areas of high erosion damage.	R, M	
14	Replace existing static, centrifugal type with rotary [dynamic] type.	R, M	A
15	Repair/refurbish trunnion seals, seal air system including dedicated seal air fans, mechanical components, as required for each ball mill. Retro-fit mill coal level and ball charge weight automatic control/monitoring system [Powersonic or similar]	R, M	B
16	Refurbish/repair fuel injectors [eight per boiler for #10] swirl burners [sixteen per boiler for #13].	R, M	
17	Refurbish wet bottom furnace slag tap refractory lining as required	R, M	
18	Refurbish sootlances, retractable of the pendant superheater and reheater tube banks, also the pulse/vibratory sootcleaning system of each boiler, refurbish as required	R, M	

19	Add burner management system for each boiler, including individual burner flame scanners, for pulverized coal, natural gas, mazut firing	R, M	
20	Add continuous emission monitoring [CEM] system for monitoring No_x, So_x, CO, particulates, unburnts, install for each boiler	M	-
21	Add duct burner for ball mill inlet PA temperature boost , mazut fired: repair/refurbish existing one per boiler, install one per boiler new duct burner system complete	R, M	C

Legend		
	R -	Increase Reliability
	M -	Reduce Maintenance
	A -	Reduce Auxiliary Power
	B -	LOI reduction and output
	C -	Increased steam output

4.2.1.2 Performance Improvement

It should be pointed out that use of clean coal with the minimal refurbishment will restore the boiler steam output to the design output of 640 tonnes per hour and 15% auxiliary natural gas firing required. The use of unclean coal with minimal refurbishment result in the maximum (derated) boiler steam output of 400 tonnes per hour with 30% auxiliary natural gas firing required. The reduction of ingress of ambient air due to repair of casing, roof tube penetration seals, expansion joints, ducts will reduce the ID fan auxiliary power requirements and will result in more stable combustion condition. The replacement of air preheater seals will reduce both FD and ID fan auxiliary power requirements.

4.2.2 Minimal Refurbishment - Improved Emission Control

4.2.2.1 System and Equipment Considered for Refurbishment

This option is the same scope of work as stated in Section 4.2.1.1 but includes replacement low NOx burners.

When the new source performance standards were enacted in the United States, this prompted boiler manufacturers to offer low NOx producing burners.

The typical new, double register low NOx burner retains the proven feature of tangential admission of coal and primary air into the burner body and is fitted with two air registers in series for complete control of the axial and radial velocities of the secondary air. Each burner is also equipped with its own -perforated air hood and movable sleeve to allow the independent measurement and control of air flow to individual burners. (See Fig. 4.2-2).

The design evolved results in a more gradual mixing of the primary air-coal stream with the secondary air, since both streams now enter the furnace on parallel paths with controlled mixing. The movable sleeves are adjusted during commissioning to accurately balance the air to each burner to keep carbon monoxide emissions as low as possible. No further movement of the sleeve is anticipated after initial balancing. Normal on/off control of secondary air for light-off or for shutdown of individual, or groups of, burners is accomplished by remote, manual or automatic operation of the larger outer burner register only.

To further reduce NOx level or to increase design margin, individual manufacturers will offer priority over fire air ports, burner staging and/or boundary air slots. For welded wall furnace construction only, boundary air ports can be added (See Figure 4.2-3). These ports inject combustion air along the sidewalls, producing a high excess oxygen concentration that will not vary significantly as all mills are taken in and out of services over the boiler's control range. A boundary air system can maximize the overall flexibility to control oxygen distribution during combustion.

4.2.2.2 Performance Improvement

The performance improvement for these options are the same as stated in Section 4.2 but will have an improvement in emission levels as shown in Table 4.2.2.2.

4.2.3 Conversion to Double Arch Firing - Improved Emission Control

4.2.3.1 System and Equipment Considered for Refurbishment.

This option is the same scope of work as stated in Section 4.2.1 but includes removing the entire furnace enclosure and replacing with welded membrane furnace tube walls and furnace roof. Also included is furnace double arches with tube openings for slot type pulverized coal burners. Also the furnace framing system, lower furnace fireside refractory lining, insulation and lagging will be replaced.

Welded wall construction was developed by several American boiler manufacturers in the 1950's to improve boiler reliability and reduce maintenance costs. Today, welded wall construction for utility type boilers is standard for both American and foreign manufactured boilers (See Figure 4.2-4).

These welded wall panels form a gas tight enclosure, thereby eliminating gas leakage and false air ingress and subsequent casing corrosion or burnout. Such construction also reduces material and maintenance costs, simplifies design and improves structural rigidity.

It also permits the use of simple outer casing insulation which is easily removed, exposing all pressure parts. From the standpoint of maintenance, this easy access feature represents a real time-saving advantage.

In conjunction with adding fully welded furnace walls and roof tubes, the furnace walls will be rearranged in a double arch with new downward pulverized coal fired burners and suitably positioned fireside refractory cover. (See Figures 4.2-5, 4.2-6).

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The typical new anthracite burners which will be added, receive a decreased air-coal ratio of the mixture leaving the burner nozzle to a value which will assure quick and stable ignition of low volatile fuels. In most cases, the continuous use of natural gas firing to stabilize the pulverized coal flame is not required. The down fired burner arrangement permits a longer flame path which results in lower NOx and lower loss on ignition (LOI) in bottom ash (See Fig. 4.2-7).

The rearranged configuration furnace will have a dry bottom i.e. dry bottom ash. Disposal will be with submerged scraper conveyors (two per boiler). The furnace tube hopper slopes will be increased accordingly, from 15 to 50 degrees from the horizontal (two tube hoppers per boiler). For the uncleaned coal firing alternative of the double arch down-fired furnace boiler, it will be necessary to replace the existing ball mills with two (2) per boiler ball mills with an increased coal throughput of 60 te/h each.

In summary, the minimal modification and upgrades including double arch firing in a dry bottom furnace and new low Nox burners for boiler Nos. 10 and 13 together with their benefits are shown in Table 4.2.3.1.

4.2.3.2 Performance Improvement

The performance improvement for these options are the same as stated in Section 4.2.1 but will result in improvement of emission levels as stated in Section 4.2.2 and will reduce the amount of natural gas required to support coal firing (See Table 4.2.2.2). Also the main steam output will be restored to the original design value of 640 ton/hour for both the clean coal and uncleaned coal firing, as agreed in the Lugansk meetings between power plant personnel and BRC team.

Table 4.2.3.1

Conversion to Arch Firing-Improved Emission Control

For Boilers No. 10 and 13

ITEM NO.	ITEM DESCRIPTION	BENEFIT	IMPROVEMENT
1	Replace RILC in furnace area	R, M	A
2	Repair convective back pass refractory and casing	R, M	A
3	Replace furnace wall tubing with membrane wall including furnace roof with double arch configuration and fireside refractory coverage	R, M	A
4	Replace/repair superheater and reheater pendant tube bands with inlet and outlet headers (This item will be done by Lugansk GRES).	R, M	
5	Repair/replace low temperature reheater tubes	R, M	
6	Repair/replace economizer tubes	R, M	
7	Inspect superheater and reheater attemperator components	R, M	
8	Install erosion shield for superheater, reheater and economizer tubes	R, M	
9	Replace furnace roof tube penetration seals	R, M	A
10	Replace air preheater radial and circumferential seals. Add swinging arm sootblower for each air preheater	R, M	A
11	Repair ID fan casing and install ceramic liner. Repair/replace ID fan impellers as necessary	R, M	A
12	Refurbish flue gas ducting from rotary air preheater to particulate emission control equipment and from emission control equipment to stack. Replace metallic expansion joints at the cold end of rotary air preheater with new upgraded fabric type expansion joint.	R, M	A
13	Repair/refurbish grinding circuits, two per boiler, including circulating air centrifugal fans, separating cyclones, PA/PC ducting, raw coal conduits, vent conduits. Retro-fit abrasion resistant ceramic tiling in areas of high erosion damage.	R, M	
14	Replace existing static, centrifugal type with rotary [dynamic] type.	R, M	B
15	Repair/refurbish trunnion seals, seal air system including dedicated seal air fans, mechanical components, as required for each ball mill. Retro-fit mill coal level and ball charge weight automatic control/monitoring system [Powersonic or similar]. For uncleaned coal, install two (2) 60 ton per hour ball mills per boiler.	R, M	C for unclean coal only
16	Install new slot burners for each boiler	R, M	B
17	Furnace tube hopper modifications for dry bottom ash removal	R, M	
18	Refurbish sootlances, retractable of the pendant superheater and reheater tube banks, also the pulse/vibratory sootcleaning system of each boiler, refurbish as required	R, M	

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19	Add burner management system for each boiler, including individual burner flame scanners, for pulverized coal, natural gas, mazut firing	R, M	
20	Add continuous emission monitoring [CEM] system for monitoring NO_x, SO_x, CO, particulates, unburnts, install for each boiler	M	-
21	Add duct burner for ball mill inlet PA temperature boost , mazut fired: repair/refurbish existing one per boiler, install one per boiler new duct burner system complete	R, M	C for wet coal conditions

Legend R - Increase Reliability

M - Reduce Maintenance

A - Reduce Auxiliary Power

B - LOI reduction

C - Increased steam output

4.2.4 Extensive Refurbishment - Improved Emission Control

4.2.4.1 Systems and Equipment considered for Refurbishment

This option is the same scope of work as stated in Section 4.2.1 but includes welded membrane furnace and roof tube panels but in the original furnace configuration. Included are new horizonal fired low NOx burners. With the firing of unclean coal, two (2) new 60 ton per hour ball mills are required for each boiler.

In summary, extensive refurbishment with the existing configuration of boiler does not appear to be an economical alternative, because the relatively small capital cost of adding double arch firing and slot burners will be less than the considerable savings in auxiliary natural gas firing over the remaining life of the boiler, of the double arch fired furnace design. This option is only for cost comparison to the option presented in Section 4.2.3. This option together with the benefits are shown in Table 4.2.4.2.

4.2.4.2 Performance Improvement

The use of clean coal with the extensive refurbishment will restore the boiler steam output to the design output of 640 tonnes per hour and 5% auxiliary natural gas firing required. The use of unclean coal with extensive refurbishment will result in the maximum boiler steam output of 640 tonnes per hour with 15% auxiliary natural gas firing required. The reduction of ingress of ambient air due to the retrofit fully welded furnace tubewall, roof tube penetration seals, expansion joints, ducts will reduce the ID fan auxiliary power requirements and will result in more stable combustion condition. The replacement of air preheater seals will reduce both FD and ID fan auxiliary power requirements.

Table 4.2.4.2

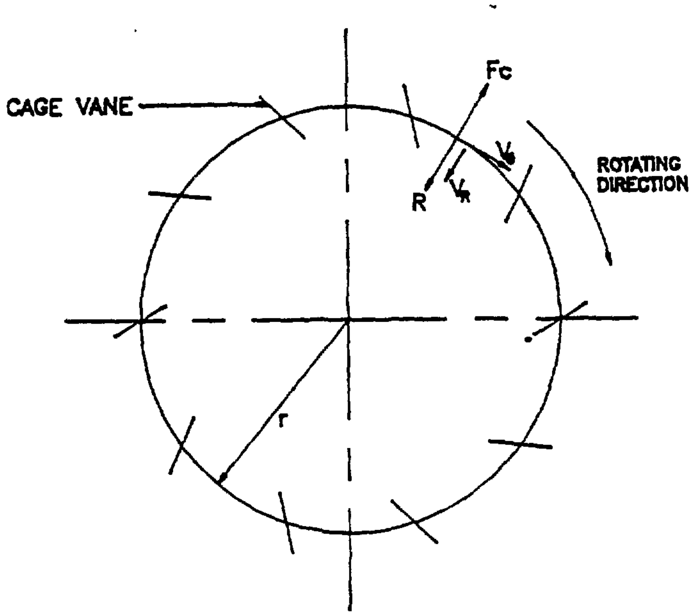
Extensive Refurbishment - Improved Emission Control

For Boilers No. 10 and 13

ITEM NO.	ITEM DESCRIPTION	BENEFIT	IMPROVEMENT
1	Replace RILC in furnace area	R, M	A
2	Repair convective back pass refractory and casing	R, M	A
3	Replace furnace wall tubing with welded membrane wall including furnace roof, with the existing configuration	R, M	A
4	Replace/repair superheater and reheater pendant tube bands with inlet and outlet headers (This item will be done by Lugansk GRES).	R, M	
5	Repair/replace low temperature reheater tubes	R, M	
6	Repair/replace economizer tubes	R, M	
7	Inspect superheater and reheater attemperator components	R, M	
8	Install erosion shield for superheater, reheater and economizer tubes	R, M	
9	Replace furnace roof tube penetration seals	R, M	A
10	Replace air preheater radial and circumferential seals. Add swinging arm sootblower for each air preheater	R, M	A
11	Repair ID fan casing and install ceramic liner. Repair/replace ID fan impellers as necessary	R, M	A
12	Refurbish flue gas ducting from rotary air preheater to particulate emission control equipment and from emission control equipment to stack. Replace metallic expansion joints at the cold end of rotary air preheater with new upgraded fabric type expansion joint.	R, M	A
14	Repair/refurbish grinding circuits, two per boiler, including circulating air centrifugal fans, separating cyclones, PA/PC ducting, raw coal conduits, vent conduits. Retro-fit abrasion resistant ceramic tiling in areas of high erosion damage.	R, M	
15	Replace existing static, centrifugal type with rotary [dynamic] type.	R, M	B
16	Repair/refurbish trunnion seals, seal air system including dedicated seal air fans, mechanical components, as required for each ball mill. Retro-fit mill coal level and ball charge weight automatic control/monitoring system [Powersonic or similar]. For uncleaned coal, install two (2) 60 ton per hour ball mills per boiler.	R, M	B
17	New swirl burners [sixteen per boiler] low NOx design.	R, M	B
18	Refurbish wet bottom furnace slag tap refractory lining as required	R, M	
19	Refurbish sootlances, retractable of the pendant superheater and reheater tube banks, also the pulse/vibratory sootcleaning system of each boiler, refurbish as required	R, M	

20	Add burner management system for each boiler, including individual burner flame scanners, for pulverized coal, natural gas, mazut firing	R, M	
21	Add continuous emission monitoring [CEM] system for monitoring NO$_x$, SO$_x$, CO, particulates, unburnts, install for each boiler	M	-
22	Add duct burner for ball mill inlet PA temperature boost , mazut fired: repair/refurbish existing one per boiler, install one per boiler new duct burner system complete	R, M	C with wet coal

Legend	R -	Increase Reliability
	M -	Reduce Maintenance
	A -	Reduce Auxiliary Power
	B -	LOI reduction and output
	C -	Increased steam output



$$F_C = \frac{\pi D_p^3 \rho_p V_\theta^2}{6r}$$

$$R = \frac{\pi C_D D_p^2 V_R^2 \rho_A}{8}$$

<u>Where</u>:

D_p : Diameter of Coal Particle
ρ_p : Density of Coal Particle
V_θ : Rotating Speed of Vane
r : Radius of Separator

C_D : Drag Coefficient
V_R : Radial Velocity of Air
ρ_A : Density of Air

FIGURE 4.2-1

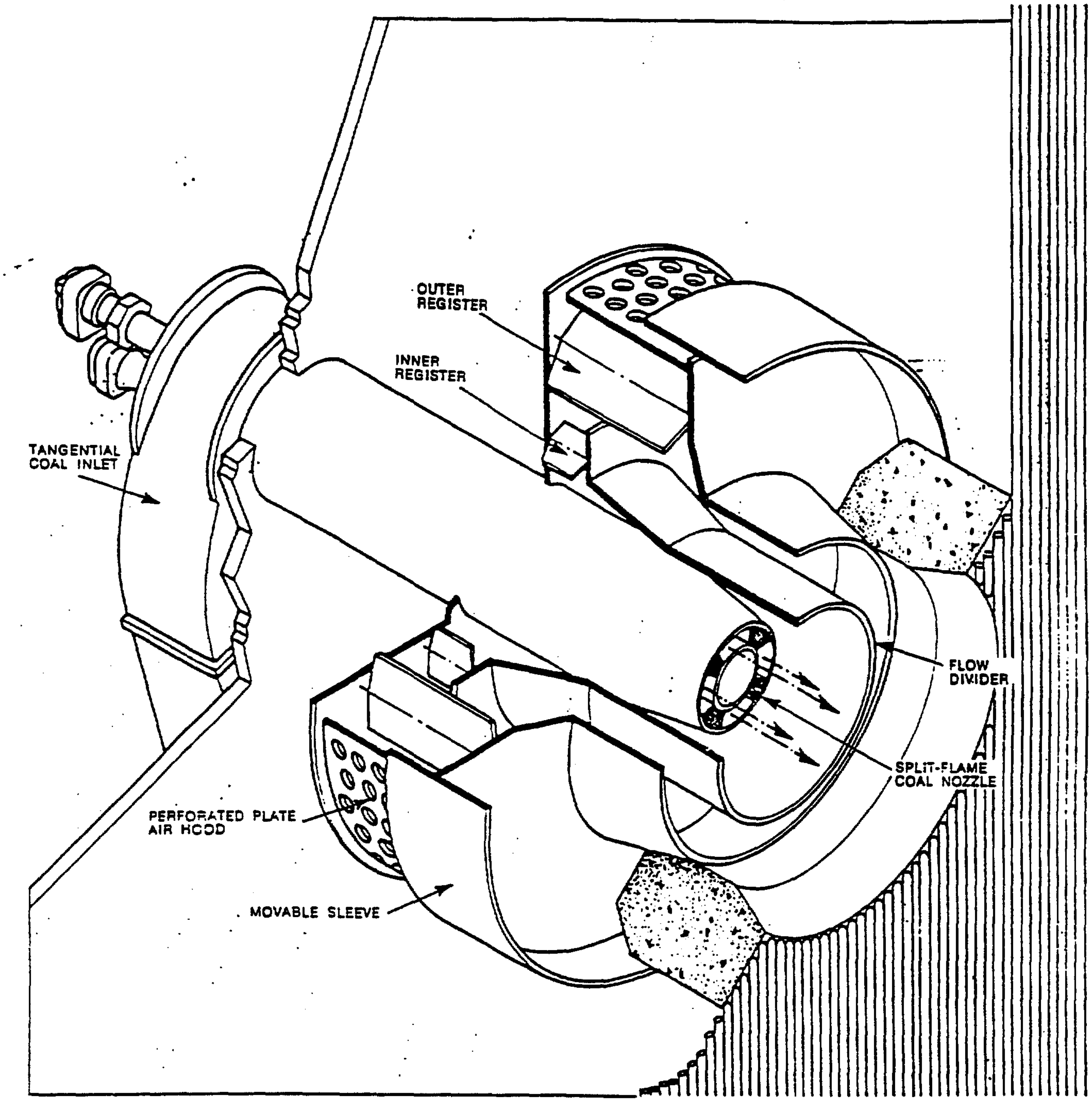

OUTER REGISTER
INNER REGISTER
TANGENTIAL COAL INLET
FLOW DIVIDER
SPLIT-FLAME COAL NOZZLE
PERFORATED PLATE AIR HOOD
MOVABLE SLEEVE

FIGURE 4.2-2

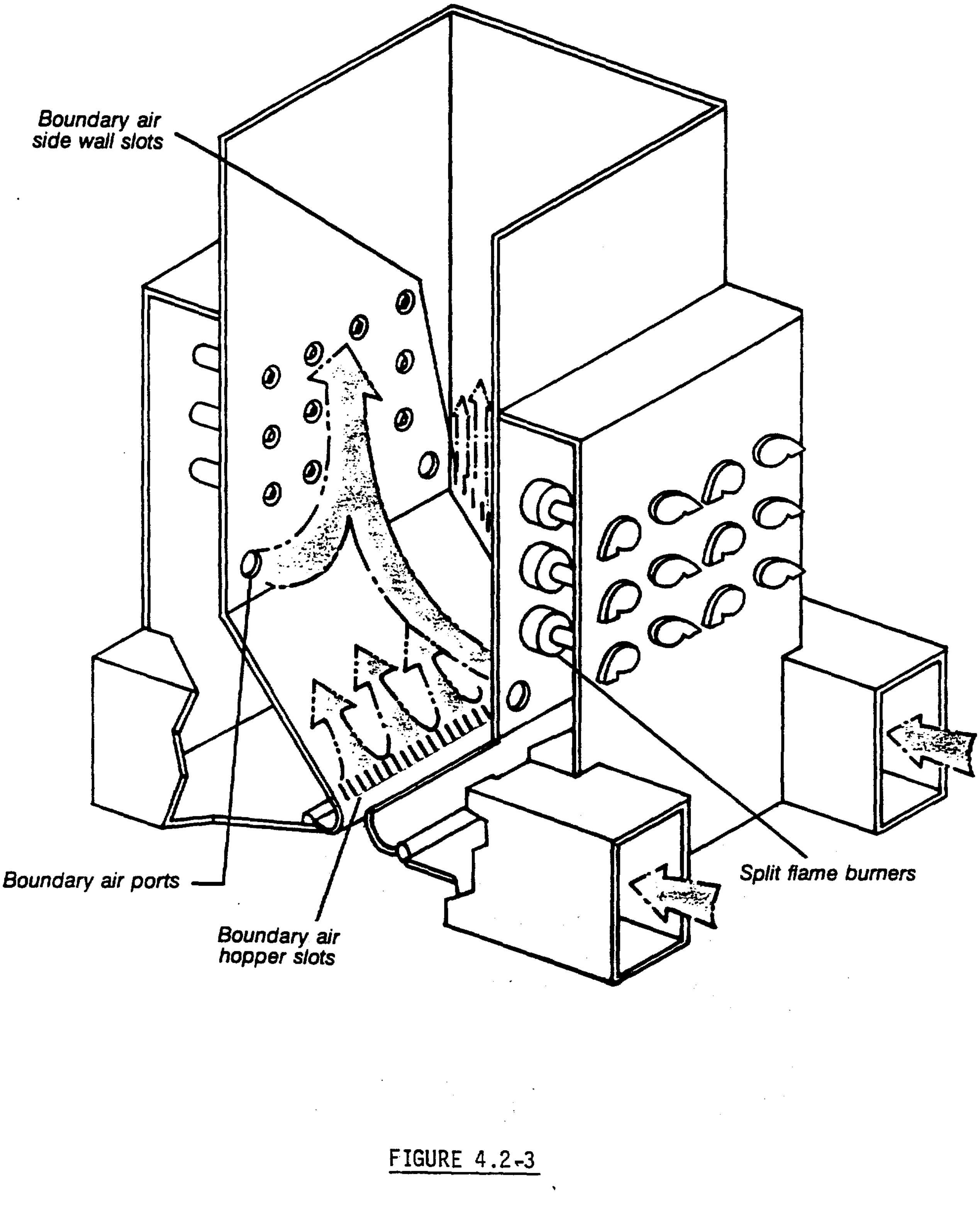

Boundary air side wall slots
Boundary air ports
Boundary air hopper slots
Split flame burners

FIGURE 4.2-3

BOILER ENCLOSURE WALL
FLUSH LAGGING

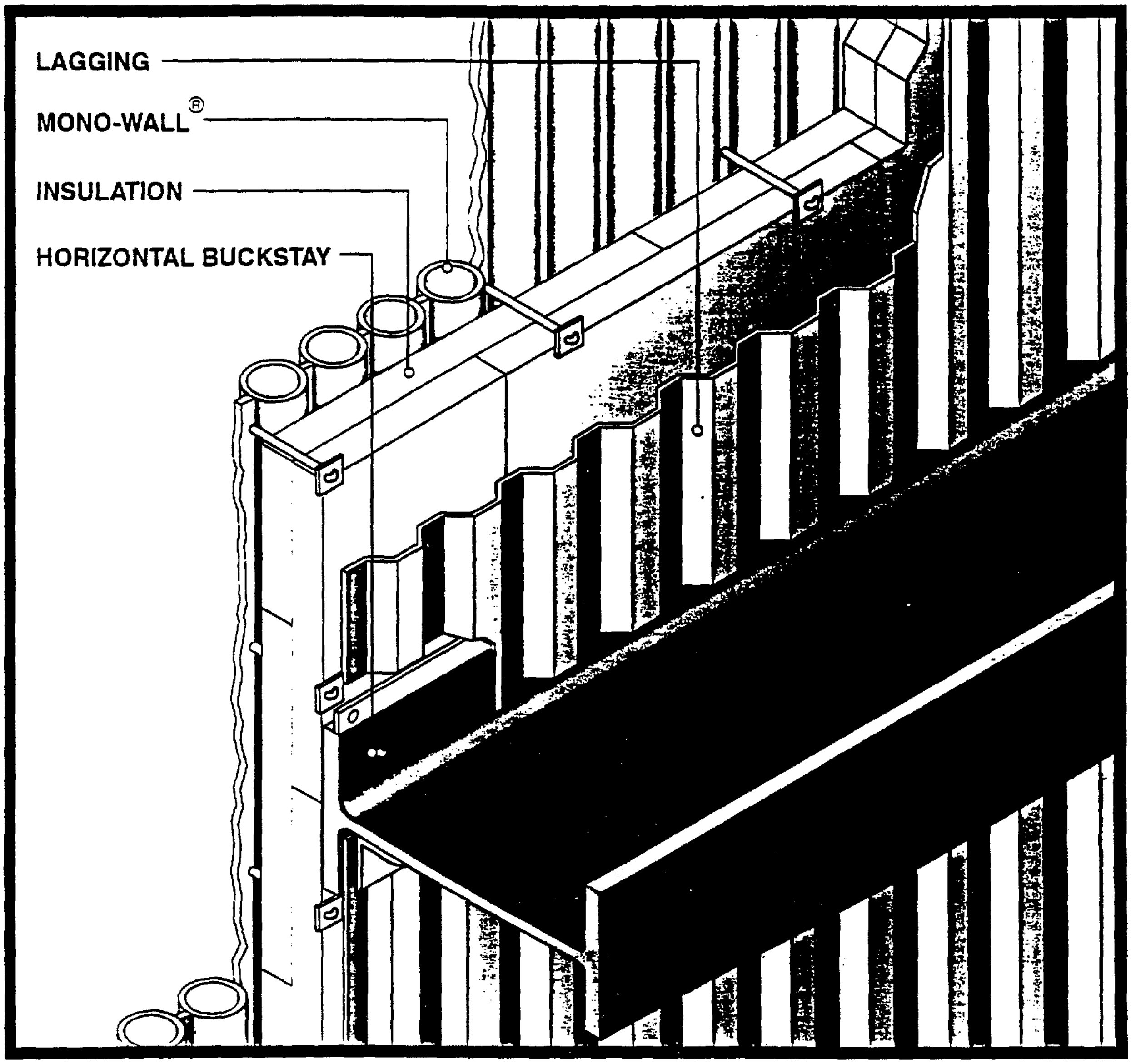


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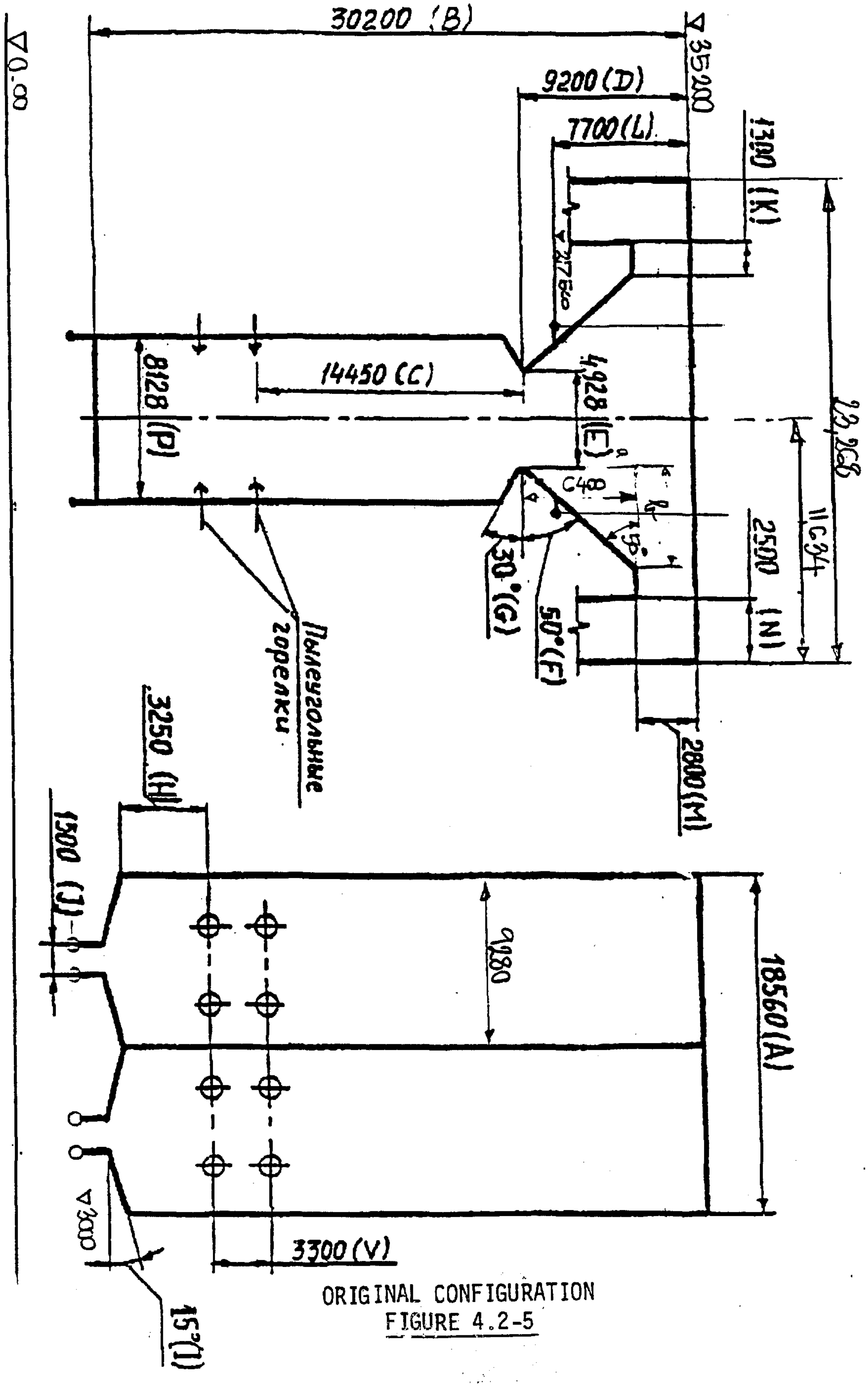
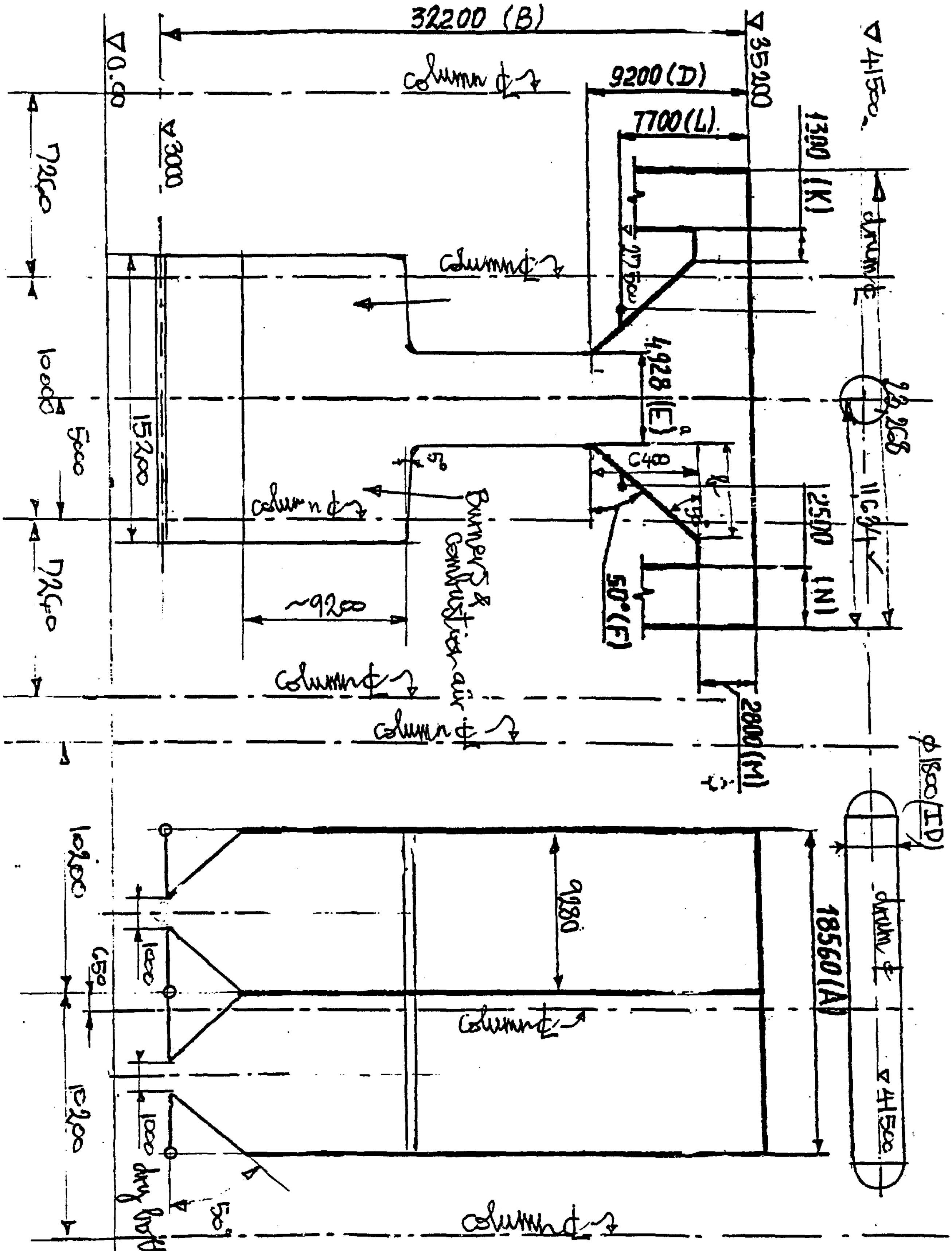
FIGURE 4.2-4



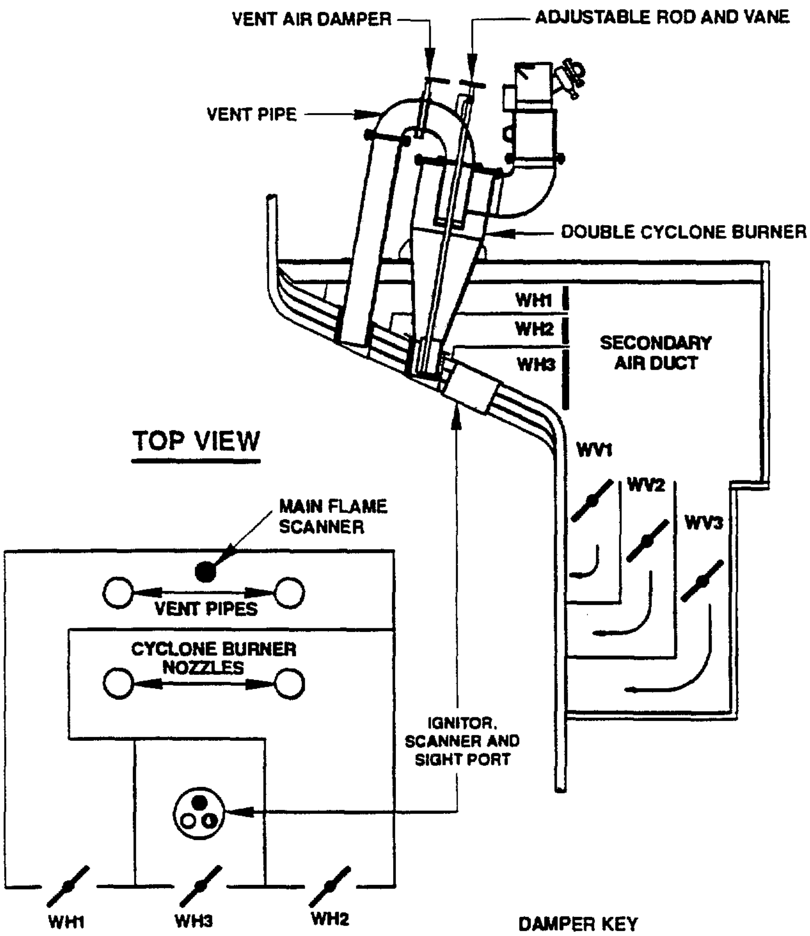
ORIGINAL CONFIGURATION

FIGURE 4.2-5



DOUBLE ARCH
DOWN FIRED FURNACE
FIGURE 4.2-6

DOUBLE CYCLONE BURNER ASSEMBLY AND DAMPER ARRANGEMENT



DAMPER KEY

WH1	VENT PIPE AIR	● LOCAL MANUAL SET
WH2	CYCLONE NOZZLE AIR	● LOCAL MANUAL SET
WH3	IGNITOR AIR	● REMOTE AUTOMATIC FROM BMS ☐ CLOSED WHWN IGNITOR O/S ☐ OPEN WHEN IGNITOR I/S
WV1	VERTICAL AIR WALL - ZONE 1	● LOCAL MANUAL SET
WV2	VERTICAL AIR WALL - ZONE 2	● LOCAL MANUAL SET
WV3	VERTICAL AIR WALL - ZONE 3	● REMOTE AUTOMATIC FROM CCS ☐ CLOSED WHEN IGNITOR O/S ☐ LIGHT-OFF POSITION WHEN CYCLONE I/S BUT BELOW INTERMEDIATE LOAD ☐ OPEN WHEN CYCLONE I/S AND ABOVE INTERMEDIATE LOAD

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FIGURE 4.2-7

4.3 EMISSION CONTROLS - REHABILITATION DETAILS

Details of the rehabilitation requirements and recommendations for each of the potential rehabilitation options are described in this section of the report. Since boiler and turbine rehabilitation options for Unit 10 and Unit 13 are almost identical, the recommendations and associated investment and operating costs are addressed only once and are applicable to both unit rehabilitation programs.

4.3.1 Minimal Refurbishment - Minimal Emission Controls

4.3.1.1 Particulate Emissions

Upgrading of the particulate emission control equipment is provided by this option. Particulate emission limits for the unit are 150 mg/Nm^3 which requires a collection efficiency of 99.6% for the uncleaned coal and 99.1% for the cleaned coal. To achieve this emission limit the existing particulate collection equipment will be replaced with high efficiency particulate collection equipment. Alternatives are described below.

Electrostatic Precipitator (ESP) Replacement

Assuming boiler steam and flue gas production rates remain substantially unchanged, the design requirements for a replacement ESP which can accomplish the required collection efficiency are estimated as follows:

Fuel Fired	Uncleaned Coal	Cleaned Coal
Steam Production, t/hr	400	564
Flue Gas Volume, Am^3/hr	933,000	1,265,500
ESP Design Efficiency, %	99.6	99.1
SCA Required, ft^2/1000ACFM	550	425
ESP Plate Area Required, m^2 (Including Design Margin)	30,870	32,350

An ESP design to achieve the 150 mg/Nm^3 limit, based on western technology, would have the following characteristics:

	Uncleaned Coal	Cleaned Coal
Field Height, m/.	14.63	14.63
Design Velocity, m/s	1.21	1.21
ESP Width, m.	14.6	19.8
Plate Spacing, mm.	304.8	304.8
Gas Passages	48	65
Plate Length, m.	22.5	17.3

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Estimated Overall Dimensions, m.		
Length (Excluding Inlet/Outlet)	25	20
Width	16	21
Height (Including Hoppers)	23	23

The proposed ESP, 21meters wide x 20 meters in length, occupies almost the same plot area as the existing ESPs while providing some 2.3 times the plate area. This is accomplished by utilizing collecting plates of a greater height (14.6 meters vs.8.1 meters), closer plate spacing (305 mm vs. 340 mm) and fewer accessways within the ESP. This design is considered "standard" for Western technology ESP.

The budgetary price for engineering and material supply, FOB East Coast USA, for **either** ESP is $2.2 million.

Fabric Filter Particulate Collection Equipment

As an alternate to the application of ESP to fly ash collection, fabric filter systems may be installed. Both Reverse Air and Pulse Jet Baghouses have been utilized to collect ash and dust from flue gas. While the reverse-air designs accounted for the majority of utility installations in the past, pulse jet type fabric filters are growing in popularity and are now the primary choice for many applications.

In the pulse jet design, flue gas containing particulate material (dust) enters the hopper below the bags and is collected on the bag's outside surface. The bags are connected to the tube sheet at the top. To prevent collapse of the bags during filtering, each bag is fitted with an internal wire cage. Bags are cleaned by short "pulses" of air delivered at the top of the bags in the reverse direction of the gas flow. These pulses cause bag movement that, combined with the back-flushing action, dislodge the dustcake collected on the outside of the bag. The dust falls into the hopper below. The cleaned flue gas leaves the fabric filter and is exhausted to the atmosphere through the stack.

The advantage of fabric filters over ESPs is the very high dust collection efficiency of the fabric filters, especially when considering fine particulate matter. Where high collection efficiency is required, for high resistivity ash, pulse jet fabric filters may be more cost effective than ESPs.

Two (2) fabric filter systems, each containing four compartments, would be provided to clean the flue gas generated in this option. The two fabric filters would occupy a plot area similar to the proposed ESP. The budgetary price for engineering and material supply, FOB East Coast USA, for such a fabric filter system is about $3.5 million for the uncleaned coal and $4.7 million when cleaned coal is fired. The increase in cost for the cleaned coal operation is the result of the greater steam output and flue gas volume generated when firing cleaned coal and the fact that fabric filter sizing and cost is sensitive to gas volume rather than to particulate collection efficiency.

Application of fabric filter technology to particulate collection would increase the auxiliary power requirements for the unit and possibly require replacement of the boiler ID fan to achieve the greater fan head required to operate with fabric filters installed in the gas path. Pressure loss through the fabric filter is estimated at 170 mm H_2O.

Based on this analysis, electrostatic precipitator technology has been selected for particulate control for this option.

4.3.1.2 NOx Emissions

NOx reduction equipment is not provided with this option. NOx emissions remain as 1600 mg/Nm^3 when firing the uncleaned coal and are estimated at 1300 mg/Nm^3 when firing the cleaned coal.

4.3.1.3 Sulfur Dioxide Emissions

SO_2 reduction equipment is not provided with this option. SO_2 emissions remain as 6,660 mg/Nm^3 when firing the uncleaned coal and are estimated at 5,206 mg/Nm^3 when firing the cleaned coal.

4.3.2 Minimal Refurbishment - Improved Emission Controls

Upgrading of the particulate emission controls and application of sulfur dioxide and nitrogen oxide emission control is provided by this option. Flue gas flow rates and uncontrolled emissions are as previously reported in Section 4.3.1. Emission limit targets and required emission reduction efficiencies are as follows:

	Particulate	SO_2	NOx
Emission Target, mg/Nm3	150	800	480
Emission Reduction Required, %			
Uncleaned Coal	99.6	88.0	70
Cleaned Coal	99.1	84.6	63

4.3.2.1 Particulate Emissions

Options for reduction in particulate emissions are described in Section 4.3.1.1 Particulate emission reduction will be achieved by replacing the existing particulate collection equipment with high efficiency electrostatic precipitators which are significantly lower in capital cost than fabric filters.

4.3.2.2 NOx Emissions

NOx reduction equipment is provided with this option. The required reductions in NOx are achieved by applying a combination of NOx control technologies namely, low-NOx burners followed by selective noncatalytic reduction of the remaining NOx.

NOx emissions from the rehabilitated boilers equipped with low-NOx burners have been estimated as 1000 mg/Nm^3 when firing the uncleaned coal and 800 mg/Nm^3 when firing the cleaned coal. Additional NOx reduction efficiency required meet the emission targets are 52% when firing the uncleaned coal and 40% when firing the cleaned coal.

Non-catalytic reduction of NO by reaction with ammonia (or urea) occurs at high operating temperatures (1600-2100°F) without a catalyst. The optimum temperature window for the NOx reduction is 1800°F to 2000°F. At higher temperatures additional NOx is created while at lower temperatures the reaction slows and requires increasing residence time. Enhancer chemicals have been developed, which when added to urea extend its effectiveness to lower temperature by accelerating the chemical reaction.

The urea process may reduce the NOx concentration in the flue gas by 50% and more. Because the process consumes a chemical reagent, the cost of NOx reduction is a function of both the percent reduction and the initial concentration of NOx. For that reason the technology is frequently applied to NOx reduction after the maximum reduction in NOx has first been achieved by combustion modifications. This reduces the concentration of NOx in the flue gas leaving the furnace, thereby reducing chemical consumption and operating costs.

The key parameters in the performance of the urea process are the residence time of the flue gas within the "temperature window" and the quantity of reagent injected into the flue gas. Although increasing the quantity of urea reagent increases the % NOx reduction, excess urea decomposes to form unreacted ammonia which exits the system into the atmosphere. This release of unreacted ammonia is known as "slip". Another problem can be the formation of excessive CO and N_2O levels in the flue gas.

Ammonia slip, whether the result of ammonia or urea injection, may be responsible for a number of operating problems. In addition to emitting a new pollutant, the ammonia may react with SO_3 and Cl in the flue gas producing ammonia salts which can foul and corrode the lower temperature air heater, can cause plugging of the air heater or can form a visible plume. Ammonia may also be absorbed on the ash collected, limiting its usefulness as a saleable byproduct.

Estimated capital cost for an SNCR NOx reduction system for a 200 MWe boiler is $975,000.

4.3.2.3 Sulfur Dioxide Emissions

Several options have been considered to achieve the required reduction in sulfur dioxide emissions. These include

- Dry Processes (Furnace and Duct Injection)
- Wet Processes
- Semi-dry Processes

Furnace and Duct Sorbent Injection

In the **Furnace Sorbent Injection** (FSI) process, calcium-based sorbent, such as limestone or lime hydrate, is introduced directly into the boiler cavity. When exposed to furnace temperatures, the sorbent decomposes to form lime particles which capture SO_2 in suspension to form calcium sulfate. The reaction solid product is removed with ash in the particulate control device. Humidification of the flue gas before it is treated in the particulate control equipment enhances SO_2 removal. If the particulate matter is collected in an electrostatic precipitator (ESP), humidification of the flue gas is beneficial in maintaining the ESP performance.

SO_2 emissions can be reduced by 30-60% depending on the type of sorbent used, Ca/S ratio and level of humidification. With fine particle size limestone and Ca/S ratio of 2 to 3, the maximum

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SO_2 removal is in the 35-40% range. Humidification of the flue gas will enhance the removal efficiency by 10% but adds to the capital investment requirements for the process.

Under similar conditions, the injection of lime hydrate will yield an SO_2 removal in the 50-60% range. The SO_2 removal performance can be also improved by recycling portions of the collected solids.

The **Duct Sorbent Injection** (DSI) Process involves injection of a sorbent into the flue gas downstream of the air heater. SO_2 capture occurs in suspension within the duct and within the downstream particulate control device. High relative humidity in the flue gas is a prerequisite for SO_2 removal.

The major advantages for the sorbent injection technologies is the low capital investment and the small plot area required for installation.

The major disadvantage of this technology is the low SO_2 removal efficiency which can be achieved and since regulations require some 85% to 90% SO_2 removal efficiency, this technology has been found to be unacceptable. An additional shortcoming is the sensitivity of SO_2 removal to the level of humidification and the efficiency of desulfurization. At low flue gas temperatures that favor SO_2 removal, there is a tendency to form wet cake deposits on duct and ESP walls that can eventually cause severe operational problems

Wet Flue Gas Desulfurizaton Processes

The wet flue gas desulfurization (WFGD) system utilizes lime or limestone slurry as the scrubbing reagent. The process is capable of producing a gypsum byproduct suitable for wallboard manufacturing and/or cement production. In the event commercial byproducts are not required, the system may produce a product which can be disposed of as landfill. The system is typically designed for sulfur dioxide removal efficiencies of 90% or higher and HCl removal efficiencies up to 95%.

The WFGD is normally installed downstream of the particulate collection equipment. Flue gas is drawn by the boiler ID fans, or booster fans, which provide the energy necessary to overcome the gas side resistance of the FGD system equipment. The flue gas stream flows into the sulfur dioxide absorber where it is immediately saturated (adiabatically) by exposure to the absorber slurry.

Contact between the flue gas and the slurry containing reagent may occur in a variety of contacting devices. Following contact with the slurry, the scrubbed flue gas passes through mist eliminators which remove entrained slurry droplets from the gas stream. The flue gas handling system frequently includes bypass ductwork which permits the flue gas exiting the fan to flow, untreated, directly to the chimney. In addition, a flue gas reheat system may be provided to reheat the saturated flue gas exiting the absorber before it is discharged to the stack.

The reagent preparation system may be designed to receive pre-ground limestone or to grind crushed limestone on-site. The product (gypsum) dewatering system is designed to concentrate the gypsum crystals to an ultimate solids content of 85-90%+ and recirculate process water to the absorption and reagent preparation systems.

The major advantage for application of the wet limestone scrubbing technology is that the system may be designed to achieve an SO_2 removal efficiency of 90% or greater and is applicable to all levels of sulfur in fuel. In addition, limestone is the least costly of all alkali reagents and the product gypsum is often usable in building materials either as cement or wallboard.

The major disadvantage of the technology is the very high investment costs associated with its application. A cost of $13 to $15 million has been estimated for US supplied material alone, for this application.

Semi-dry Desulfurization Processes

This process is classified as semi-dry, not wet, because the flue gas is not fully humidified as it is in wet systems. Typically the flue gas is humidified only to within 10-30°C of its adiabatic saturation temperature. Contact between flue gas and reagent occurs in a spray drying vessel located upstream of the particulate collection device. The system is typically designed for sulfur dioxide removal efficiencies of up to 90% when firing low to intermediate sulfur coal. Lime is the most popular reagent, although other reagents have also been shown to be effective absorbents for spray drying.

The flue gas exiting the combustion air preheater comes in contact with an alkaline solution or slurry in a spray dryer. The flue gas passes through a contact chamber, and the solution or slurry is sprayed into the chamber with a rotary or nozzle atomizer. The heat of the flue gas dries the atomized droplets while the droplets absorb sulfur dioxide from the flue gas. The sulfur dioxide reacts with the alkaline reagents to form solid phase sulfite and sulfate salts.

Most of the solids (and any fly ash present) are carried out of the dryer in the exiting flue gas. The rest fall to a hopper at the bottom of the dryer. The flue gas then flows to the solids collection device where the dry solids (reaction products, unreacted absorbent, and flyash) are collected. A fabric filter (baghouse) or ESPs may be used. When a baghouse is used, significant absorption of sulfur dioxide may occur during solids collection as absorbent in the solids collected on the surface of the bags reacts with sulfur dioxide remaining in the flue gas.

The cleaned flue gas leaves the collection device and is exhausted to the atmosphere (stack) by the boiler ID fans. As in the case of the other processes, the fans are located downstream of the particulate collection device. In contrast to the wet processes, however, the absorber (spray dryer) is located upstream of the collection device.

The discharge flue gas is maintained above the dew point by control of the spray dryer discharge temperature and by the heat of compression added by the boiler ID fans. Reheating of the treated flue gases is not normally required.

This technology utilizes lime, not limestone, as the reagent. In lime systems, pebble lime (CaO) is slaked to produce a reactive lime slurry. Utilization of the reagent can often be improved by recycle of the waste solids particularly in lime systems where the unreacted absorbent remaining in the waste solids can be used.

Waste solids from spray dryer processes have handling properties similar to dry fly ash and are usually conveyed pneumatically to storage bins and then trucked to landfill sites for disposal.

The major advantages to the application of semi-dry technology when compared with wet scrubbing processes are the lower investment cost, reduced plot area requirements, lower gas side pressure drop and reduced complexity of operation.

The major disadvantage of this technology is the requirement for the use of more costly lime, instead of limestone, as the reagent for SO_2 removal. In addition, the reaction product is dry powder containing fly ash and must disposed of with same considerations as fly ash. No useful saleable product is available.

A cost of $6.3 to $8.1 million has been estimated for US supplied material alone, for this application.

Based on its investment cost advantage, the semi-dry flue gas desulfurization technology has been selected to achieve the SO_2 removal required to meet emission standards. The spray dryer desulfurizaton equipment would be installed upstream of an electrostatic precipitator which will collect fly ash and desulfurization waste product.

The cost for US supplied material for the combined spray dryer/electrostatic precipitator emission control system has been estimated at about $8.4 million for the uncleaned coal and $10.3 million for the cleaned coal with the higher cost case reflecting the greater steam production and MWe output. The cost including the required NOx reduction system ranges from $9.4 million ($65/kW) for the uncleaned coal to $11.3 million ($56/kW) for the cleaned coal case. Application of the selected technologies will reduce emissions to the stated emission targets.

4.3.3 Conversion to Arch Firing - Improved Emission Controls

Modification of the boiler firing system, upgrading of the particulate emission controls and application of sulfur dioxide and nitrogen oxide emission control is provided by this option. As pointed out previously, application of arch firing technology essentially eliminates the requirement for natural gas cofiring and permits generation of 200 MWe even with the uncleaned coal. This results in greater coal firing rates and a flue gas containing somewhat higher quantities of ash and SO_2, requiring slightly higher removal efficiencies to achieve the target emissions.

Flue gas flow rates and uncontrolled emissions for the rehabilitated arch fired boilers are:

Fuel Fired	Uncleaned Coal	Cleaned Coal
Steam Production, t/hr	564	564
Flue Gas Volume, Am^3/hr	1,037,1000	1,070,250
Uncontrolled Emissions, mg/Nm^3		
Particulates	47,315	18,313
SO_2	8,451	5,865
NOx	750	680

Emission limit targets and required emission reduction efficiencies are as follows:

	Particulate	SO_2	NOx
Emission Target, mg/Nm^3	150	800	240
Emission Reduction Required, %			
Uncleaned Coal	99.7	90.5	85.0
Cleaned Coal	99.1	84.4	81.5

4.3.3.1 Particulate Emissions

Options for reduction in particulate emissions are described in Section 4.3.1.1 Particulate emission reduction will be achieved by the installation of electrostatic precipitators which are significantly lower in capital cost than fabric filters.

4.3.3.2 NOx Emissions

NOx reduction equipment is provided with this option. The emission targets in the case of the arch fired (dry bottom) boiler are only half the concentration permitted for the wet bottom boiler design however (240 mg/Nm^3 vs. 480 mg/Nm^3). Reductions to 480 mg/Nm^3 are achieved by applying a combination of NOx control technologies namely, low-NOx burners (combustion modifications) followed by selective noncatalytic reduction of the remaining NOx (post combustion controls).

NOx emissions from the arch fired boiler equipped with low-NOx burners have been estimated as 750 mg/Nm^3 when firing the uncleaned coal and 680 mg/Nm^3 when firing the cleaned coal. Additional NOx reduction efficiency required meet the emission targets are as follows:

Emission Target, mg/Nm^3	480	240
Estimated Emissions, mg/Nm^3		
Uncleaned Coal	750	750
Cleaned Coal	680	680
Emission Reduction Required, %		
Uncleaned Coal	36	68
Cleaned Coal	30	65

The table indicates that while a reduction in NOx emissions of only 30% to 36% would be required to achieve an emission target of 480 mg/Nm^3 , the post combustion NOx emission reduction requirements are increased to 65% to 68% to achieve the lower emission target of 240 mg/Nm^3. While the 480 mg/Nm^3 is easily achieved by implementation of the SNCR technology described in the previous section, this technology has limited emission reduction capability and can not achieve the lower emission target. Achieving reduction in NOx emissions of greater than 50%, utilizing post combustion technology requires the application of a catalytic reduction system usually referred to as selective catalytic reduction (SCR).

Selective Catalytic Reduction

Selective Catalytic Reduction (SCR) is a post combustion NO_x control technology utilizing ammonia (NH_3) as the reducing agent. The operating temperature (600-900°F) permits the reaction to take place outside the furnace with the catalyst typically installed between the economizer outlet and the air preheater inlet.

Selective catalytic reduction is an effective method for reduction of NO_x generated from combustion. Reductions of greater than 80% can be achieved through the use of this technology, independent of the inlet NOx concentration. Since ammonia reagent is consumed in the process however, SCR is frequently applied to a system after combustion modification has been implemented.

The key to the effectiveness of the technology is the performance and life of the catalyst and a great deal of research has been devoted to both of these topics. The catalysts are typically manufactured as modules which may be installed in a reactor through which the flue gas flows. Catalysts may be manufactured of metal (titanium, vanadium, etc.) oxides or coated ceramic molecular sieve (Zeolite). The size and number of catalyst modules are determined by the flue gas flowrate, the level of NO_x reduction required and the design life of the catalyst.

Catalyst deactivation, or loss of reactivity over time requires the catalyst to be replaced and contributes significantly to the cost of the SCR NOx reduction technology. The deactivation occurs by both physical means (high temperatures, plugging with particulates, etc.) and chemical poisoning caused by contaminants in the gas stream. This is especially true for applications where very high ash coals are fired in the boiler resulting in high fly ash loading in the flue gas.

SCR application to existing units results in increased draft loss and may require upgrading or replacement of the I.D. fan(s).

Costs associated with the application of SCR are quite high. Typical costs have been estimated at about $65 per kW of capacity which would equate to $13 million for this 200 MWe coal fired boiler.

Hybrid Selective Catalytic Reduction

Recognizing the very high cost associated with the installation of an SCR system, and the fact that for many applications reductions in NOx concentration of 80% to 90% are not required, industry has been exploring the application of hybrid NOx reduction systems which utilize a small SCR catalyst in combination with a boiler reagent injection system (SNCR).

In this design, costs for the SCR catalyst are reduced because significant reduction is achieved by the SNCR technology. Reducing NOx emissions by 68%, for example, could be achieved by a hybrid installation where the SNCR process operates at 45% NOx reduction efficiency requiring only an additional 42% reduction in NOx emissions to be provided by the catalyst system.

Hybrid SCR systems have been installed and demonstrated on utility boilers. The systems have been applied in various configurations with SNCR combined with in-duct and air heater SCR perhaps the most applicable to this investigation. This application utilizes the unreacted ammonia (slip) from the SNCR system as part or all of the ammonia required for the catalytic reduction by the SCR system installed downstream, either in the ductwork between the economizer and the air heater or as catalyst containing baskets In the air heater, or both. The hybrid system requires substantially reduced unit modifications, with lower costs, as well as reduced system pressure drop.

Investment cost for a hybrid SNCR/SCR system is highly site specific. Based on published information the cost for a combined SNCR/in-duct SCR/air heater SCR is in the range of \$25 to \$30/kW or about one third the cost of a full size SCR. This is still some four to five times the cost of an SNCR system alone which, as pointed out above, would have sufficient NOx reduction efficiency to achieve an emission concentration of 480 mg/Nm^3.

4.3.3.3 Sulfur Dioxide Emissions

The semi-dry flue gas desulfurization technology described in Section 4.3.2.3 has been selected to achieve the SO_2 removal required to meet emission standards. The spray dryer desulfurizaton equipment would be installed upstream of an electrostatic precipitator which will collect fly ash and desulfurization waste product.

The cost for US supplied material for the combined spray dryer/electrostatic precipitator emission control system has been estimated along with the required NOx reduction system.

4.3.3.4 Cost Summary

Investment costs for each of the possible alternative technologies are summarized below:

Fuel Fired	Uncleaned Coal		Cleaned Coal	
Emission Control Equipment Cost	\$ x10^{-6}	\$/kW	\$ x10^{-6}	\$/kW
SO_2 and Particulate Controls	9.5	48	9.0	45
NOx Reduction Alternatives				
Reduction to 480 mg/Nm^3 (SNCR)	1.0	5	1.0	5
Reduction to 240 mg/Nm^3 (SNCR/SCR)	5.6	28	5.6	28
Reduction to 240 mg/Nm^3 (SCR)	13	65	13	65

4.3.4 Extensive Refurbishment - Improved Emission Controls

Extensive refurbishment of the system will result in increased steam production requirements to serve the rehabilitated steam turbine. This, in turn will require increased fuel input.

Upgrading of the particulate emission controls and application of sulfur dioxide and nitrogen oxide emission control is provided by this option.

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Flue gas flow rates and uncontrolled emissions for the rehabilitated arch fired boilers are:

Fuel Fired	Uncleaned Coal	Cleaned Coal
Steam Production, t/hr	626	626
Flue Gas Volume, Am^3/hr	1,106,750	1,149,250
Uncontrolled Emissions, mg/Nm^3		
Particulates	43,206	17,538
SO_2	7,760	5,648
NOx	1,000	800

Emission limit targets and required emission reduction efficiencies are as follows:

	Particulate	SO_2	NOx
Emission Target, mg/Nm3	150	800	480
Emission Reduction Required, %			
Uncleaned Coal	99.6	89.7	70
Cleaned Coal	99.1	85.8	63

These emission reduction requirements are almost identical to those described in Section 4.3.2, and the recommended technologies to be applied are the same.

4.3.4.1 Particulate Emissions

Options for reduction in particulate emissions are described in Section 4.3.1.1 Particulate emission reduction will be achieved by the installation of electrostatic precipitators which are significantly lower in capital cost than fabric filters.

4.3.4.2 NOx Emissions

The NOx reductions are achieved by applying a combination of NOx control technologies namely, low-NOx burners followed by selective noncatalytic reduction of the remaining NOx. These technologies are described in Section 4.3.2.2.

4.3.4.3 Sulfur Dioxide Emissions

The semi-dry flue gas desulfurization technology as described in Section 4.3.2.3 has been selected to achieve the SO_2 removal required to meet emission standards. The spray dryer desulfurizaton equipment would be installed upstream of an electrostatic precipitator which will collect fly ash and desulfurization waste product.

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The cost for US supplied material for the combined spray dryer/electrostatic precipitator emission control system has been estimated along with the required NOx reduction system. Costs are as follows:

Fuel Fired	Uncleaned Coal		Cleaned Coal	
Emission Control Equipment Cost	\$ x10^{-6}	\$/kW	\$ x10^{-6}	\$/kW
SO_2 and Particulate Controls	9.9	44	9.5	42
NOx Reduction to 480 mg/Nm^3	1.0	4	1.0	4

4.4 TURBINE GENERATOR - REHABILITATION DETAILS

4.4.1 Systems and Equipment Considered for Rehabilitation

4.4.1.1 General Considerations

As it was shown in Section 4.1.3 the turbine generator output capability is presently severely reduced. Unit 10 currently generates about 139 MW (gross), and the gross output of Unit 13 is 145.5 MW. The reduction in output is mostly due to the operation of the steam generators on unsatisfactory fuel. However, due to the advanced age of the subject units reliable long term operation cannot be ensured without significant refurbishment of the turbo-generators even if the steam generating capability of the boilers is restored. In addition, various turbine rehabilitation measures can be made which will increase turbine output and reduce heat rate.

As indicated in the condition assessment section the steam turbines have accumulated excessive number of operating hours and show signs of metal fatigue and wear. Both units have developed cracks in the turbine casings and valves, and had a series of problems with turbine components and require significant maintenance to keep them running. The lack of spare parts also contributes to the reduction of availability of the turbines. There are serious problems with the turbine control system due to excessive wear which causes the operation to be unstable. Unit 10 turbine has exceeded its original design life by a factor of more than 2 and also exceeded its officially extended life of 220,000 hours. Unit 13 has lower operating hours than Unit 10 but will approach the above extended hours in the next 5-6 years.

The current operation of the units includes the production of make-up water by using evaporators in the steam/feedwater cycle. However, as part of this study the refurbishment of the water treatment system is also recommended (see Section 6.1). After refurbishment and installation of the new CFB boilers and the 125 MW unit in the old Phase I section of the plant, all units will operate with steam cycles of 140 ata pressure. A modern water treatment system is not only necessary to provide high quality make-up to the plant, but by eliminating the evaporators from the steam cycle, power output from each turbine can be increased. Increasing the power output from the units is one of the objectives of the present study.

As noted earlier the plant is currently operated in a 2-shift cycling mode. This requires the individual units to have frequent startups or load changes. This may place additional thermal stresses on the units. From the data collected it can be seen that while the actual hot and warm starts are well within the numbers allowed for the turbines, the number of actual cold starts, which are the most severe type of startups, exceed the originally allowed figures. Even though the low number of hot and warm starts tend to mitigate the effects of the high number of cold starts somewhat, it is very important to frequently monitor the condition of the various turbine components to prevent potential catastrophic failures and to minimize forced shutdowns. In this respect modern, replication type non-destructive testing equipment is needed to monitor creep cavitation of turbine high temperature components. This becomes more and more important as the units get older. In addition, given the current operating mode of the plant, it is important to implement upgrades which enhance turbine startups. Such upgrades will help to increase the speed of warm-up and also reduce heat rate.

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In general, two levels of refurbishment are considered for the turbines in this report: Minimal Refurbishment and Extensive Refurbishment.

Minimal refurbishment items are aimed to restore capacity and improve reliability and efficiency of the turbines. The list of minimal refurbishments considered for the 200 MW units includes the following:

- Replacement of HP stop valves
- Replacement of reheat stop valves
- Replace governor valves
- Replace intercept valves
- Replace crossover pipes at turbine inlet
- Replace HP turbine section
- Replace IP turbine section
- Replace front standard
- Add EH Control system with supervisory and vibration monitoring capability
- Remove evaporators from service and isolate the corresponding extraction steam pipes
- Replace last stage bladings in the LP section (30th and 31st stage and bandage)
- Install automatic bypass system around lowest pressure heaters
- Reduce level of vibration at turbogenerator supports
- Replace lube oil cooler
- Improve Steam Packing Exhauster (SPE) system
- Upgrade turbine flange connection heating system
- Enhancement of warm-up drainage - blowdown system of turbine
- Improve electric generator H_2 side sealing system

- Purchase replication type creep monitoring system and monitor frequently
- Reduce air inleakage into condenser

Extensive Modifications and Upgrades are those which are aimed at increasing the capacity of the units over and above the original 200 MW, in addition to improve reliability and heat rate. The following upgrades and modifications were considered for the extensive refurbishment of the units:

- Replacing the existing LP section of the turbine with a new more efficient section
- Replacement of the entire turbine and auxiliaries with a modern 225 MW machine

4.4.1.2 Recommended Refurbishment for Unit 10

Minimal

Based on the data collected and our assessment of the condition of this unit described in Section 4.1.3 various items from the preceding list have been selected for implementation for the minimal refurbishment of Unit 10. Some of the selected items also include the recommended refurbishments and reconstruction modifications developed by Minenergo of the former USSR for the high-temperature components of those K-200-130 LMZ turbogenerators which have overcome their entire life. The development of these reconstruction upgrades are based on the requirement that the efficiency and reliability of the new assemblies and parts shall not be lower than the corresponding parameters for modern equipment. Therefore, the new parts and assemblies shall be manufactured using not the original design but rather they shall take into account the more recent advancements of science and technology in the area of turbogenerator manufacturing.

The affected components and parts recommended for refurbishment include stop valves, regulating valves, connecting steam pipes at turbine inlet, complete HP and IP cylinder sections with modern turbine blading, and front standard with new regulating parts which enable the modernization of the turbine control system. In practical terms, those assemblies have been used in manufacturing a new 200 MW category LMZ steam turbine, the LMZ K-215-130 machine. This machine was certified for the current highest quality category and it can be installed on the existing 200 MW turbine pedestal. The increase in quality is the result of new methods of casting and welding, balancing of the rotors at operating speeds, and the use of improved metals for some components. All the above significantly increase the reliability and operability of the turbogenerator and provide for long term operation of a unit. The incorporation of some of the above components can improve turbine heat rate. The complete replacement of the HP and IP cylinders which have the newest blading results in a heat rate improvement of 12.8 kcal/kWh.

Power output improvement can be achieved on the unit by removing the evaporators from service and isolating the corresponding extraction pipes. This is further described in Section 4.5, however the elimination of these evaporators was calculated to result in an increase of output from the turbine of about 3.5 MW at maximum load.

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Because of the potential for water induction and the experience with forced shutdown due to the breakage of 11 tubes in the lowest pressure feedwater heaters it is recommended that bypass piping arrangement be incorporated in the condensate system with valves which effectively remove the heaters from service upon high-high level in the heater shells. The last 2 rows of turbine blades should also be replaced for the minimal modification together with the bandage. These blades usually experience erosion. (The forced outage was associated with the breakage of these blades before due to the excess moisture resulting from the tube breaks.)

Due to the instability of the operation and to interface with the new distributed plant control system it is recommended that the turbines be retrofitted with electro-hydraulic control (EHC) system. This system will interface with the new control parts which are located in the new front standard which will be incorporated in the minimal modifications. The EHC system is further described in Section 4.7. The new EHC system will be of the fault-tolerant design, and will be furnished with vibration monitoring instruments, which have the capability of providing hold points during startups or in case the vibration levels exceed allowable limits. The system will provide reliable signals to warn operators or provide for safe shutdown.

In connection with more efficient startups and in view of the current operating mode of the units at Lugansk, it is recommended to incorporate a number of measures which ease startup operations as well as improve unit heat rate. Such measures were developed by the Kharkov Central Design Office, and include modernization of the steam packing exhauster (SPE) system, modernization of the HP and IP flange heating system and increasing the capacity of the turbine heating and drain system. The implementation of these measures results in an improvement of heat rate by about 15.6 kcal/kWh.

The problems with the rotor vibration at the turbine supports will be reduced significantly due to the installation of new rotors as part of the replacement of the HP and IP sections. These rotors are undergoing a high quality balancing procedure at the manufacturing plant. In addition the new steam path in the HP and IP sections together with the new thrust bearing pads of equal thickness will permit the normal operation of the thrust bearing without overheating.

The lube oil coolers for the unit must be replaced to eliminate oil leaks into the cooling lakes. The installation of a dedicated closed cooling system doesn't appear to be a cost effective solution.

The recommendation to improve the H_2 side seal oil system of the generator shaft is described in Section 4.6. It is also recommended that the plant institute modifications to minimize air inleakage into the condenser of the unit. These modifications are further described in Section 4.5.

In summary the minimal modifications and upgrades recommended for the Unit 10 turbine together with their benefits are shown in Table 4.4-1.

Extensive

As indicated in Section 4.4.1.1 the extensive upgrades and modifications considered replacement of the LP section utilizing the Baumann exhaust with a new more modern section, and the complete replacement of the 200 MW unit with a new 225 MW modern unit. The purpose of

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such modifications are to increase power output above the original 200 MW turbine output in addition to reliability and heat rate improvements.

From the information collected and as further discussed in the electrical section of this report, the electric generator is already working with the maximum 4 kg/cm^2 hydrogen pressure. As this is the design pressure for the electrical generator to operate at 200 MW, the first alternative was eliminated from further consideration.

The second alternative was considered since the LP section of this 200 MW unit has been constructed with the Baumann exhaust configuration. The LP turbine design consists of four stages of reaction blading including the Baumann stage. The Baumann exhaust, a 1950's technology, was introduced to increase the exhaust annulus area in order to reduce the leaving kinetic energy, and it was used to establish blade material technology for that period. However, the Baumann exhaust configuration has flow regimes with high flow losses. In addition, the annulus area achieved by the Baumann exhausts did not optimize turbine performance for most installed site conditions.

During the past 40 years the turbine steam flow path design has undergone significant development and today state-of-the-art new designs can be applied to replacement turbine sections. Turbine manufacturers have developed alternatives to the LP sections operating with Baumann exhaust. Westinghouse, for instance, has been working on such turbine modifications in Poland. Their experience with 200 MW units indicates that the Russian-design turbines frequently operate with LP section efficiencies below 70%. However, modern LP turbines can achieve efficiencies of between 86 and 88 percent.

In furnishing a modernized state-of-the-art LP turbine section the design usually tries to retain the existing fits of the turbine outer cylinder, but the number of stages, the type of blade design, the type of attachment of blades to the shaft, and the shaft design change. The turbine blading change allows the re-optimization of the condenser and the location of any low pressure heater (extraction point) in the low pressure end of the steam/condensate cycle. The new optimized design results in a heat rate and output improvement. In some cases this improvement can be up to 6 to 7 percent, depending on the original blade design and the actual operating and physical condition of the LP blading.

The application of such modification to the Lugansk Unit 10 will result in the requirement for the replacement of the existing electrical generator, and the associated total capital costs for all the above mentioned equipment (new LP turbine, condenser, feedwater heater, extraction and steam piping modifications, new generator) is estimated to be in the order of 12 million dollars. When this modification cost is added to the cost of the minimal modifications and upgrades discussed above, which would also be incorporated in the extensive upgrade, the resulting total cost is about the same magnitude as that required for the complete replacement of the unit with a new 225 MW modern Kharkov designed turbine and auxiliary equipment. This is partly attributed to the fact that the new HP and IP casings, front standard, valves, etc. are supplied by LMZ from Russia, and the new LP section and the EHC equipment are either Russian and/or Western equipment. On the other hand, the new 225 MW steam turbine can entirely be supplied from within the Ukraine at an apparently lower cost. The new turbine can be mounted on the existing foundation and it comes

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with electric hydraulic control system. The gain in additional output is about 25 MW which is 12.5% increase above the original 200 MW turbine capacity.

In order to see what would be the improvement in output and heat rate due to the incorporation of a new LP section to the existing 200 MW unit, the original heat balance data was examined which gives a stage-by-stage account of the steam expansion in the turbine so that the turbine internal efficiency can be determined. This was also necessary because the data collected at the plant indicates - and as Section 4.1.3.3 also shows - the profiles of the blading in the LP sections where changed in 1982 in an effort to achieve better efficiency. Therefore, the magnitude of the improvement that can be expected from a new LP section may be limited.

The heat balance data indicated that the efficiency of the LP section is 76.07%. Assuming an average efficiency for a state-of-the-art new LP section of 87%, the resulting efficiency improvement is 10.93% for the LP section. Therefore an increase in output of 6.8 MW can be calculated. This, in turn, then results in an output and heat rate improvement of about 3.5% for the original 200 MW unit.

The improved output is significantly less than that which can be obtained from a new turbine. In addition, since the total heat rate improvement is also less than what can be obtained from the new unit and since the cost of the new unit is about the same as that of the retrofitted unit, the new turbine replacement option was selected as the recommended option for the extensive upgrade of the turbine. This new turbine will be furnished with all the features and improvements which will be able to provide reliable long term operation under the more severe operating regime associated with cycling which may be expected to continue at Lugansk.

The recommended modification for the extensive upgrade of the Unit 10 turbine is also shown in Table 4.4-1. The improvement in output and heat rate compared to the original 200 MW design is also indicated.

4.4.1.3 Recommended Refurbishment for Unit 13.

Minimal

For the minimal refurbishment of the Unit 13 steam turbine, the control system will be modernized in order to achieve a stable operating mode. The modifications will include the replacement of the stop and control valves at the HP and IP sections. The front standard will also be replaced which enables the installation of the same type of EHC control and vibration monitoring system discussed under the Unit 10 modifications. The HP and IP casing will not be replaced for this modification as the cylinders have so far appeared to develop relatively fewer cracks than Unit 10. However, it is absolutely essential that the thick metal parts and components operating under high temperature be frequently monitored for creep degradation as the unit has accumulated about eighty-seven percent of its officially extended life. Therefore, it is recommended that replication type NDE equipment be procured by the plant to be able to monitor the molecular structure of the affected components. This is even more important for this unit because of the frequency of startups associated with cycling operation.

The various improvements recommended to be included with the minimal upgrade of Unit 10 to ease startup operations, and to improve heat rate are also recommended to be included for Unit 13.

The replacement of sets of blades for the 30 and 31st stage of the LP sections is recommended together with a modification of the condensate piping around the lowest pressure feedwater heaters in order to avoid the type of water induction problems that seemed to occur at Unit 10.

The evaporators at this unit are also recommended to be removed from service and the corresponding extraction lines isolated. The removal of the evaporators from service expected to result in an output increase of about 3.5 MW at full load conditions.

The other recommendations regarding the replacement of the lube oil coolers, the improvement of the H_2 side generator shaft seal system mentioned under the minimal modifications and upgrades for Unit 10 are also applicable to the minimal modifications to the Unit 13 turbine.

The recommended minimal upgrades and modifications for the Unit 13 turbogenerator are summarized in Table 4.4-2 together with their benefits.

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Extensive

The extensive refurbishment for Unit 13 considered the same alternatives as Unit 10. For an extensive refurbishment, however, the replacement of the HP and IP sections of Unit 13 would also be recommended primarily because of the age and the type of operation (frequent cycling) expected for this unit. This plus the minimal modifications, coupled with the replacement of the existing LP section with a new state-of-the-art modern LP section would result in costs in the same order of magnitude than the cost of a new 225 MW Ukraine turbine. Since the new turbine will provide higher output and better heat rate than the retrofitted turbine, the replacement of the complete turbine is recommended for the extensive refurbishment of Unit 13. This recommended alternative together with the heat rate and output gains obtainable with this refurbishment is also shown in Table - 4.4-2.

Table 4.4-1

RECOMMENDED REFURBISHMENT FOR UNIT #10 TURBINE

Item No	Item Description	Benefit	Improvement in Performance
	Minimum Refurbishment		
1	Replace H.P. Stop Valves	R	-
2	Replace Governor Valves	R	-
3	Replace Intercept Valves	R	-
4	Replace crossover steam lines at turbine inlets	R	-
5	Replace HP Turbine (casing, rotor, diaphragm, etc.)	H, R	6.4 Kcal/kWh
6	Replace IP Turbine (Casing, rotor, diaphragm, etc.)	H,R	6.4 Kcal/kWh
7	Replace Front Standard	R	-
8	Add EHC System w/supervisory & vibration monitoring	R	-
9	Replace L.P. Turbine Last Stage Blading	R	-
10	Install Bypass around LP HTR #1	R	-
11	Remove Evaporators from Service	O,R	~3.5 MW
12	Reduce Vibration at T-G Supports	R	
13	Replace Lube Oil Cooler	R	-
14	Improve SPE System	H	12.5 Kcal/kWh
15	Upgrade Turbine Flange Connection Heating System	H	2.5 Kcal/kWh
16	Enhance Drainage/Blowdown Equip.	H	0.6 Kcal/kWh
17	Improve Generator H2 Sealing System	R	-
	Extensive Refurbishment		
	Total Replacement of 200 Mwe Turbine + Auxiliaries with 225 MWe Equipment	O,H,R	25 MWe 100 Kcal/kWh

Benefits Code:

R = Reliability Improvement

H = Heat Rate Improvement

O = Output Improvement

Table 4.4-2

RECOMMENDED REFURBISHMENT FOR UNIT #13 TURBINE

Item No	Item Description	Benefit	Improvement in Performance
	Minimal Refurbishment		
1	Replace H.P. Stop Valves	R	-
2	Replace R. H. Stop Valves	R	-
3	Replace Governor Valves	R	-
4	Replace Intercept Valves	R	-
5	Replace Front Standard	R	-
6	Add EHC System w/supervisory & vibration monitoring	R	-
7	Replace L.P. Turbine Last Stage Blading	R	-
8	Install Bypass around LP HTR #1	R	-
9	Remove Evaporators from Service	O,R	~3.5 MW
10	Replace Lube Oil Cooler	R	-
11	Improve SPE System	H	12.5 Kcal/kWh
12	Upgrade Turbine Flange Connection Heating System	H	2.5 Kcal/kWh
13	Enhance Drainage/Blowdown Equip.	H	0.6 Kcal/kWh
14	Improve Generator H2 Sealing System	R	-
15	Purchase Creep Monitoring Equip. & Monitor Frequently	R	-
	Extensive Refurbishment		
	Total Replacement of 200 MWe Turbine + Auxiliaries with 225 MWe equipment	O,H,R	25 MWe 100 Kcal/kWh

Benefits Code:

R = Reliability Improvement

H = Heat Rate Improvement

O = Output Improvement

4.4.2 Performance Improvement

4.4.2.1 Gross Turbine Performance

As indicated in Table 4.4-1 the improvements and modifications proposed for the Minimal Refurbishment resulted in a total heat rate improvement for Unit 10 of about 28.4 kcal/kWh and 3.5 MW of additional power output. Table 4.4-2 indicates that minimal refurbishments recommended for Unit 13 result in a heat rate improvement of about 15.6 kcal/kWh and an additional output capability of 3.5 MW. The percent improvement that can be calculated depends on the reference point from which the improvements are calculated. The reference point may be the full load capability of the original units or the actual performance of the units as they operate today. The original 200 MW turbine performance is shown in Figure 4.4-1. The gross heat rate of this unit at full load is about 1989 kcal/kWh. Therefore, the efficiency or heat rate improvement of the Unit 10 and Unit 13 Minimum Refurbishment over the original designs would be about 1.42% and 0.78%, respectively.

For Extensive Refurbishment the utilization of the new turbine is indicated to result in a heat rate improvement of about 100 kcal/kWh and a new output of 225 MW. The turbine performance (heat rate and output) as a function of main steam flow is plotted on Figure 4.4-2. From this figure it can be seen that at the maximum output the gross heat rate is about 1889 kcal/kWh. Therefore if the original 200 Mw unit performance is considered the reference point, the heat rate improvement for both Units 10 and 13 is 5.03%. Figure 4.4-3 shows both the original and the new turbine performance curves to illustrate relative gross performance and to indicate generator limits.

The above curves can be utilized in determining the actual performance improvements for various options that are of interest to this project. These options were described in Section 2.1 and consider various fuel uses (uncleaned and cleaned coals), various boiler refurbishments (minimal, arch fired, and extensive) as well as various emission control measures. It is in this context that the various performance improvements must be assessed, as the turbine performance figures are influenced by the steam outputs from the steam generators and the electric generator limits influence the steam flow that can be accepted by the turbines. The result of calculations of gross output and heat rates for Units 10 and 13 are shown in the following subsections for the various options.

It should be noted that the extensive turbine refurbishments discussed in this section are only applicable to the extensive boiler refurbishments options. All other boiler refurbishments options are applicable together with the minimal turbine refurbishments.

Furthermore, the basis of comparison for all refurbishments are the degraded performances which can be achieved for Unit 10 and Unit 13 with the present uncleaned coal. These were shown in Section 4.1.3.2.

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4.4.2.2 Gross Performance Improvements for Unit 10 Options

The Option I cases are Minimal Refurbishment with uncleaned (Option Ia) and cleaned (Option Ib) coal. In Option Ia, the boiler steam flow output is limited to 400 t/h. This will limit the turbine output even though the turbine modifications would allow the turbine generator to operate at its original full load, and with better heat rate. The turbine will operate at the Option Ia condition somewhat better than currently achievable because of the removal of the evaporator from service (providing more output) and because of the heat rate improvement possible with the modifications proposed. Based on the above maximum steam flow the calculated gross output is now 144.5 MW and the new heat rate is 2012 kcal/kWh. Since the currently achievable gross performance of Unit 10 is 139 MW and 2042 kcal/kWh, the actual gross performance improvements for Option Ia are:

$\Delta N_G = 5.5$ MW (3.96%)

$\Delta GHR = 30$ kcal/kWh (1.47%)

For Option Ib the utilization of cleaned coal and the minimal modifications in the steam generator allows the boiler to operate with maximum original design flow. This steam flow would be more than the steam flow required to operate the steam turbine at 200 MW. It was determined that the steam flow required for the turbine at this load without the evaporators in service is 564 t/h. The new heat rate at the 200 MW maximum load with the various heat rate improvement incorporated with the minimal turbine upgrades was calculated as 1960 kca/lkWh. Therefore the gross performance improvements for Unit 10 for Option Ib are:

$\Delta N_G = 61$ MW (43.9%)

$\Delta GHR = 82$ kcal/kWh (4.01%)

Similar calculations were performed for Options 2 through 4. For Option 4, the extensive upgrade of both the steam generator and the steam turbine-generator, the improvements in gross performance are:

$\Delta N_G = 225\text{-}139 = 86$ MW (61.9%)

$\Delta GHR = 2042\text{-}1889 = 153$ kcal/kWh (7.5%)

The various gross outputs, heat rates, main steam flows and heat inputs to the steam cycle for the various options are shown together with performance improvements in Table 4.4-3.

Table 4.4-3

GROSS PERFORMANCE IMPROVEMENTS FOR UNIT 10

Option No.	Base	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Fuel Fired	Uncl.	Uncl.	Clean	Uncl.	Clean	Uncl.	Clean	Uncl.	Clean
Upgrade-Blr	-	Min	Min	Min	Min	Arch	Arch	Exten.	Exten
Upgrade-TG	-	Min	Min	Min	Min	Min	Min	Exten	Exten
Main Stm Flow, t/h	389	400	564	400	564	564	564	626	626
Output, MW	139	144.5	200	144.5	200	200	200	225	225
ΔOutput, MW	-	5.5	61	5.5	61	61	61	86	86
Heat Rate, kcal/kWh	2042	2012	1960	2012	1960	1960	1960	1889	1889
ΔHeat Rate, kcal/kWh	-	30	82	30	82	82	82	153	153
Steam Cycle Heat Input (10^8 kcal/hr)	2.83	2.91	3.92	2.91	3.92	3.92	3.92	4.25	4.25

4.4.2.3 Gross Performance Improvements for Unit 13 Options

The gross performance and the improvements achievable for the various boiler upgrade options coupled with the applicable turbogenerator upgrades have also been determined for Unit 13. The results are shown in Table 4.4-4.

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Table 4.4-4

GROSS PERFORMANCE IMPROVEMENTS FOR UNIT 13

Option No.	Base	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Fuel Fired	Uncl.	Uncl.	Clean	Uncl.	Clean	Uncl.	Clean	Uncl.	Clean
Upgrade-Blr	-	Min	Min	Min	Min	Arch	Arch	Exten.	Exten
Upgrade-TG	-	Min	Min	Min	Min	Min	Min	Exten	Exten
Main Stm Flow, t/h	404	400	564	400	564	564	564	626	626
Output, MW	145.5	148	200	148	200	200	200	225	225
ΔOutput, MW	-	2.5	54.5	2.5	54.5	54.5	54.5	79.6	79.5
Heat Rate, kcal/kWh	2032	2018	1972	2018	1972	1972	1972	1889	1889
ΔHeat Rate, kcal/kWh	-	14	60	14	60	60	60	143	143
Steam Cycle Heat Input (10^8 kcal/hr)	2.96	2.99	3.94	2.99	3.94	3.94	3.94	4.25	4.25

4.4.2.4 Net Performance for Unit 10 Options

Net unit output and net unit heat rate figures were also generated for the various upgrade options for Unit 10. This required the development of the various auxiliary power consumption figures associated with the minimal and extensive steam generator upgrades as well as of other auxiliaries associated with plant improvements such as those for water treatment improvements. However, in general, the auxiliary load components were categorized into turbine cycle related, boiler related, emission related, and other plant related items.

Instead of calculating the hundreds of individual auxiliary load components for all plant equipment, the method of determining the auxiliary loads followed the calculation of the differential auxiliary power requirements for the various upgrade systems and then adding or subtracting these from the auxiliary loads of the original Unit 10 design auxiliary power requirements. The auxiliary power load for the original 200 MW units was 7.8%. This corresponds to 15,600 kW at a turbine gross output of 200 MW.

The turbine cycle related auxiliary power components remained essentially the same as for the original 200 MW unit. Of course, these were smaller in absolute value for the minimum refurbishment options, where the maximum output is based on a steam generator output of only 400 t/h. The ratio of the percentage of auxiliary loads at this load and those at the original 200 MW output was 1.143. This ratio was determined based on the shape of the auxiliary power consumption curves for power plants previously evaluated by Burns and Roe.

The boiler related auxiliary power components were adjusted similarly for the above options, which are based on the use of uncleaned coal. For all other options which are based on the use of clean coal, the boiler related auxiliary power components were further reduced by the ratio of the heating values of the uncleaned versus cleaned coal. In addition, estimated values of auxiliary power were also added to account for the additional equipment associated with the double arch fired boilers.

Emission control-related auxiliary power components were also determined. They were assumed to vary proportionately with load. The water treatment related incremental auxiliary load was determined separately.

The total auxiliary power consumption was determined from the algebraic sum of the above auxiliary power components and subtracted from the gross turbine output in order to determine the unit net output.

The net unit heat rate was determined utilizing this net output with steam cycle heat input and boiler efficiency.

The results of the net performance calculations for Unit 10 at the 100% load levels are shown in Table 4.4-5.

4.4.2.5 Net Performance for Unit 13 Options

Auxiliary power calculations, similar to those described for Unit 10 were also performed for Unit 13. Net output and net unit heat rate were similarly determined for the Unit 13 options.

The results of these calculations for Unit 13 at the 100% load levels are shown in Table 4.4-6.

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Table 4.4-5

NET PERFORMANCE OF UNIT 10 OPTIONS AT 100% LOAD

Options	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Turbine Gross Output, MW	144.5	200	144.5	200	200	200	225	225
Turbine Gross Heat Rate, kcal/kWh	2012	1960	2012	1960	1960	1960	1889	1889
Auxiliary Load, kW	12955	13828	13750	14928	17200	15328	18175	16150
Boiler Efficiency, %	79.0	82.0	79.0	82.0	90.0	90.0	90.0	90.0
Net Output, MW	131.5	186.2	130.8	185.1	182.8	184.7	206.8	208.9
Net Unit Heat Rate, kcal/kWh	2797	2567	2814	2583	2382	2358	2283	2261

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Table 4.4-6

NET PERFORMANCE OF UNIT 13 OPTIONS AT 100% LOAD

Options	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Turbine Gross Output, MW	148.0	200	148	200	200	200	225	225
Turbine Gross Heat Rate, kcal/kWh	2018	1972	2018	1972	1970	1970	1889	1889
Auxiliary Load, kW	13164	13828	13978	14928	17200	15328	18175	16150
Boiler Efficiency, %	79.0	82.0	79.0	82.0	90.0	90.0	90.0	90.0
Net Output, MW	134.8	186.2	134.0	185.1	182.8	184.7	206.8	208.9
Net Unit Heat Rate, kcal/kWh	2804	2584	2821	2599	2395	2370	2283	2261

4.4.3 Conceptual Design - Replacement Turbine

Conceptual design was developed for the extensive upgrade associated with the replacement of the turbogenerator for Units 10 and 13. The replacement involves the turbogenerator and associated auxiliaries and the balance of the equipment in the turbine plant. Balance of plant equipment required for the extensive upgrade are described in Sections 4.5, 4.6 and 4.7. This section describes the new turbine-generator.

The conceptual outline drawing of the turbine together with overall dimensions is shown in Figure 4.4-4. The turbine is a 225 MW reheat unit manufacturer by Kharkov Turbine Works. The technical characteristics of the turbogenerator unit are as shown in Table 4.4-7.

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Table 4.4-7

TECHNICAL CHARACTERISTICS OF THE 225 MW TURBOGENERATOR

Manufacturer	Kharkov Turbine Works
Model	K-225-12.8 NPO "turboatom"
Nominal Output	225 MW
Nominal Main Steam Flow	625.7 t/h
Maximum Steam Flow Capability	670 t/h
Steam Inlet Pressure	130 ata
Steam Inlet Temperature	540°C
Reheat Steam Temperature	540°C
Turbine Heat Rate	1888.8 kcal/kWh
Number of Regenerative Extractions	7
Configuration of Turbine	Tandem-compound
Cylinders	HP, IP, Double Flow LP
Condenser Type	K-13750
Electric Generator Type	TGB-220M
Power Factor	0.8

The turbine was specifically designed to be used for the replacement of the existing 200 MW reheat steam turbines which have expended their lives. Therefore, the turbine was designed to be able to be mounted on the existing foundation of the 200 MW unit's pedestal. The turbine has the same maximum steam flow capability as the original 200 MW unit, however, the replacement unit takes advantage of the latest technological development in steam path design. Therefore this new

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turbine is much more efficient than the original 200 MW turbine. In comparison to the original 200 MW turbine the new replacement turbine will provide the following full load performance benefits:

Output increase	:	25 MW
Heat rate improvement	:	100 kcal/kWh

The main heat cycle diagram for the 225 MW turbine is shown in Figure 4.4-5. The corresponding extraction conditions (flow, pressure, temperature and enthalpy) for various load points are indicated in Table 4.4-8.

Some equipment are furnished with the steam turbine as a package including the condenser. The turbine is complete with main steam and reheat stop valves, control and intercept valves, extraction check and isolation valves, oil system, air ejector system, gland seal condenser, vacuum breaker and turning gear with electric motor.

Various other turbine hall mechanical equipment are described in Section 4.5. In addition, a general arrangement for the extensive modification has been developed by Burns and Roe showing the overall configuration of the upgraded units. The general arrangement is shown in Dwg Nos. SM201A, 201B and 202 in Appendix D.

Table 4.4-8

EXTRACTION PARAMETERS FOR THE 225 MW TURBINE

Load	Feedwater Heater	Extraction Steam Flow t/h	Extraction Steam Parameters		
			Extraction Press., ata	Temperature °C	Enthalpy kcal/kg
Max	HR HTR 7	44.12	41.11	375	753.46
	HP HTR 6	55.88	23.76	305	722.89
	Deaerator	17.21	10.53	432	795.61
	LP HTR 4	27.36	4.665	320	741.84
	LP HTR 3	18.11	1.797	209	690.25
	LP HTR 2	25.96	0.926	145	660.86
	LP HTR 1	18.17	0.169	56	599.73
100%	HP HTR 7	39.7	38.51	371	752.19
	HP HTR 6	49.24	22.36	302	721.98
	Deaerator	18.08	9.884	431	795.64
	LP HTR 4	25.06	4.384	320	741.93
	LP HTR 3	17.92	1.69	209	690.35
	LP HTR 2	24.31	0.871	145	660.95
	LP HTR 1	16.62	0.159	55	599.85
75%	HP HTR 7	25.62	29.11	349	744.27
	HP HTR 6	27.41	17.29	285	716.03
	Deaerator	19.96	7.557	430	795.64
	LP HTR 4	17.3	3.367	319	742.18
	LP HTR 3	12.33	1.301	209	690.65
	LP HTR 2	18.33	0.671	145	661.24
	LP HTR 1	10.47	0.123	50	600.44
50%	HP HTR 7	14.92	19.2	328	738.48
	HP HTR 6	8.17	11.247	265	710.05
	Deaerator	22.37	11.247	265	710.05
	LP HTR 4	10.01	2.297	325	745.7
	LP HTR 3	7.5	0.891	214	693.72
	LP HTR 2	11.87	0.461	150	664.02
	LP HTR 1	4.23	0.086	43	603.19
25%	HP HTR 7	1.61	9.366	313	735.97
	HP HTR 6	-	-	-	-
	Deaerator	14.4	9.0	484	823.2
	LP HTR 4	4.03	1.217	326	746.8
	LP HTR 3	3.4	0.475	216	694.94
	LP HTR 2	5.56	0.248	152	665.46
	LP HTR 1	1.16	0.052	33	608.11

4.4.4 Cost of Modifications and Upgrades

Capital costs estimates for the various turbine upgrades have been developed. Some of the costs were obtained from Russian or Ukrainian sources, and some were developed either from U.S. vendor information or from Burns and Roe in-house data. The component costs of minimal and extensive upgrades for turbines of Unit 10 and 13 are summarized in Tables 4.4-9 and 4.4-10, respectively. The costs represent 1995 capital cost expressed in U.S. dollars.

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Table 4.4-9

CAPITAL COSTS FOR UNIT 10 TURBINE UPGRADES

Item No.	Item Description	Qty.	Price Per Unit-(US)	Total Price (US)	Pricing Source	
	Minimal Upgrade				B&R	Ukr.
1	Replace R.H. Stop Valves	2	$90,000	$180,000	X	
2	Replace Governor Valves	4	$67,500	$270,000	X	
3	Replace Intercept Valves	4	$67,500	$270,000	X	
4	Replace crossover steam lines at turbine inlet	8	-	included (5&6)	X	
5	Replace HP Turbine (casing, rotor, diaphragm, etc.)	1	$2,575,000	$2,575,000	X	
6	Replace IP Turbine (Casing, rotor, diaphragm, etc.)	1	$2,575,000	$2,575,000	X	
7	Replace Front Standard	1	$550,000	$550,000		X
8	Add EHC System w/supervisory & vibration monitoring	1	$500,000	$500,000	X	
9	Replace L.P. Turbine Last Blading Stages	4	$250,000	$1,000,000	X	
10	Bypass Around LP HTR #1	1	$5,000	$5,000	X	
11	Isolate Evaporators from Service	2	-	Included	X	
12	Replace Lube Oil Cooler	2	$4,000	$8,000	X	
13	Improve SPE System	1	$200,000	$200,000		X
14	Upgrade Turbine Flange Connection Heating System	1	$130,000	$130,000		X
15	Enhance Drainage/Blowdown Equip.	1	$70,000	$70,000		X
16	Improve Generator H2 Sealing System	1	$20,000	$20,000	X	

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	<u>Extensive Upgrade</u>					
	Replacement 225 MWe Turbine + Auxiliaries	1	$9,003,400	$9,003,400		X
	Electrical Generator	1	$3,500,000	$3,500,000		X
	Excitation System	1	500,000	500,000		X

. Table 4.4-10

CAPITAL COSTS FOR UNIT 13 TURBINE UPGRADES

Item No.	Item Description	Qty.	Price Per Unit-(US)	Total Price (US)	Pricing Source	
	Minimal Upgrade				B&R	Ukr.
1	Replace H.H. Stop Valves	2	$90,000	$180,000	X	
2	Replace R.H. Stop Vavles		$90,000	$180,000	X	
3	Replace Governor Valves	4	$67,500	$270,000	X	
4	Replace Intercept Valves	4	$67,500	$270,000	X	
5	Replace Front Standard	1	$550,000	$550,000		X
6	Add EHC System w/supervisory & vibration monitoring	1	$500,000	$500,000	X	
7	Replace L.P. Turbine Last Blading Stages	4	$250,000	$1,000,000	X	
8	Bypass Around LP HTR #1	1	$5,000	$5,000	X	
9	Isolate Evaporators from Service	2	-	Included	X	
10	Replace Lube Oil Cooler	2	$4,000	$8,000	X	
11	Improve SPE System	1	$200,000	$200,000		X
12	Upgrade Turbine Flange Connection Heating System	1	$130,000	$130,000		X
13	Enhance Drainage/Blowdown Equip.	1	$70,000	$70,000		X
14	Improve Generator H2 Sealing System	1	$20,000	$20,000		
15	Replication Type Creep Monitoring Equipt.	1	$10,000	$10,000	X	
	Extensive Upgrade					
	Replacement 225 MWe Turbine + Auxiliaries	1	$9,003,400	$9,003,400		X
	Electrical Generator	1	$3,500,000	$3,500,000		X
	Excitation System	1	500,000	500,000		X

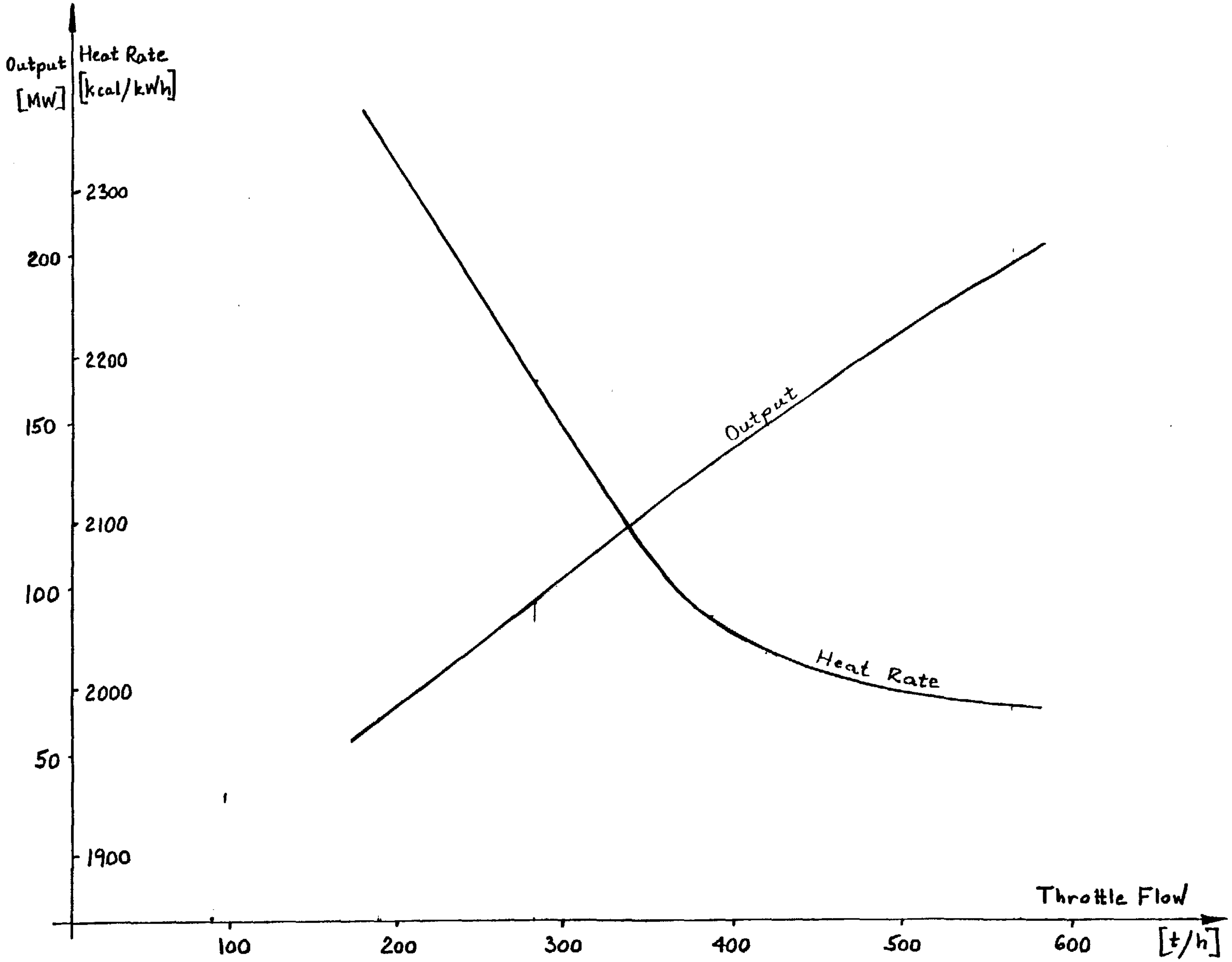

Figure 4.4-1 Gross Performance of 200 MW Original Turbine

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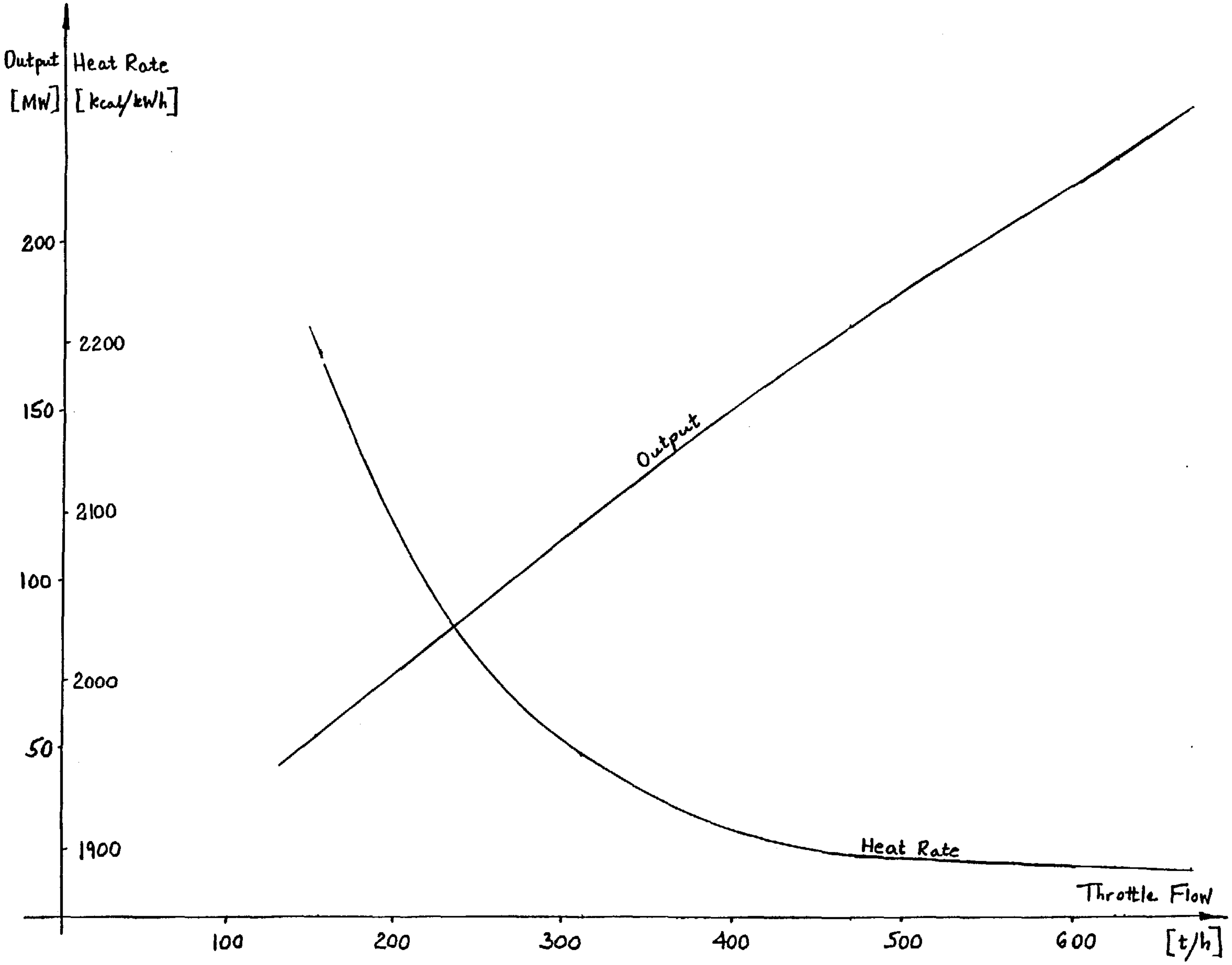


Figure 4.4-2 Gross Performance of New 225 MW Turbine

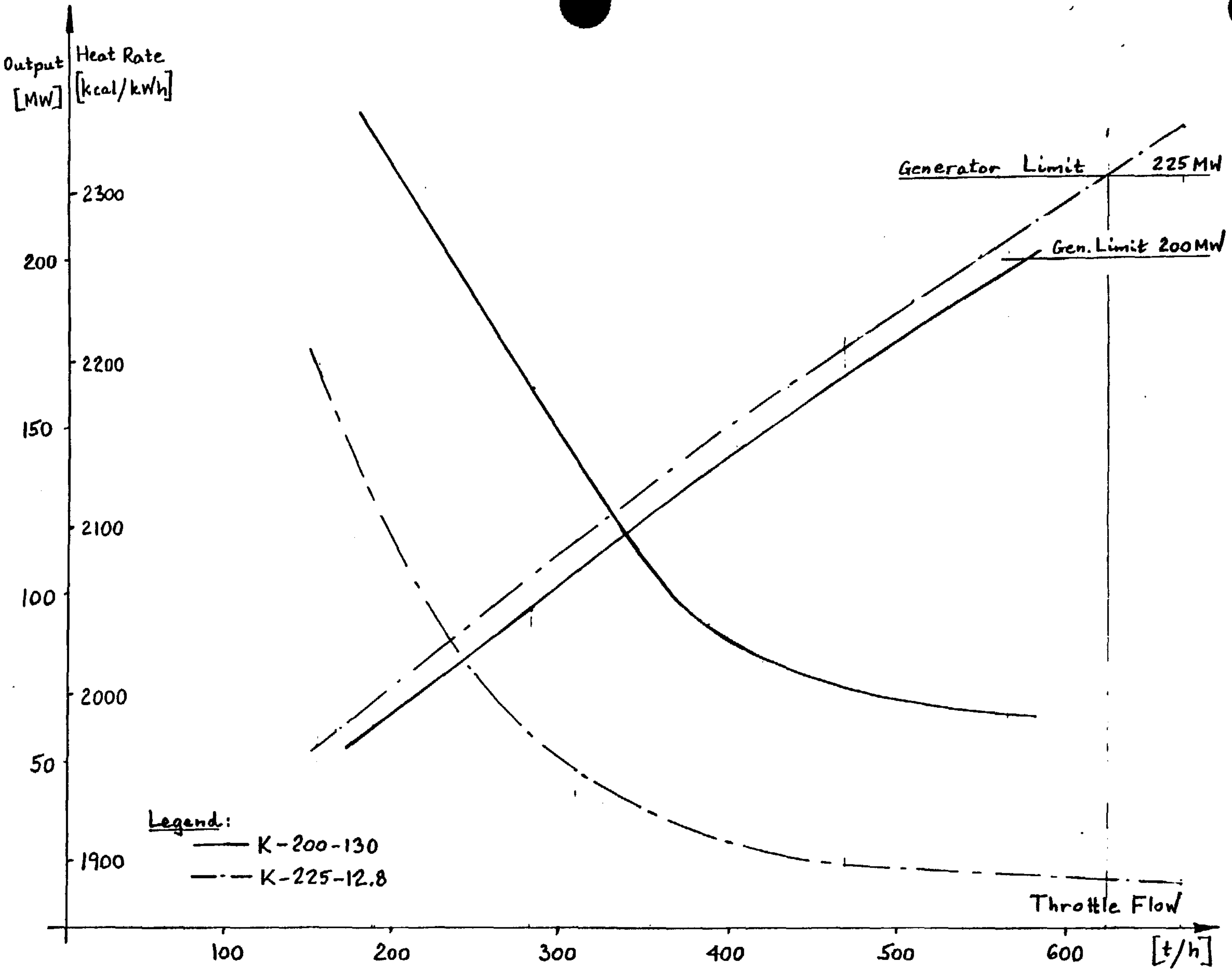


Figure 4.4-3 Superimposed Performance of the Original and New Turbine with Generator Limits

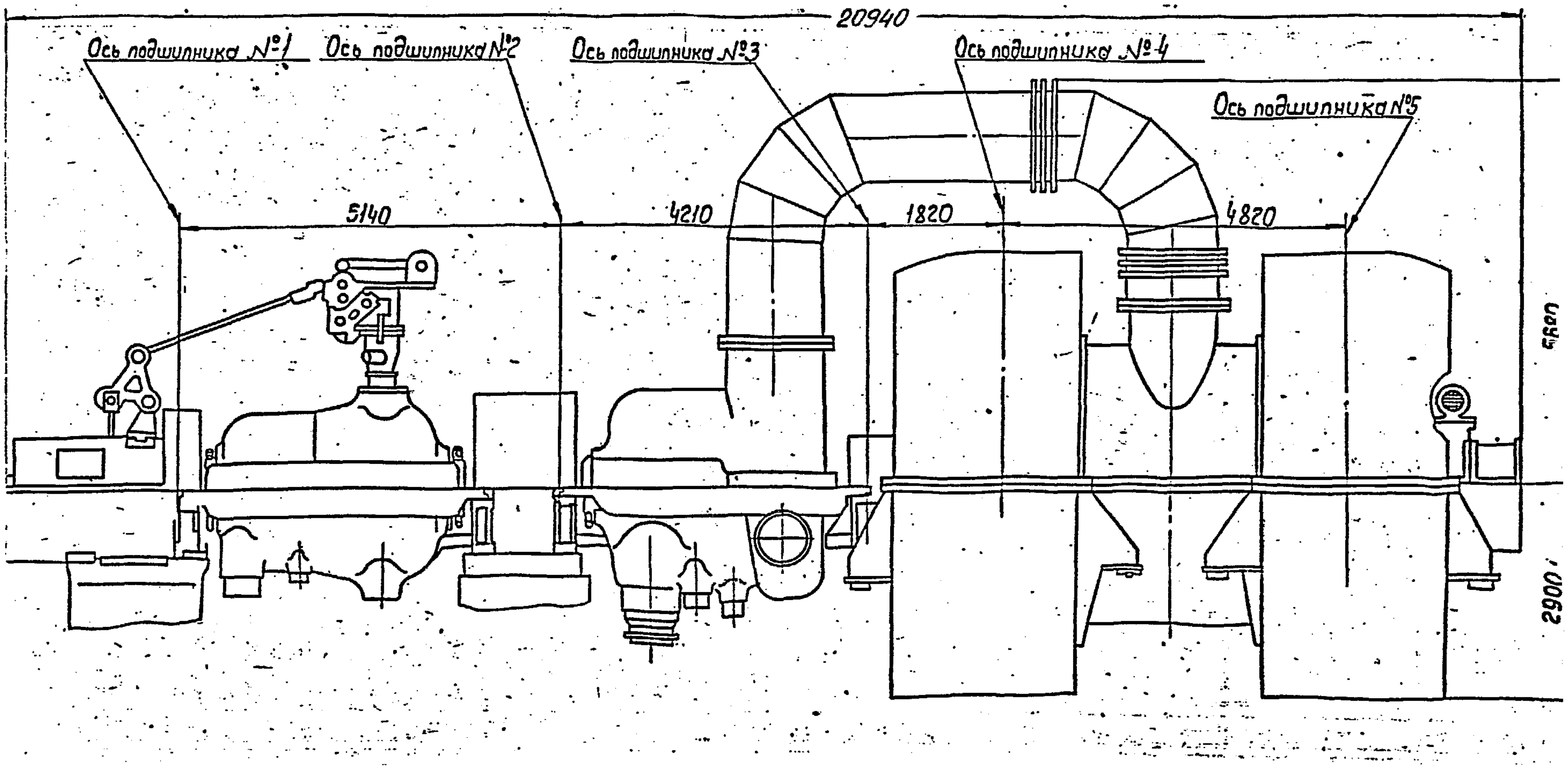
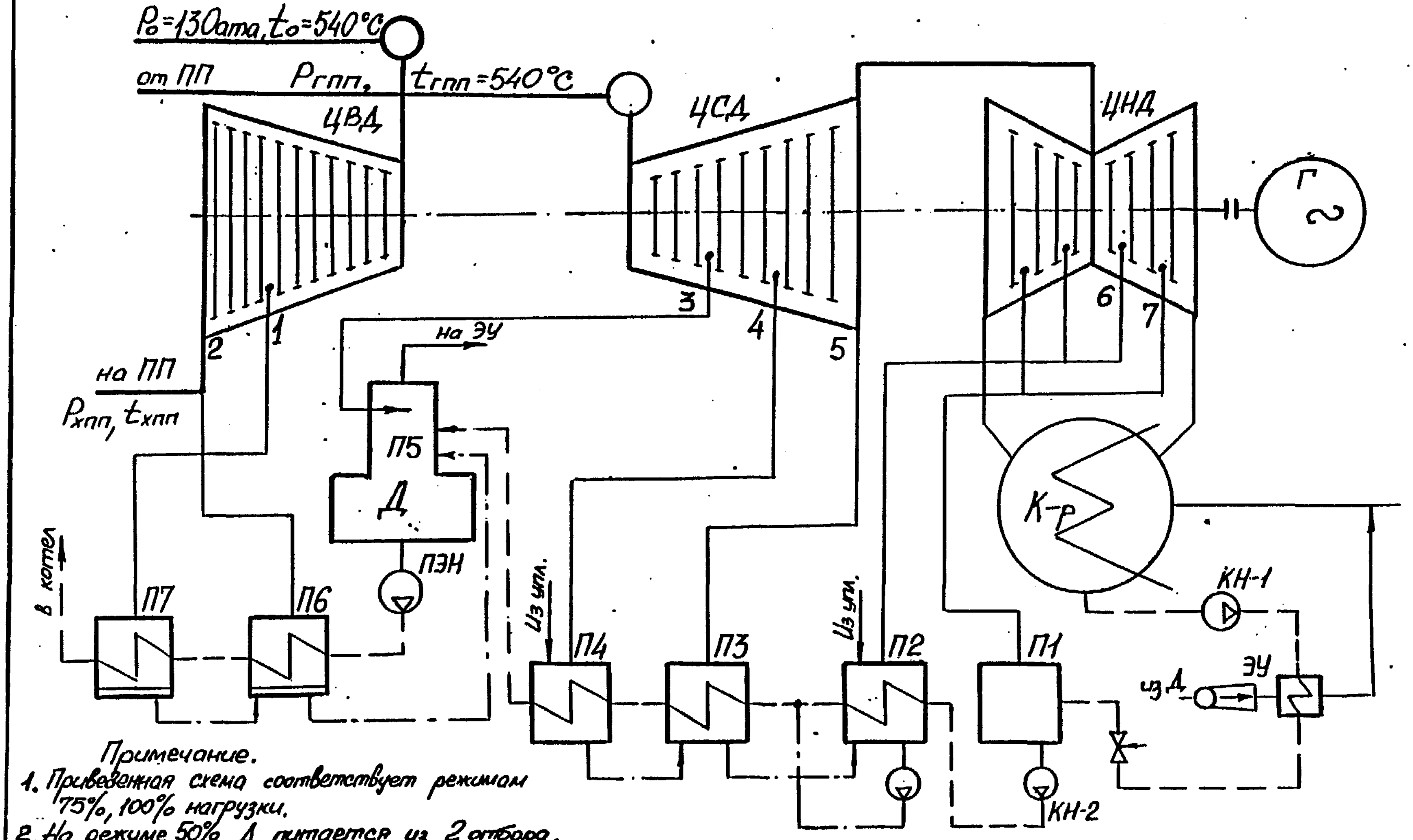


Figure 4.4-4 Outline of 225 MW Steam Turbine

Принципиальная тепловая схема турбоустановки К-225-12,8 НПО „Турбоатом"



Примечание.
1. Приведенная схема соответствует режимам 75%, 100% нагрузки.
2. На режиме 50% Д питается из 2 отбора.
3. На режиме 25% Д питается от БРУ. Дренаж П6 сбрасывается в РБ. 4. Параметры приведены в табл. 3,4

Figure 4.4-5 Main Heat Cycle Diagram for the 225 MW Turbine

4.5 MECHANICAL SYSTEMS AND EQUIPMENT - REHABILITATION DETAILS

4.5.1 Systems and Equipment Considered for Rehabilitation

As with the turbine generator rehabilitation discussed above, the balance of plant mechanical equipment and systems considered for rehabilitation on Units No. 10 & 13 may be grouped by rehabilitation level. The two groupings are "Minimal Refurbishment" and "Extensive Refurbishment". Minimal refurbishments, in this context, are defined as plant rehabilitation items considered for the purpose of improving plant efficiency (Heat Rate), improving reliability, or reducing maintenance costs. Extensive refurbishment are those items which are associated with rehabilitation efforts to increase plant output above the 200mwe design level. Rehabilitation items which were considered for these two levels of rehabilitation are summarized in Table 4.5-1. Unless otherwise noted, the items listed are applicable to both Units 10 & 13.

4.5.2 Conceptual Description and Cost Impact of Recommended Rehabilitation Items

This section contains a description of the Mechanical balance of plant items identified in Table 4.5.1 and recommended for rehabilitation. The costs associated with these items are listed in the table.

Equipment layout information is shown on drawings Nos. SM201 and SM202, "General Arrangement, Units 10 and 13 Upgrade," included in Appendix D.

4.5.2.1 Minimal Refurbishment Items

Item 1 - Replace Existing Feedwater Pumps - Due to the fact that the current pump models are no longer manufactured, spare parts are unavailable to maintain the pumps in good running order. In order to improve unit reliability, new pumps of the same line will be purchased to replace the existing two pumps on each unit. The efficiencies of the original feedwater pumps ranged from 71% and 72-77% on the Unit 10 pumps (PE-430-200 & PE-640-180 respectively) to 82% on the Unit 13 pumps (PE-720-185). Replacement of the pumps on both units with a current version of the PE-720-185 will result in an overall improvement in efficiencies over what is currently being experienced with the pumps in a deteriorated mode. Efficiencies in the 85% range can be expected for any new pumps.

Item 2 - Replace Condensate Pumps - Although no significant problems have been reported with the Condensate Pumps, these pumps will be replaced due to their age and to achieve greater unit reliability for the extended plant life under consideration.

Item 3 - Replace H.P. Feedwater Heaters - Even though the high pressure feedwater heater shells have been reported as being in good condition, the heating coils are suspect. In order to improve the reliability of the rehabilitated unit, during the extended life cycle, the heaters (No. 5, 6, & 7) will be replaced at this time. Also included with the heater replacements will be replacement of the heater drain level-control valves which have experienced unsatisfactory operation due to frequent cycling and shutdown of the heaters.

TABLE 4.5-1

Mechanical B.O.P. Items Considered for Rehabilitation

Units No. 10 & 13

Item No.	Item Description	Benefit	Qty.	Price Per Unit (US)	Total Price (US)
	Minimal Refurbishment				
1	Replace Existing Feedwater Pumps (1 + 1 spare)	R, O	-	-	-
	- 2 x 100% capacity	-	2	$300,000	$700,000
2	Replace Condensate Pumps (3 x 70%)	R	3	$53,300	$160,900
3	Replace H.P. FW Heaters No. 5, 6 & 7 + Drain Valves	R, M	3	$200,000	$600,000
4	Replace L.P. FW Heaters No. 1, 2, 3, & 4 + Drain Valves	R, M	4	$70,000	$280,000
5	Add Condenser Cleaning System	R, M,H	1	$220,000	$220,000
6	Repack/Replace Leaking Condenser Valves & Expansion Joints	H	1	$10,000	$10,000
7	Replace Feedwater Control Valves	R, M	1	$14,500	$14,500
8	Replace Attemperator Control Valves	R, M	1	$35,000	$35,000
9	Add Turbine Water Induction Protection @ L.P. Htr. No. 1	R	1	$5,000	$ 5,000
10	Replace Main and Reheat Steam Relief Valves	R, M	1	$25,000	$25,000
11	Replace Main Steam Piping	R	1	$650,000	$650,000
	Extensive Refurbishment				
1	New Condenser	H	1	$2,660,000	$2,660,000
2	Condenser Cleaning System ("Technos", one twin line system)	H	1	$225,000	$225,000
3	New Feedwater Pumps for 225 MWe cycle (2 x 100% capacity)	H	2	$350,000	$700,000
4	New H.P. FW Heaters for 225 MWe cycle (No. 6 & 7)	H	2	$200,000	$400,000
5	New L.P. FW Heaters for 225 MWe cycle (No. 1,2,3, & 4)	H	4	$70,000	$280,000
6	New Condensate Pumps for 225 MWe cycle (2x100% capacity)	H	2	$90,000	$180,000
7	Add Condensate Booster Pumps for 225 MWe cycle (3x60%) capacity)	H	3	$53,300	$159,900
8	New Heater Drain Pumps (2x 100% capacity)	H	2	$25,000	$50,000
9	Modify Turbine Cycle Piping Systems for New Cycle Equipment	H	1	$800,000	$800,000

Benefits Code:

R = Reliability Improvement O = Output Improvement

H = Heat Rate Improvement M = Reduction of Maintenance Costs

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Item 4 - Replace L.P. Feedwater Heaters - Due to the incidents of shell deformation, cracks, and erosion wear, the low pressure heaters will be replaced in order to achieve improved reliability for the rehabilitated unit. Heater replacement will include heater drain level-control valves.

Item 5 - Replace Condenser Cleaning System - Since condenser tube fouling due to sludge deposits is a continual problem, a dependable tube cleaning system is necessary. A new system will be provided for the condenser on each unit. This system would be of the continuous on-line type wherein tube surface cleaning is accomplished by constant circulation of sponge rubber balls. The circulating balls have a diameter slightly larger than the tube diameter and a density, when wet, similar to that of the circulating water. These balls are injected into the circulating water inlet. The force of the flowing water carries them into the water boxes, through the tubes, and into a ball collection strainer in the water outlet line. From there the balls are drawn off and pumped through a ball collector and return to the water inlet. Each ball takes approximately 30 seconds to complete one roundtrip of the flow path.

Condenser cleaning systems of this type must be custom designed in relation to the specific circulating water characteristics, the actual fouling mechanism, and the physical constraints of the circulating water piping arrangement. Therefore, the services of one of the suppliers who specialize in tube cleaning systems will be enlisted to develop a specific system design. However; given the one-nozzle arrangement of the condenser shells, one twin-line system, of the type supplied by "Technos" (a subsidiary of GEC Alsthom), could be used for each unit.

Installation of a properly designed condenser tube cleaning system will have the effect of maximizing heat transfer accross tube walls and improving condenser vacuum with a resultant increase in unit efficiency and heat rate improvement. Additionally, the high cost associated with the current air blowing or mechanical cleaning, would be reduced.

Item 6 - Reduce Condenser Air Inleakage - The plant should initiate a program of investigation of the possible locations where air is leaking into the condenser and causing the excessive inleakage rates described in Section 4.1.4. Such a program would involve the repacking of valve stems on the control valves in lines entering the condenser or replacing them if this appears to be more appropriate. Many of these valves will be replaced as part of the replacement of feedwater heaters discussed above. Specialized methods are available for detecting and measuring valve stem leakage. The plant should persue these methods and obtain any specialized instruments available.

The expansion joints which separate the two sections of the surface condenser will have any cracks or perforations repaired, if repairs are feasible, or replaced if the damage is serious and not repairable.

Items 7 & 8 - Replace Feedwater and Attemperator Water Control Valves - In order to reduce excessive maintenance and improve unit reliability, the main feedwater control valves to boilers No. 10 & 13 will be replaced. Additionally, the main steam attemperator control valves, from the feedwater system, require replacement. This situation developed as a result of excessive valve pressure drops due to the high feedwater header pressure resulting from unit operation at the derated condition.

Item 9 - Add Turbine Water Induction Protection At L.P. Feedwater Heater No. 1 - A protection system will be added to prevent the induction of water into, and damage to, the turbine low pressure casing. It is believed that the destruction of L.P. casing blades was due to high levels in the heater shell resulting form damage to the heater tubes. The system will operate in such a way that, during heater high water level conditions, condensate flow to the heater tubeside will be bypassed to eliminate the source of water. Shellside drainage will be controlled by use of level control off a heater drains reservoir and by the addition of a secondary drain path to the condenser (see Figure 4.5-1).

Item 10 - Replace Main and Reheat Steam Relief Valves - The age of the main and reheat steam relief valves has resulted in excessive maintenance. In order to reduce maintenance and increase the reliability of the overpressure protection systems, all the main and reheat steam relief valves will be replaced.

Item 11 - Replace Main and Hot Reheat Steam Piping - Based upon the excessive creep rate in the main and hot reheat steam piping systems and the indications of the degradation of metal structure, consideration has been given to replacing these piping systems. Reference has been made to a technique of restoring the metal structure in these lines by heating the metal to a temperature of 1050 ^{0}C and then cooling it. It is questionable whether such a procedure can restore the structure of these stainless steel lines, therefore, they will be replaced. Replacement will include the following lines:

- Two 325 mm main steam lines from boiler outlet to H.P. turbine inlet along with portions of cross-over piping to the condenser.
- Four 427 mm reheat steam lines from the boiler outlet to the I.P. turbine inlet along with portions of cross-over piping to the condenser.

4.5.2.2 Extensive Refurbishment Items

The extensive refurbishment items associated with the Balance of Plant mechanical systems and equipment consist of the replacement of cycle equipment and piping systems required to support the installation of the new 225 Mwe turbine generator described in section 4.3. These items are listed in Table 4.5-1 and described below.

Items 1& 2 - New Condenser and Tube Cleaning System

A new steam surface condenser with tube cleaning system as described in section 4.5.2.1 above is required to handle the new duty associated with the 225 Mwe turbine.

Item 3 - New Feedwater Pumps

Each unit requires two new 100% capacity feedwater pumps to supply the increased capacity of 809 m^3/hr and head of 2300 meters (w.c.).

Items 4 & 5 - New H.P. and L.P. Feedwater Heaters

The new cycle for the 225 Mwe turbine includes two high pressure heaters, H.P.-6 & 7, and four stages of low pressure heaters, L.P.-1,2,3,&4. These six heaters will be supplied with heater drain control valves.

Items 6 & 7 - New Condensate Pumps

The new main condensate pumps will be 2 x 100% capacity pumps with a flow of 500 m^3/hr and a head of 85 meters (w.c.). Unlike the current plant cycle, the new cycle requires condensate booster pumps. These pumps will be 3 x 60% capacity pumps with a flow of 320 m^3/hr and a head of 160 meters (w.c.).

Item 8 - New Heater Drains Pumps

New heater drains pumps will be required to pump condensate from the new heater L.P.-2. These pumps will be 2 x 100% capacity pumps with a flow of 80 m^3/hr and a head of 155 meters (w.c.).

Item 9 - New Cycle Piping Systems

In order to install the 225 Mwe turbine and related cycle equipment it will be necessary to extensively modify the Extraction, Condensate and Feedwater Piping Systems, and to a lesser extent the Circulating Water Piping Systems. It has been assumed that the existing piping in these systems can not be reused.

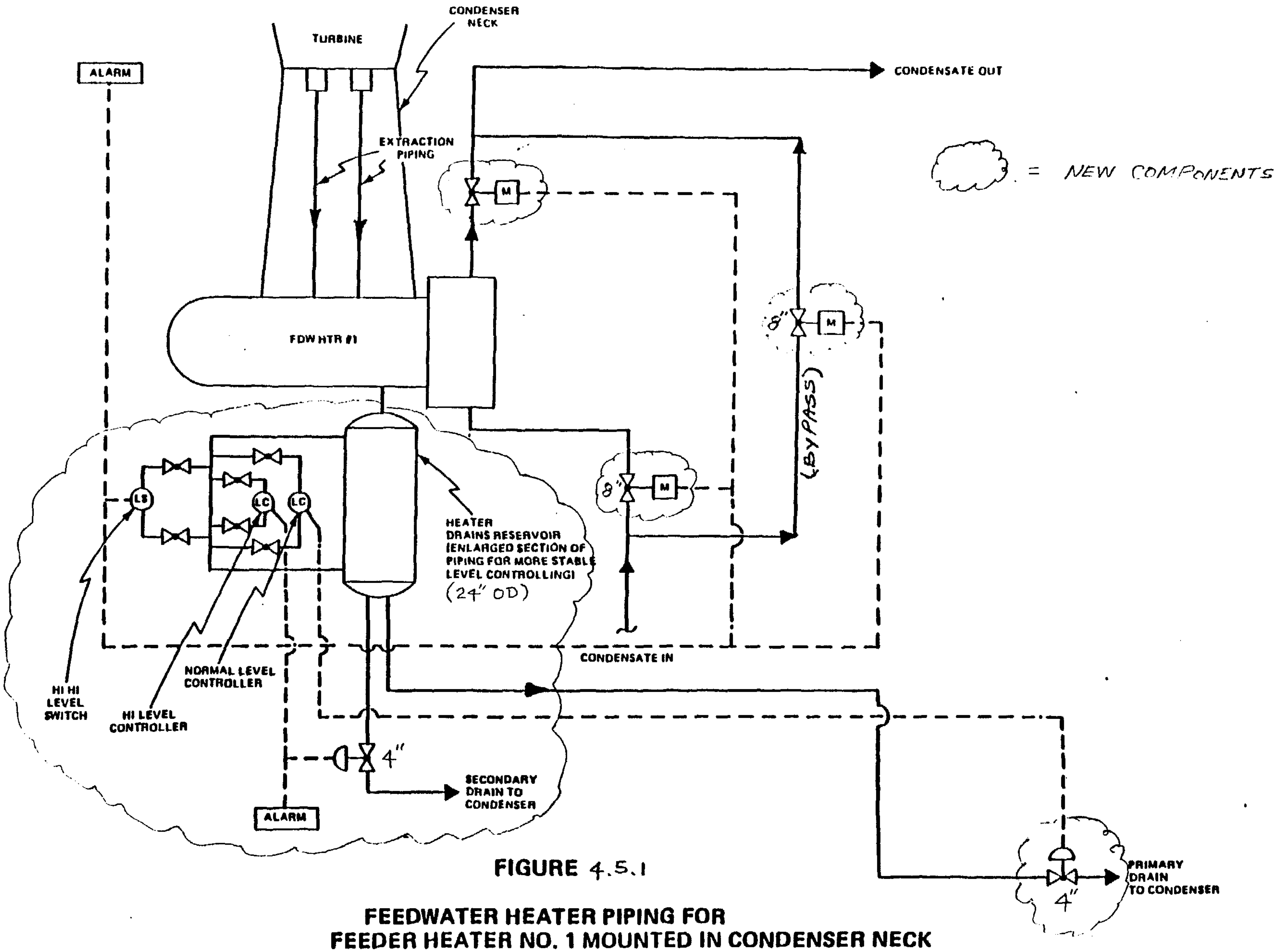

FIGURE 4.5.1

FEEDWATER HEATER PIPING FOR
FEEDER HEATER NO. 1 MOUNTED IN CONDENSER NECK

B.O.P., ITEM #9 - TURBINE WATER INDUCTION PROTECTION

4.6 ELECTRICAL SYSTEMS AND EQUIPMENT REHABILITATION DETAILS

4.6.1 Systems And Equipment Considered For Rehabilitation

Essentially, the entire distribution system at the 6.3kV level and lower must be replaced. This equipment includes all 6.3kV and 400V switchgear, 400V Motor Control Centers and all associated raceways, medium and low voltage power and control and instrumentation cables. In addition, 220kV circuit breakers, disconnect switches, potential transformers, surge arresters, protective relay system, turbine control system, and DC system must also be replaced. The existing cable tunnel can be utilized to route the new cables on a new tray system. The replacement of these equipment is required under all options.

Minimum Refurbishment

Table 4.6-1 lists electrical systems and equipment for Units 10 & 13 that should be replaced. This replacement is required irrespective of the extent of refurbishment of mechanical equipment in the boiler, turbine generator or other mechanical auxiliary systems and equipment.

Table 4.6-1

Item No.	Equipment Considered For Replacement
1	220 kV Circuit Breaker, 31 kA
2	220 kV Disconnect Switches
3	220 kV Potential Transformers & Lightning Arrestors
4	6.3 kV Switchgear
5	400V Switchgear
6	400 V Switchgear Transformers
7	6.3 kV Non-Segregated Phase Bus Duct
8	220 V DC Battery Chargers and Batteries
9	220 V DC Switchboard
10	6 kV / 380 V Motors (e.g. Mill Ventilator fan motor
11	All Power, Control and Instrument Cables
12	All Cable Trays and Conduits
13	Protective Relay Boards

Item No.	Equipment Considered For Replacement
14	Electrical Control Board
15	All Electrically Operated Valves
16	Lighting System
17	Fire Detection System

Extensive Refurbishment

Table 4.6-2 lists electrical equipment for Units 10 & 13 to be replaced under Options for Extensive Refurbisment:

Table 4.6-2

Item No.	Equipment Considered For Replacement
1	200MWe , 15.75kV, 0.85 PF, H_2 Cooled Turbine-Generator
2	1542kVA Excitation Transformer

The present 200MWe generator(s) cannot be modified to increase the unit output to 225MWe. A new generator rated 225MWe, 0.85 power factors will be required. Preliminary discussions with Ukrainian engineers indicate that a 220MWe, 0.80 power factor generator is available from the manufacturer. The physical parameters of the new generator are identical to the 200MWe generator and it can be modified to generate 225MWe at 0.85 power factor. The existing turbine generator pedestal can be used with the new 225MWe generator.

The existing ratings of generator step-up transformer unit auxiliary transformer and isolated phase bus are adequate to match the 225MWe rating of the generator. However, the excitation transformer(s) will have to be replaced

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4.6.2 Performance Improvement

Power plant performance can be greatly improved if the obsolete and degraded electrical equipment are replaced with new equipment. Section 4.6.3 describes the conceptual design criteria and brief descriptions of new electrical equipment.

Upgrading the electrical equipment to equipment of newer design will provide performance improvements over existing operations. For example, much of the new equipment will, in general, have a smaller probability of failure allowing the plant to achieve a higher capacity factor. The increase in capacity factor will not only be due to a reduction in plant outages but also a reduction in part load operation due to the failure of parts of the system. New 6.3 kV and 400 V switchgear breakers will be properly coordinated to reduce the effect of an isolated fault causing a complete trip of the unit.

Operating and maintenance will be reduced for the new electrical equipment especially for the existing motors which are prone to faults on the windings and existing electromechanical protective relays which require a great deal of maintenance.

Most importantly, much of the existing electrical equipment is considered unsafe and may be prone to frequent failures.

4.6.3 Conceptual Design

4.6.3.1 General

Reference Drawings (in Appendix D)

SE001 Conceptual Main One-Line, Units 6, 10 and 13 Upgrade

SE002 6.3 kV and 416V System One-Line, Unit 13 Upgrade

SE0004 General Ararngement, 6.3 kV Switchgear and 416V Unit Substation, Unit 13

The above Single Line Diagrams and General Arrangement drawing indicate the extent of refurbishment. Drawings SE001 and SE002 are conceptual single line diagrams which indicate major electrical equipment recommended for upgrade or replacement. Drawing SE004 shows preliminary locations and space requirements for the equipment.

The portions of the electrical system that will be upgraded or replaced are described herein under the headings: Switchyard, Turbine Island, Boiler Island and Miscellaneous Systems. All Unit No. 13 equipment recommendations are also applicable to Unit No. 10, unless otherwise noted.

Sources of supply for major equipment were discussed with the plant chief engineer to determine the recommended source for the equipment. The chief engineer suggested that when feasible, the equipment of the required ratings and quality locally available in Ukraine should be used. The equipment should be purchased from a foreign supplier (e.g. United States, Europe, Russia, etc.) only when not available in the Ukraine.

Major equipment that can be supplied from the Ukraine include 400V switchgear transformers, all medium and low voltage power, control and instrumentation cables and cable raceways. The new equipment that will be supplied from foreign sources include 220kV circuit breakers, potential transformers and surge arresters 6.3kV switchgear, 400V switchgear, motor control centers, DC system, UPS system and plant protective relays.

4.6.3.2 Switchyard

Electrical equipment in the switchyard recommended for replacement includes 220 kV circuit breakers, lightning arrestors, potential transformers and disconnect switches.

220 kV Circuit Breakers

The existing circuit breakers in the switchyard are of the air-blast type and have a short circuit rating of 31kA. Since the system short circuit level has increased during last 20 years, these breakers will be replaced with SF6 type breakers with short circuit rating of 40kA. The SF6 breakers will be of the dead tank design.

Potential Transformers and Surge Arresters

Potential transformers and the surge arrestors in the switchyard will be replaced with new equipment manufactured with improved insulating materials.

Disconnect Switches

Disconnect switches in the switchyard will be replaced with motor operated switches.

Generator Excitation Transformer(s)

The generator excitation transformer will require replacement under Extensive Refurbishment option to match the rating of 225MWe turbine generator.

4.6.3.3 Turbine Plant

The electrical equipment located in the turbine island that will be replaced include: 6.3 kV non-segregated phase bus, 6.3kV switchgear, 400V dry type transformers and switchgear; 220V DC batteries, chargers and switchboard; protective relay boards, motor control centers and electrical motors. A new 220V AC uninterruptible power supply (UPS) will be installed to supply power to plant automatic control system (DCS System).

6.3kV Non-Segregated Phase Bus

New 6.3kV non-segregated phase buses are recommended to supply power from the existing unit auxiliary transformer 13TCH (25 MVA, 15.75 / 6.3 - 6.3 kV) to the new 6.3 kV switchgear sections 13A and 13B. The existing 6.3 kV non-segregated phase reserve buses appear to be in good condition and, therefore, need not be replaced. However connections to the new 6.3 kV switchgear shall be required.

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The bus duct will be of a non-ventilated (self-cooled), non-segregated design for operation in the plant environmental conditions.

6.3V and 400V Switchgear

The 6.3kV and 400V switchgear will be provided consisting of vertical sections mounted side by side and connected mechanically and electrically together. Auxiliary compartment(s) will be provided to mount potential transformers, surge arrestors, control power transformers, etc.

6.3kV circuit breakers will be mounted two (2) per vertical stack and will consist of electrically operated removable vacuum circuit breaker elements.

The circuit breakers for 400V switchgear will be three-pole, single throw, air break, electrically operated, drawout type rated 600 volts.

The breakers will be operated by motor-charged, spring-type stored energy mechanism.

Unit Substation Transformers

The new unit substation dry-type transformers associated with 400V switchgear will be rated 1000kVA (existing 750kVA) to supply additional loads due to plant refurbishment.

Motor Control Centers

Motors from 1/2kW to 100kW will be fed from motor control centers (MCC's). The 400V motor control centers will feed all turbine-related low voltage loads. MCC's will consist of one or more vertical sections and will be of the non-ventilating type.

220V DC Power System

The DC system will consist of two battery chargers, batteries and DC power distribution switchboard. The DC system will be sized to supply power to all DC loads including emergency oil pumps, uninterruptible power supply, and switchgear controls.

DC power distribution switchboard will contain molded case circuit breakers; all breakers will be 2-pole. Batteries will consist of 98 cells and be rated 220V at the required ampere-hours.

The battery cells will be of a sealed, nongassing, explosion proof design with a 20 year life expectancy using an immobilized electrolyte, requiring no water and no venting under normal conditions.

All necessary inter-step jumpers and connectors between cells, between groups of cells, and between rows of cells will be furnished complete with hardware. The cell terminal posts and all inter-step jumpers and connectors will have adequate capacities to prevent excessive losses and to prevent overheating on short-time high-current loads.

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The DC switchboard circuit breakers will be furnished with auxiliary contacts to monitor breaker position. This auxiliary contact will be used to indicate to the operator if the circuit breaker is open or tripped.

220V AC Uninterruptible Power Supply

The UPS will provide regulated, transient-free sine wave 220V AC power to plant distributed control system (DCS) and other selected loads during both normal and abnormal conditions. It will consist of a rectifier, inverter, static transfer switch, manual bypass switch, bypass transformer and accessories. DC power will be provided by the station 220V DC lead calcium batteries. The inverter unit will be a solid state device.

The AC distribution panel circuit breakers will be furnished with auxiliary contacts to monitor breaker position. This auxiliary contact will be used to indicate to the operator if the circuit breaker is open or tripped.

Protective Relay Boards

The protective relay boards will contain all solid state protective relays for the turbine generator, step-up transformer and auxiliary transformer protection and 220kV lines.

Protection relaying schemes will include primary and backup protective relaying. Backup protective relaying schemes will be designed such that no single point of failure of a primary protection system function would result in significant damage to the protected equipment or result in a fault not being cleared. Primary and backup protective relaying will have separate control power sources and operate separate tripping devices. The dc power supply for all devices will originate from the 220 V dc battery system.

4.6.3.4 Boiler Plant

The main electrical equipment associated with the boiler island that will be replaced include 400 volt unit substations and 400 volt motor control centers and power distribution panels.

New 400V unit substations and motor control centers will be provided to feed all boiler-related low voltage loads. These equipment will be similar to those as stated in Section 4.6.3.3.

The 400/230V AC power distribution panels will be located at the load centers.

4.6.3.5 Miscellaneous Systems

Electrical equipment included in the miscellaneous systems are medium and low voltage power, control and instrument cables, cable trays and conduits, lighting system, grounding system, cathodic protection system, communication system, fire detection system, new motors for circulating water pumps, control room air conditioning, and electrically operated valves.

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Power, Control and Instrumentation Cable

All medium and low voltage power control and instrumentation cables will be replaced. Cables will be asbestos free.

The power cable, including the individually insulated or insulated and jacketed conductors, will be resistant to heat, moisture, and flame. Their thermal properties will be such as to maintain its critical electrical and physical qualities, when the continuous conductor temperature for normal operation will be 90 degrees C.

Cables for control, metering, indicating and alarm circuits will be jacketed multiple conductor. Single conductor control cable will not be used.

Cable Trays and Conduit

New cable trays will be provided for 6.3kV power cables, 400V single conductor and multiconductor power cables, 220V AC and 220V DC power cables, control cables (220V AC and 220V DC) and instrumentation cables. Cable trays for power and control cables will be ladder type. Instrumentation trays will be solid bottom (steel) with solid covers. Cable tray will be installed in the existing cable tunnel and other plant areas where required.

Cable trays, except trays for instrumentation cable, will be either aluminum or steel. Steel cable trays will be hot-dipped galvanized after fabrication.

All conduits will be rigid steel, hot-dipped galvanized inside and out.

Metal conduits will be grounded. For isolated conduits or conduit systems, grounding bushings will be used for ground connections.

Conduit connections to vibrating equipment such as motors, to equipment which may move due to expansion or adjustment such as motor-operated valves or belt-driven equipment, or to equipment which must be capable of ready removal for maintenance will be made with flexible conduit. Flexible conduit will be jacketed galvanized steel.

Lighting System

The existing lighting system will be reevaluated and supplied with new fixtures to meet required illumination levels for plant operation. Emergency lighting will be provided to provide emergency light levels in the event of loss of normal power.

Grounding System

The existing grounding will reevaluated to insure safety to personnel and equipment in case of electrical equipment failures. All equipment enclosures and or equipment ground busses will be grounded through the plant's ground loop.

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Cathodic Protection System

The existing cathodic protection system will be evaluated. It will provide corrosion protection for all buried metallic systems and structures.

Communications System

The existing communication system will be refurbished to provide multi-channel communications system with paging capability.

Generator Hydrogen Cooling

Turbine generator rated output of 200MW is based on hydrogen pressure of 3 atmosphere. The generator output cannot be increased by simply increasing the hydrogen pressure. The limiting factors in increasing the generator output include: mechanical design limitations in generator casing parameters, hydrogen cooler heat absorption capacity and exciter output. Therefore, the output of the generator cannot be increased beyond rated capacity of 200MW under the Minimum Refurbishment Options.

Excessive leakage of hydrogen gas from the turbine-generaor casing, described in Section 4.1.5, will be addressed during the refurbishment. The generator seal oil rings and the seal oil system equipment will be examined and the required parts will be replaced.

A new turbine generator rated 225MWe 0.85 power factor will be installed under the Extensive Refurbishment Option.

4.6.3.6 Equipment not Requiring Replacement/Refurbishment

Under Minimum Refurbishment Options, equipment which does not require replacement or refurbishment includes the generator, generator excitation system, bearing oil system and associated AC and DC motors, self-cooled isolated phase bus duct, step-up, auxiliary and reserve transformers. The technical particulars of this equipment are as shown in the following Table 4.6-3:

Table 4.6-3

	Unit 10	Unit 13
Generator		
Designation	G10	G13
Nominal Power (MW / MVA)	200 / 235	200 / 235
Cooling System / Pressure	Hydrogen / 3 Atmospheres	Hydrogen / 3 Atmospheres
Sator (Amps / kV)	8630 / 15.75	8630 / 15.75

	Unit 10	Unit 13
Rotor (Amps / Volts)	1750 / 380	1750 / 380
Neutral Grounding	Ungrounded	Ungrounded
Excitation Transformer		
Designation	10TB	13TB
kVA Rating	1542	1542
Excitation Current (Amps)	2100	2100
Step-Up Transformer		
Designation	10T	13T
MVA Rating	250	240
Voltage	242 / 15.75	242 / 15.75
Connection	WYE / DELTA	WYE / DELTA
Auxiliary Transformer		
Designation	10TCH	13TCH
MVA Rating	31.5	25
Voltage	15.75 / 6.3 - 6.3	15.75 / 6.3 - 6.3
Connection	DELTA / DELTA - DELTA	DELTA / DELTA - DELTA
Reserve Transformer		
Designation	0BT01 (Common to all units)	0BT02 (Common to all units)
MVA Rating	25	31.5
Voltage	115 / 6.3 - 6.3	110 / 6.3 - 6.3
Connection	WYE / DELTA	WYE / DELTA

4.7 INSTRUMENTATION AND CONTROLS SYSTEMS - REHABILITATION DETAILS

4.7.1 Systems and Equipment Considered for Rehabilitation

The following systems and equipment will be upgraded/furnished for all refurbishment options considered:

1. Unit control system
2. Process systems control
3. Digital electro-hydraulic turbine control system (EHC)
4. Burner Management System (BMS)
5. Pollution control system
6. Continuous Emission Monitoring System (CEM)
7. Duct burner
8. Field instrumentation
    - Transmitters (Pressure, Level, Flow) - 100
    - Thermocouples/RTD's -70
    - Process Switches (Pressure, Level, Temp. Etc.) -45

Details of the new systems are provided in Section 4.7.3.

4.7.2 Performance Improvement

Upgrade of unit control system, process systems control, and process equipment, identified in Section 4.7.1, will result in improved unit reliability, availability, and downtime reduction due to easy maintenance. In addition, unit efficiency will improve considerably. Unit efficiency will come primarily from improved boiler efficiency which is due to most efficient combustion. The combustion, feedwater control and steam temperature control systems determine how a boiler actually operates and whether it achieves its efficiency potential. The controls should be designed to regulate the full, air and water to a boiler and maintain a desired steam pressure while simultaneously optimizing the boiler efficiency.

During either normal or abnormal operation, the greater the sophistication of the controls, the greater the efficiency potential of the boiler system. Distributed control system (DCS) as defined in Section 4.7.3, acts as a tool to achieve the most efficient combustion and coordinated regulation of feedwater flow, fuel feed, air flow and the electrohydraulic turbine governor in all modes of operation.

4.7.3 Conceptual Design

4.7.3.1 Unit Control System Modification

Reference Drawing (in Appendix D)

SI001 Control System Block Diagram, Units 10 and 13

The existing unit control system will be demolished and replaced with new sophisticated distributed type control system (DCS)

The system will be designed to allow plant start up, operation and shutdown under normal and upset conditions from the main control room. Local control with control room alarming may be utilized where conditions permit sufficient reaction time without undue jeopardy to equipment or the ability to maintain unit output.

Most plant control will be accomplished through the DCS in conjunction with direct hardwired controls of emergency and critical functions. Control of packaged equipment will be incorporated into this system to the greatest reasonable extent possible without jeopardizing system safety, performance, and economics.

Operation of the unit will be from the operator's console. This console will include as a minimum, multiple CRTs, keyboards and printers.

A vertical board will be provided for additional components, such as recorders, miscellaneous alarms and specialized inserts (including T/G and electrical controls and boiler trip pushbuttons).

Additional equipment such as input/output cabinets and electronics cabinets associated with the DCS will be installed in the DCS section of the control room.

Vertical control board will incorporate selected hardwired interfaces to give the operator direct control of emergency and critical functions, independently of the DCS equipment.

Hardwired devices will include:

- Burner Management emergency trip
- Turbine emergency trip
- Miscellaneous electrical devices

The existing control console and vertical board related to unit process control and monitoring, will be demolished and removed.

4.7.3.2 Process Systems Control Modifications

Turbine Control System

Existing Mechanical Hydraulic Control (MHC) System will be replaced by a complete digital electronic-hydraulic turbine governing system including throttle steam pressure control, speed monitoring, load limiting and independent overspeed protection. A free-standing local turbine generator gauge panel will be provided. All interconnections to the turbine will be to prewired junction boxes on the turbine skid. Also to be provided will be a control room insert panel and a digital control and monitoring cabinet in the DCS section of the control room for remote control of the turbine.

Interconnection to the insert panel will be by prefab plug-in cable. The insert will be located on a vertical control panel. Provisions will also be made for controlling the turbine generator from the main plant control system (DCS).

Provisions will be made for monitoring of the functions listed below. New vibration monitoring system will also be furnished. Remote temperature signals will be connected directly to the plant distributed control system (DCS) for monitoring.

- Remote bearing temperature monitoring
- Remote vibration monitoring
- Remote metal temperature monitoring
- Local oil flow indication
- Local bearing drain temperatures

All analog output signals which are necessary as guiding intelligence or as diagnostic data to aid the safe and efficient operation of the unit will be wired to the DCS. Analog outputs will be 4-20 mAdc.

Alarm contacts for annunciation of abnormal conditions will be wired to the DCS.

Steam Generator and Auxiliaries

a. Burner Management System (BMS)

Existing burner control will be replaced with a new BMS. The BMS will be of the programmable solid state type with provisions for remote-manual operation of lightoff and for hardwired master fuel trip push buttons located on the auxiliary control panel in the control room. The system will include timed purging and a complete fuel safety arrangement incorporating a system of interlocks and permissives for fail-safe operation. Operator interface with the system will be implemented through a communication interface with the unit DCS which will

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provide the operator all required control capability and status and alarm information via the DCS console. Since the power supply feed is subject to voltage dip, frequency shift and power interruption, the burner system will be designed to react with a predictable and safe response in those instances. Requirements of NFPA 85C will be observed.

b. Steam Temperature Control

The Steam Temperature Control System will be provided in the unit control system (DCS) in complete compliance with the Steam Generator manufacturers' requirements. The control valves and shut-off valves to the attemperators will be arranged to trip closed upon a boiler or turbine trip as per ASME water induction prevention recommendations.

c. Coordinated Control

The main plant control system will provide the coordinated regulation of feedwater flow, fuel feed, air flow, and the electro-hydraulic turbine governor in all modes of operation. The control system will maintain desired unit generation, proper throttle steam pressure, and proper excess air, as well as desired drum and deaerator levels.

This self-balancing control system will operate the turbine-generator and the boiler as an integrated unit. It will apply control actions in a coordinated manner so as to minimize interactions between the controlled variables of unit generation, throttle steam pressure, and flue gas oxygen by appropriate operation of the manipulated variables of fuel, air, and governor.

The combustion control system, an integral part of the coordinated control system, will control all feeders, pulverizers, and damper drives to supply the proper amount of coal and air to all burners in service. Master manual/auto stations, and manual/auto stations for all burners, coal feeders, pulverizers, and associated damper drives will be provided in the DCS to permit biasing units as required.

d. Draft Measures

The following categories of draft measurements (by new 2-wire, 4-20 mAdc transmitters) will be transmitted to the unit control system (DCS):

- Air pressure at air heaters.
- Gas pressures at air heaters, reheaters, superheaters, economizers, baghouse and FGD system.
- Furnace and wind box pressures.
- Fan pressures.

- Pressures associated with coal feeders, primary, secondary and overfire air, etc.

e. Steam generator Drum Level Measurements

The following drum level instrumentation will be provided:

- Two new drum level transmitters for feedwater flow control and high and low alarms.
- One new drum pressure transmitter for pressure compensation of drum level transmitter signals.
- Two new direct reading remote level indications. These indications will be visible in the control room.
- A highly reliable drum level measurement system to be used for primary high and low drum level sensing. Backup high and low level alarms will be developed by alternate devices such as the transmitters or other devices.

f. Air Heater Controls

The regenerative air heater will be primarily controlled from the unit control system (DCS). Local control panels shall be furnished for heater support systems such as leakage control and infrared detectors.

g. Soot Blower Controls

Existing sootblower system will be replaced by new sootblower system. The blowers will be controlled from an automatic sequential sootblower panel, mounted on the auxiliary boiler panel in the control room. The sootblower panel will be hardwired.

h. Furnace Draft Control

The furnace draft control system will ensure that pressure inside the furnace remains at the desired setpoint. This will be accomplished by regulation of the I.D. fan flow control devices.

Feedwater System

The feedwater system will be a conventional, combination, 3-element/single-element system using feedwater flow, steam flow, and steam generator drum level to control feedwater flow. The feedwater flow signal will have temperature compensation. The main steam flow signal will be the same as used for combustion control. Feed pumps will trip on low deaerator level and low flow.

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Condensate System

Condenser hotwell level will be measured and used to position make-up and dump valves between the condensate system and the condensate storage tank. In addition, total condensate pump discharge flow after the gland steam condenser will be measured and used to control the condensate recirculating valve, thus establishing a minimum flow condition based upon the condensate pump and/or gland steam condenser requirements.

A combination 3-element/single-element control system using feedwater flow, condensate flow and the deaerating heater storage tank level, will function to maintain the deaerator storage tank level within limits by means of a condensate flow control valve. The condensate flow signal will have temperature compensation. A turbine trip will cause the shutting of the deaerator level control valve for an adjustable time period with auto return to previous state.

Pollution Control System

The existing electrostatic precipitator (ESP) will be replaced with new high efficiency electrostatic precipitators.

The system will be self-contained. The ESP and fly ash transfer will be controlled locally from stand-alone control panels, containing PLC's, a graphic mimic, complete status indicators, control switches, alarm annunciators and other devices to allow the operator to monitor and manipulate the system as necessary. These systems will have the capability to communicate with the DCS. Primary elements, local indication, and final control elements, drives and linkages are to be provided as part of the fly-ash system. All interfacing wiring will be brought to the Boiler Area DCS I/O Cabinets.

Flue Gas Analysis

A continuous emissions monitoring system (CEM) will be provided to analyze, record, alarm, process data, and generate reports for the concentrations of SO_2, O_2 and/or CO_2 and particulate of stack effluents in accordance with criteria set by the Environmental Protection Agency and other cognizant regulatory bodies. Isolated outputs for alarms and monitored variables will be provided to the unit control system (DCS). A control room insert and report generation equipment will be provided for operator interface to the analyzers which will be installed in an analyzer house located near the base of the stack.

An oxygen analyzer system separate from the CEM will be provided as a trim for the Combustion Control System. Oxygen trim shall ensure that proper excess air level is maintained.

Duct Burner System

Duct Burner System for Primary Air temperature boost will have stand-alone control system. Duct burners will be monitored/controlled by its own fuel safety system. The control room operator via the DCS will be able to activate the duct burner if the proper permissives are satisfied.

Uninterruptible Power Supplies (UPS)

An uninterruptible power supply will be provided. Details of the system are provided in section 4.6-3.

The loads served by the UPS are as follows:

a) Burner Management System

b) Control system for main turbine-generator

c) Distributed Control System

d) CEM Data Acquisition System.

Field Instrumentation

a. Transmitters

Transmitters will be used for control, indication, recording, data acquisition and to avoid the exposure of the Control room to high pressure or temperature fluids and fuel oil.

Measuring elements for measured variables such as flow, level, pressure, and differential pressure transmitters will be of the electronic force-balance or capacitance type.

Each transmitter will be furnished with a NEMA Type 4 enclosure in accordance with ICS-6.

All transmitters will have zero elevation and suppression capability.

All transmitters will have an accuracy of ± 0.5% of calibrated span, minimum.

b.. Thermocouples/RTD

Temperature measurements for control and computer inputs will be made with chromel-constantan thermocouples and/or resistance temperature detectors (RTD); except that chromel-alumel thermocouples will be used for the furnace temperature probes and tube temperature sensors.

Thermocouples and RTD's will be of the dual element type. Thermocouples will have ungrounded tips unless high speed response is required for control. Local thermocouple cold junctions will not be used. Cold junctions will be located at the receiving end with automatic reference junction compensation provided (i.e., at the monitor input cabinets). All thermocouple and low level dc wiring will be shielded.

c. Pressure and Temperature Switches

Pressure and temperature switches will be of the snap action type; and will include at least DPDT contacts or equivalent, unless the application requires SPDT because of dead-band requirement. In such a case, contacts will be multiplied by relays.

d. Level Switches

All level switches will be of the packless type. This includes the feedwater heater high level switches used to trip the turbine extraction line valves. Contact requirements will be the same as for pressure and temperature applications.

4.8 STRUCTURAL SYSTEMS

4.8.1 Systems Requiring Refurbishment

The structural support and access platforms for both Unit No. 10 and No. 13 will require rehabilitation. In the option where the Boiler Design is modified to an Arch Fired Configuration, the complete structural supports and platforms will require replacement. The new mill classifiers in all options will require a modification in the support structures from that which now exist.

4.8.2 Conceptual Design

Refurbishment of the existing supports and access platforms will be to the original design. Equipment that is replaced will be designed to utilize the existing structural support to the greatest extent possible.

5. REPLACEMENT DETAILS - BOILERS NOS. 13 AND 14, AND TURBINE NO. 6

5.1 PRESENT CONDITION

5.1.1 Plant Equipment

Boilers Nos. 13 and 14, and Turbine No. 6 are located in the Phase 1 section of Lugansk GRES. The construction of this phase started in 1952 with the first unit commissioned in 1956. Phase 1 consisted of seven 100 MW turbine generator units supplied with steam from fourteen boilers in a headered arrangement.

At the present time all Phase 1 equipment has been decommissioned and most equipment is in various stages of disassembly and removal. Portions of only twelve boilers still remain, including Boiler No. 13, but Boiler No. 14 has been removed. Parts of three turbine generator units remain, including Turbine No. 6.

The scope of this investigation includes replacement of the original 100 MW Turbine No. 6 with a new 125 MW turbine, and replacement of Boilers Nos. 13 and 14 with two new circulating fluidized bed (CFB) type boilers to supply the necessary steam to Turbine No. 6.

With the increased capacity of the new boilers and turbine, and the general poor condition of the Phase 1 equipment, it has been established that the existing balance of plant systems are inadequately sized, beyond repair and must be replaced, except for common systems, such as ash handling and circulating water which will be refurbished. This involves the removal of all previously installed equipment from their foundations and from within the confines of the existing turbine and boiler building structures. Existing flue gas handling equipment and breeching will be either removed or abandoned to accommodate a new breeching system, baghouse, I.D. Fan and stack liner.

The following listed equipment and systems will be removed as a minimum:

Boiler and Boiler Accessories

Turbine Generator

Mechanical Systems and Equipment

Electrical System and Equipment

I&C Systems and Equipment

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Foundations and structures will be reused and modified as necessary to support all new equipment.

The existing fuel handling equipment (conveyors, discharge trippers and hoppers) will be refurbished in place and reused to service the new CFB boilers. Also an existing subterranean ash sluice system will be refurbished to be suitable for the removal of all CFB ash.

Circulating water for cooling the Phase 1 turbine unit condensers is provided via a closed system from one of the three pumphouses (No. 1) which comprise the Lugansk Gres facility. Water is taken from the Donets river and returned to individual cooling ponds via concrete water channels. As originally designed, Pumphouse No. 1 consists of eight capacity-controlled circulating water pumps (12,000 to 19,000, t/h capacity) with intake pipe and screens. Water was discharged through two steel pipelines (2500 mm dia.) to the Phase 1 area. Two leads (1200 mm dia.) from each discharge header supply each turbine condenser (i.e. - two leads to each of the two condenser sections for a total of four) with four leads discharging to the return channels. The circulating water discharge headers from Pumphouse No. 1 are tied into those from Pump Stations No. 2 and 3 via electric actuated valves. This concept provided greater flexibility in ensuring cooling water supply to all units when any one pumphouse is not operational.

The eight circulating pumps are very old and obsolete and the capacity control devices no longer function properly. The steel supply lines are in poor condition due to corrosion damage related to their long years of service. The rotating screens no longer provide adequate removal of wood chips, leaves and other mechanical debris from the pump intakes contributing to excessive deposits in the circulating water system.

5.1.2 Structural Systems

The Boiler Foundations of Units No. 13 and No. 14 were inspected and appeared to be in acceptable condition, however modifications may be necessary depending on the CFB technology selected for the project. The roof of the boiler house will require complete replacement in the area of the new CFB boilers. The area previously constructed for Boiler 14A will be used as a laydown area during construction of the new CFB boilers and to house ancillary equipment.

The coal conveyor and coal storage bunker areas of the structure were inspected and are in good structural condition. Modifications will be required in these areas to accommodate the new equipment of the CFB technology.

The Turbine Hall and the operating floor areas surrounding Turbine No. 6 appeared to be in good condition except for the floor near the condenser circulating water inlet and outlet piping. The floor will require repair due to what appears to be underground water leaks in the piping. The overhead crane is operable and looked to be in good condition.

The Switchgear Room, Battery Room and Control Room are in good condition and will require no structural modification.

The Switchyard is in acceptable condition except for the areas surrounding the Unit Transformers which will require some rehabilitation work to assure the containment of any future oil leaks.

The Circulating Water Building for Phase 1 of the facility is not in good condition and will require refurbishment.

The foundations supporting the particulate control devices will require complete replacement to accommodate the new emission control technology.

The flue gas ductwork will be removed and replaced and the induced draft fan supports will be relocated.

The stack and foundation appeared in good condition and will not require replacement based on our discussions with the plant operating and engineering personnel. The stack will require a liner to handle the exhaust flow of the two new CFB boilers.

5.1.3 Demolition Requirements

The demolition required for this portion of the project will involve a significant amount of tasks to be completed. In some areas, demolition activities will require the handling of asbestos containing material and contaminated oils. Demolition of these types of materials is discussed in Section 7. Demolition will include the complete removal of the existing boilers No. 13 and No. 14, the removal of the roof of the boiler house in the area of Units No. 13 and 14. The removal of the boiler foundations for Unit No. 14A, the removal of all equipment and piping in the Turbine Hall in the areas of Turbine No. 6 and No. 7, the refurbishment of the coal bunkers, and removal of mill circuits in this area.

Major demolition will also be required in the area of the existing cyclones, forced and induced draft fans. In these areas, the existing equipment, foundations, and ductwork to the stack will require complete demolition and replacement.

All the existing wiring and motors will be removed and will require complete replacement.

The control system will be completely replaced and will require the removal of the existing system.

5.2 REPLACEMENT OF 50 MWe BOILERS NOS. 13 AND 14

5.2.1 CFB Technologies Evaluated

The CFB Technologies evaluated are those proposed by ABB-Combustion Engineering, Babcock and Wilcox, Foster Wheeler and Tampella Power. All proposed systems are capable of meeting the performance criteria (both environmental and steam production) as set forth for this project and as stipulated in later sections of this report.

With regard to specific process design approach ABB-Combustion Engineering, Foster Wheeler and Tampella Power utilize similar concepts. These systems all incorporate cyclone and loop seal systems for ash recirculation. The Foster Wheeler system is unique among the cyclone/loop seal CFB process as the cyclone vessel is steam cooled, thereby eliminating the need for thick refractory linings. The B&W offering is a two stage system which utilizes suspended U-beams and a multicyclone collector as the primary elements in the ash recirculation process.

The balance of plant systems (i.e., external solids handling, air and gas handling, steam generation) are all, with minor variations, basically similar. It should be noted that at this stage of conceptual design further refinement to actual systems configuration is likely and could result in changes to the currently offered arrangements without significant impact on the comparative proposed costs or overall system performances.

.5.2.2 Selected CFB Technology

From the aforementioned CFB technologies the two stage system was selected. This selection was based on the following criteria:

- Acceptable Cost
- Vendor familiarity with low quality Ukrainian anthracite fuels
- Vendor familiarity with the Ukrainian Power Industry thereby enhancing potential to maximize local content in supply of components.
- Acceptable experience as demonstrated by a domestic waste fuel cogeneration facility of similar size
- Acceptable design

With regard to the above listed factors, design is a criteria which gives the two stage system a unique advantage as described below.

- General - This process utilizes a two-stage solids separation system. This includes an impact type primary solids separator (U-beams) integral with the boiler enclosure installed at the furnace exit and a multi-cyclone secondary separator located in the

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lower temperature region downstream of boiler convection surfaces. This CFB technology has evolved from field experience leading to the development of the two stage internal recirculation design offered for this project.

- Compactness - The boiler volume is considerably reduced (20-30% versus the cyclone-type CFBs) because the U-beams are compact and located within the boiler enclosure. This advantage is particularly important for the power plant repowering applications, like Lugansk GRES, where the two stage CFB fits in the building plan area occupied by the existing PC boilers. The other technologies would require a larger building.

- Simplicity - The two stage design reduces the complexity (and cost) of the CFB system. This design avoids the use of cyclone separators and external recycle devices such as loop seals and L-valves.

- High Reliability and Low Maintenance

  - Thick refractory elements are not required. The two stage system boiler has about one-fifth of the total refractory mass of an uncooled cyclone-type CFB. This is particularly important for developing countries lacking quality refractory and refractory maintenance services.

  - Uniformity of flow and low gas velocity (26 ft/s) in the U-beam separator result in low levels of erosion at the upper furnace or the U-beams. This compares favorably with the cyclone-type CFB's which frequently experience erosion at the cyclone entrance (gas velocity of 65-85 ft/s), vortex finder and upper furnace.

  - The U-beam solid separators have exhibited superior durability and longevity in comparison to cyclone vortex finders.

  - This design avoids high temperature expansion joints which are a maintenance element of the cyclone-type CFBs.

- High Solids Collection Efficiency - The two-stage solids separator system provides higher overall efficiency (99.5 - 99.7%) as compared with the cyclone-type CFB due to the high efficiency of the secondary multi-cyclone separator typically comprised of 10-inch ID elements as compared with large hot cyclones with diameters of 20-30 ft. The high collection efficiency provides better retainment of fine circulating particles enhancing carbon burnout, sorbent utilization and furnace heater transfer.

- Enhanced Operability - This includes a turndown ratio of (5:1), responsive load control and short startup time achieved due to:

  - Furnace inventory control through the transfer of solids between the furnace and the particle storage under the secondary collector achieved by means of

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controllable secondary recycle rate.

  - Higher CFB furnace gas velocity and solids circulation rate.
  - Low refractory mass.
  - Proper selection of the lower furnace geometry, overfire air system and primary air distributor nozzles.

- Low Convection Pass Fouling - The scouring effect of coarse particles (up to 300 microns) escaping through U-beams prevents fouling of the convection tube banks without the use of sootblowers, while tube erosion is prevented by a proper selection of the flue gas velocity. The coarse particles are collected by the multi-cyclone and recirculated to the furnace.

The boiler design proposed for this project will be suitable for burning Ukrainian anthracite culm (schtib) with limestone injected as a sorbent. The anticipated qualities of fuel and sorbent are listed below:

Characteristics of Schtib and Limestone

Schtib Ultimate Analysis, Wt%

C	49.57
H_2	0.89
S	1.72
O_2	0.77
N_2	0.52
Ash	36.53
H_2O	10.00

Schtib HHV, Btu/lb 7270

Limestone Analysis, Wt%

$CaCO_3$	90.00
$MgCO_3$	4.50
SiO_2	4.50
H_2O	1.00

5.2.3 CFB Systems Descriptions

Each boiler is a single-drum natural circulation unit. The boiler furnace enclosure is top-supported and constructed of gas-tight membrane walls. The cross-section area of the lower furnace is reduced to enhance materials mixing and solids entrainment. The lower furnace tube walls are covered with wear-resistant refractory.

Fuel is fed from a coal feed bunker with two volumetric feeders to two bi-directional screw feeders and discharged to the furnace through the furnace front wall using four gravity feed chutes. Limestone is supplied pneumatically through the front and rear walls. The pneumatic system includes two blowers and eight injecting points (four points at each wall).

Combustion air is supplied from one FD fan. Primary air is introduced into the bed through the furnace floor via a bubble cap air distributor. Secondary air enters the lower portion of the furnace through different size nozzles on the front and rear walls. The boiler is equipped with one ID fan.

For start-up the boiler is provided with in-duct and overbed burners.

The primary solids collector is an impact-type separator consisting of a staggered array of U-shaped elements (U-beams) hung from the roof of the boiler. The U-beams form a labyrinth of passages for gas and solids. Two rows of U-beams are installed inside the furnace across the gas exit plane. A second set of U-beams is installed immediately downstream of the furnace exit. Solids collected by the in-furnace U-beams discharge directly into the furnace along the rear wall. Solids collected by the second set of U-beams (external U-beams) are discharged by gravity from the particle transfer hopper to the upper furnace through ports on the rear wall. All solids collected by the U-beams fall freely to the bottom of the furnace along the rear wall resulting in all-internal recycle of primary-collected solids.

Solids passing through the primary collector are cooled through the convection pass and enter a multicyclone dust collector. Solids collected by the multicyclone are stored in the hopper located under the multicyclone and recycled to the lower furnace at a controllable rate determined by the requirements of the furnace inventory/temperature control. The solids are recycled via an air-assisted gravity recycle system and discharged into the bed through eight return points at the rear wall.

Final solids collection from the gases leaving the unit is to be carried out by a baghouse.

Bed ash is purged from the furnace to control bed solids inventory and remove oversized material that enters with the fuel. Three water-cooled screws are used to cool the material and control the rate of the bed drain. A fluidized bed bottom ash cooler/classifier may be considered as an option depending on the anthracite test burn results. After cooling, the bed ash is mechanically conveyed to the existing ash sluice system.

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The convection heating surfaces, located downstream of the U-beams, include superheater banks, economizer banks and a recuperative air heater. Upper convection pass enclosure walls are steam-cooled.

5.2.4 CFB Boiler Performance

Predicted boiler performance data for full load are as follows:

CFB Boiler Predicted Performance Data (each boiler)

Steam Flow, t/hr	249
Steam Temperature, °C	560
Steam Pressure, ata	137
Feedwater Temperature, °C	230
Coal Flow, t/hr	42.9
Ca/S Molar Ratio	2.2
Limestone Flow, t/hr	5.8
Total Solids Flow from Boiler, t/hr	21.4
Fly Ash/Bottom Ash Split	0.05/0.5
Dry Theoretical Air Flow, Kg/Kg fuel	6.06
Excess Air, %	25
Primary/Secondary Air Split	0.65/0.35
Air Inlet Temperature, °C	27
Air Temperature leaving Air Heater, °C	291
Average Bed Temperature, °C	899
Boiler Exit Gas Temperature, °C	149
Sulfur Retention, %	90
Boiler Output, Kcal/hr	$147x10^6$
Boiler Efficiency, %	86.0

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5.2.5 CFB Operations and Maintenance

CFB boilers have unique considerations regarding operations and maintenance (O&M). The distinctive features of the two stage CFB system O&M are described below. The section on maintenance gives an update on procedures which reflect latest operating experience.

A. Boiler Operation

Start-Up

The sequence of a cold start-up operation is as follows:

1. Start the multicyclone dust collector recycle system.
2. Start ID fan followed by the start of FD fan and establish the initial air flow.
3. Introduce bed material (preferably spent bed solids) to the furnace and build a minimum required inventory.
4. Start in-duct start-up burners and heat-up the bed to 700-800°F while gradually adding the bed material.
5. Start over-bed burners and heat-up the bed to about 1450°F (for anthracite fuel) continuing to add the bed material.
6. Start the coal feed when the bed temperature reaches 1450°F and gradually increase fuel flow, air flow and boiler load bringing the bed temperature to 1600°F.
7. Start limestone feed after a stable bed temperature increase is observed after the beginning of coal feed, maintaining the target SO_2 value in the stack gas.
8. During the boiler start-up, maintain the steam pressure, flue gas temperature and steam temperature according to the operating requirements.
9. Transfer solids from the multicyclone storage hopper to the furnace to maintain the target furnace pressure differential according to operating requirements.
10. Stop start-up burners after the bed temperature of about 1550°F is reached.
11. Gradually increase boiler load by increasing fuel flow, adjusting air flow (primary and secondary) and controlling the bed pressure differential according to the operating requirements.

The duration of the cold start-up is 6-8 hours. The hot start-up (when the initial bed temperature is above the coal ignition point) can be done in about 1 hour.

Load Carrying

A. Steady State Operation

1. Fuel flow is adjusted to maintain the boiler steam output to meet the load demand.

2. Total air flow is adjusted proportional to the boiler heat input and corrected to maintain the target O_2 concentration in the flue gas.

3. Primary-to-secondary air split is maintained as a function of the boiler load.

4. The furnace temperature is controlled by adjusting the upper furnace (shaft) pressure differential and the primary air ratio and excess air (at partial loads only). The shaft pressure differential is controlled primarily by the variable solids recirculation rate from the multicyclone particle storage hopper and additionally by changing the primary air ratio.

5. The solids inventory in the lower furnace (primary zone) is controlled by the bed drain rate. In the case of excessive loss of the circulating bed material together with the coarse particles removed by the bed drain, bed drain classification and recirculation of the fine particles to the furnace are to be adjusted in order to maintain a proper combustor pressure differential profile.

6. The solids inventory in the particle storage hopper is controlled by the purge (when the upper level limit is reached) or by the solids recirculation rate (when the lower level limit is reached).

7. The solids transfer hopper is operated with free solids flow through discharge openings and without solids accumulation.

8. If the solids inventory in the furnace and distribution required for the furnace temperature control cannot be achieved within the established operational constrains, the size distribution of fuel and/or limestone is adjusted to meet the performance requirements. In certain cases, addition of an inert bed material (usually sand) is needed.

9. The limestone feed is adjusted proportional to the fuel input with a feed-back correction from the measurement of the SO_2 concentration in flue gases.

B. Load Change

1. Fuel flow and total air flow are adjusted as required by the load demand with the cross-limiting preventing from fuel-rich conditions.

2. The excess air and primary-to-secondary air ratio are changed as a function of boiler load.

3. The solids recirculation rate from the multicyclone storage hopper is adjusted to control the furnace temperature. On the load decrease, the recirculation rate is reduced to reduce the shaft pressure differential. On the load increase, the recirculation rate is increased resulting in a transfer of the circulating bed material from the hopper to the furnace as required for the proper furnace heat absorption and temperature control. This method of control enhances responsiveness of the load control.

4. The primary air ratio and excess air are trimmed as required for the furnace temperature control.

5. The limestone feed rate follows the fuel feed rate with an adjustment based on the SO_2 concentration measurement.

The expected maximum rate of load change is 5-8% min in the load range of 70-100% and 4-5% min in the load range of 40-70%.

Shut Down

1. During normal shut-down the boiler load is decreased by the rate established by the turbine requirements to the minimum turbine load point. This is done by reducing fuel and air flows, with air following fuel.

2. After the turbine trip the fuel feed and limestone are stopped.

3. The air flow is maintained at the predetermined level to provide burnout of carbon particles in the primary zone. Start-up burner can be fired-up to maintain the bed temperature during the carbon burnout to prevent formation of excessive CO emissions.

4. The FD fan and the ID fan are shut-down when the bed is cooled below 500°F and solids inventory in the furnace is adjusted to the level required for the shutdown.

5. Depending on the purpose of the boiler shut-down, the bed material may be removed or left in the boiler. The bed material removal through the bed drain requires bed fluidization by the primary air flow.

6. When the boiler is shut-down for a subsequent quick restart the fuel feed is stopped followed by the shutdown of the FD and ID fans to prevent the bed temperature decrease below the coal ignition point.

B. Boiler Maintenance

The maintenance requirements are evaluated based on: a) the 4.5 years operating experience of a 50 MW_e two stage CFB boiler utilizing high ash (40-45%) medium sulfur coal waste producing erosive bed material, and b) improvements made in the currently offered two stage CFB boiler design.

The boiler is operated with two 10-day planned outages a year, with the average forced outage rate of 2.5%.

Maintenance-Free Areas

Primary Separator - Due to the low gas velocities and uniform flow distribution no U-beam erosion is experienced and no maintenance/repair was required.

Refractory - No maintenance was needed for refractory in the furnace and L-valves (solids return legs from the U-beams).

Furnace Heating Surfaces - No tube wear was observed on the furnace heating surfaces including tube walls, division walls and wing walls, except of the tube wall-refractory interface in the lower furnace (see below).

The uniform gas velocity distribution in the furnace due to the full-width low gas velocity exit to the U-beams prevents local erosion.

Superheater- No maintenance was needed for unshielded pendant superheater tubes.

Maintenance Areas

These are areas requiring regular maintenance during scheduled outages. The maintenance addresses wear caused by the erosive nature of the bed material and fuel ash.

Fuel Feed

Due to the abrasive nature of fuel ash problems were experienced with plugging and wear of the fuel injection screws. The plugging problem was solved by shortening the screws, and the wear was solved by finding a suitable weld overlay material.

In new designs, with gravity air-assisted fuel feed chutes, plugging is not expected. Minimum maintenance during planned outages may be required for wear areas in the chutes that shall be locally protected by the wear-resistant weld overlay.

Bed Drain Coolers

The severe wear or the screw-cooler troughs and flights was prevented by the hard weld overlay and installation of replaceable trough inlet sections. With these modifications only minor touch up repairs during planned shutdowns are needed. Further design refinement may preclude the need for screw coolers by utilizing fluid bed ash coolers.

Tube-Refractory Interface in Furnace

The only area in the furnace experiencing tube wear is the refractory interface at the top of the tapered lower furnace section. This area is protected by a metalizing spray coating. Periodical respraying is needed during planned outages once a year.

Multicyclone Dust Collector

The wear of the multicyclone dust collector elements is minimized to the acceptable rate by using wear-resistant materials. The most wear is experienced on the outlet tubes. The tubes made of a cast material with 500 Brinell hardness have a wear rate corresponding to at least 4 years life time. Other parts, such as spin vanes and inlet tubes have a lower wear rate. The dust collector is designed for easy access for inspection and replacements.

Dust Collector Recirculation

The pneumatic dust collector recirculation system requires routine maintenance to prevent leaking at pipe couplings. In the new design, a gravity air-assisted recirculation system reduces considerably the maintenance requirements.

Horizontal Convection Surfaces

The convection heating surfaces with horizontal in-line tube arrangement (superheater and economizer) require careful tube alignment and installation of tube shields and erosion barrelers preventing gas laning and local erosion. Proper selection of gas velocities and tube bank depth provides for minimal tube erosion. The tube alignment and conditions of the protective shields and barriers are inspected during the outages and corrected as needed.

Air Heater

Wear has been experienced at the inlet parts of the air heater tubes having flue gas flow inside the tubes. In the new design, the air heater has air inside and gas outside the tubes. With this design, the air heater conditions are similar to other horizontal convection surfaces.

5.2.6 CFB System Equipment

The fuel and limestone preparation systems, and the fabric filter are the main support systems required by a CFB boiler facility. Each system is configured as discussed in the following description.

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Fuel and Limestone Preparation Systems

Fuel for the plant is stored in a large long rectangular outside storage pile which runs parallel to the main boiler building. Coal is removed from the pile by bucket cranes which deposit the coal into a receiving hopper which in turn delivers the coal into one of the two coal pile conveyor belts which run parallel to the main pile. Before reaching the end of the pile the belts are inclined and enter the top of a transfer tower. The coal is then transferred to one of the two redundant gallery feed conveyors which run perpendicular to the previous conveyors and convey the coal to the gallery conveyors which bring the coal to the surge bunkers of the Phase II and III boilers.

For this project, it is planned to utilize one of the two coal pile conveyors to feed two (2) redundant reversible hammer mill crushers located adjacent to the transfer tower. The mills are each full capacity and redundant in order to accommodate frequent routine hammer replacement and adjustment. Under the bottom discharge of each mill are hoppers which transfer the coal to individual redundant conveyors which run parallel to the existing gallery feed conveyors. These conveyors will bring the coal to the gallery conveyors which service the Phase 1 boiler house.

The hammer mills selected have been used on other CFB projects and are capable of reducing the fuel from the 2" x 0 as received size to a size acceptable for direct feed into the CFB furnace. This arrangement eliminates the complexity of two stage crushing and eliminates the need for performing any crushing within the boiler building.

The limestone preparation system anticipates the receipt of 1-1/2" x 0 top size limestone. The limestone is deposited by a truck into an undergrade enclosed hopper adjacent to the Phase 1 boiler building end wall closest to the Phase II and III boiler building underground through the end wall underground. The deposited limestone is conveyed underground by a vibrating feeder to a bucket elevating conveyor which in turn feeds a rotary dryer. After drying the limestone is conveyed to another bucket which deposits it into a 24 hour storage bin configured with two bottom outlet hoppers. Each hopper outlet is connected to a vibrating feeder which in turn passes the limestone into vertical spindle roller screen mills. These mills which have also been successfully used for crush limestone for other CFB projects reduce the material to its final feed size. The crushed limestone is then pneumatically pressure conveyed to the main limestone storage silo.

Fabric Filter

A fabric filter system will be installed to control particulate emissions. The particulates will consist primarily of ash, sulfated limestone, excess lime and a limited amount of unburned carbon.

Incoming flue gas enters the fabric filter through a single point manifold connection where it is then distributed to the individual modules of the fabric filter. At each module, the gas will pass through an inlet isolation valve and will enter the hopper of that module. Flue gas will pass through the bag fabric from the outside of the tubular bag to the inside. Collected particulate is retained on the outer surface of the bag and cleaned flue gas exits the inside of the bag at the top through the tubesheet and proceeds to the induced draft fans and stack.

Particulates are removed by isolating each module and back pulsing compressed air from the inside of the bags. This causes the built-up particulates to dislodge from the bags and fall into the collector hoppers below.

The total fly ash flow rate is expected to be 15.9 t/hr.

5.2.7 Emissions

The proposed two stage CFB boilers represent a dramatic improvement over the performance of the boilers they replace. The main elements of environmental performance being evaluated are SO_2, NO_x and particulate discharge. The base case design calls for a 90.5% SO_2 removal efficiency. Cases for 85% and 95% percent have also been analyzed and the predicted performances are listed below:

Predicted Parameter

Sulfur Removal %	85	90.5	95
Cals Ratio	1.8	2.2	2.9
*SO_2 (mg/NM^3)	950	600	316
*NO_x (mg/NM^3)	200	200	470
*Particulate (mg/NM^3)	50	50	50
Sorbent Feed Rate (t/hr)	4.7	5.8	7.7
Fuel Feed Rate (t/hr)	42.8	42.9	43.1
Boiler Efficiency	86.3	86.0	85.6

*Based on 6% oxygen in flue gas

From reviewing the above data it is apparent that the 90.5% removal efficiency represents an optimum case. At 95% the NO_x emissions dramatically increase. Furthermore, the required increase in limestone feed rate would require increased capital expenditure for additional limestone preparation equipment. The 90.5% case also exhibits minor advantages with regard to boiler efficiency and fuel consumption.

5.3 REPLACEMENT OF TURBINE GENERATOR NO. 6

5.3.1 Systems and Equipment Requiring Replacement

Replacement of Turbine No. 6 is necessitated by its very poor physical condition. A turbine of greater capacity (125 MW) has been selected.

The existing turbine auxiliaries are also very old and complete replacement is necessary. All other related turbine hall equipment was also considered for replacement because of their age, as well as because the new modern steam turbine which takes into account the latest advancements made in steam path design will have extraction points different from those of the original turbine. The new steam turbine which, like the existing, would be of the non-reheat design, would use more modern steam parameters - in line with the parameters closely matching those of the Phase 2 and 3 section of the plant.

The existing turbine pedestal will be retained, since the new replacement units have been designed to fit on it. (This concept was also utilized for the 200 MW replacement units discussed in Section 4). The turbine pedestal appeared to be in good condition.

The existing main steam piping will have to be removed in order to accommodate the new CFB boiler connections as well as due to the elevated main steam conditions contemplated for the new replacement turbine unit.

5.3.2 Turbine Performance

5.3.2.1 Gross Performance

The 125 MW turbine proposed for the Unit 6 replacement was designed and will be manufactured by Kharkov Turbine Works as a KT-125/115-12.8 NPO "Turboatom" machine, specifically for replacement of the lower capacity 100 MW turbines without necessitating modifications to turbine pedestals. Its nominal output is 125 MW as indicated by its designation. The steam cycle parameters are higher than those of the original unit which it replaces. The technical characteristics of the new replacement turbine are shown in Table 5.3-1. The turbine is also adaptable to generating hot water for local heating of the plant and its domestic water needs. However, all the performance data calculated here are based on pure condensing mode of operation.

The turbine performance as a function of main steam flow is shown in Figure 5.3-1. This figure shows that the turbine main steam flow at the 125 MW turbine output is 435 t/h. At this nominal load the turbine gross heat rate is 2042 kcal/kWh.

The above figures indicate that the improvements in gross turbine output and heat rate are 25% in output and about 15% in heat rate compared to the original 100 MW turbine design conditions.

5.3.2.2 Net Unit Performance

Net power output from the Unit 6 repowering and net unit heat rates were also determined. Calculations were done for various loads between 100% and 40%. Based on the previous experience with fluidized bed units an auxiliary load of 8.5% was utilized for the full load condition. Boiler efficiency figures were also provided by CFB vendors, and an efficiency of 86% was used for the 100% load point.

Based on the above figures, the full load net unit output is 114.4 MW, and the resulting net unit heat rate is 2595 kcal/kWh. This corresponds to a net unit efficiency of 33.1%.

5.3.3 Conceptual Design

A conceptual design has been developed for the replacement of the No. 6 unit, utilizing the existing turbine pedestal and the area originally occupied by the No. 13 and 14 boilers. The conceptual design essentially involves the complete replacement of the original components. The replacement of the balance of plant equipment is described in Sections 5.4 and 5.5. This section describes the new 125 MW turbine-generator.

The technical characteristics of the steam turbine were shown in Table 5.3-1. The turbine was specifically designed for mounting it on the existing foundation. The outline drawing for this turbine is shown in Figure 5.3-2. As can be seen the unit consists of an HP section and a double flow LP section. There are four extraction points on the HP section. The first three provides extraction steam for the high pressure regenerative feedwater heaters and the deaerator, and the fourth is taken from the exhaust end of the HP cylinder for the low pressure heater number 3. Extraction steam for the remaining two LP heaters is provided from the LP section. The overall dimension for the turbine is 14075 mm.

Table 5.3-1

TECHNICAL CHARACTERISTICS OF THE 125 MW TURBOGENERATOR

Manufacturer	Kharkov Turbine Works
Model	KT-125/115-12.8 "Turboatom"
Nominal Output	125 MW
Maximum Turbine Output Capability	143 MW
Nominal Main Steam Flow	435 t/h
Maximum Steam Flow Capability	500 t/h
Steam Inlet Pressure	130 ata
Steam Inlet Temperature	555°C
Reheat Steam Temperature	-
Turbine Heat Rate	2042 kcal/kWh
Number of Regenerative Extractions	6
Configuration of turbine	Tandem-compound
Cylinders	HP and Double Flow LP
Condenser Type	K3900
Electric Generator Type	TA-120-2U3
Generator Capacity	150 kVA
Power Factor	0.8
Generator Cooling	Air Cooled

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The main heat cycle diagram for the 125 MW steam turbine is shown in Figure 5.3-3. The corresponding extraction conditions (flow, pressure, temperature and enthalpy) for various loads are shown in Table 5.3-2

The turbine will be furnished as a package including the condenser, main steam stop valves, control valves, controls. lube oil tanks and coolers, extraction check valves, safety devices, ejectors and turbine turning gear with electric motor.

Various other turbine hall mechanical equipment are described in Section 5.4. A flow diagram, 125 MW Turbine Cycle, and general arrangement drawings Nos. M203 and M204 for the new 125 MW units are included in Appendix D.

Table 5.3-2

EXTRACTION PARAMETERS FOR THE 125 MW STEAM TURBINE

Percent of Maximum Capability	Feedwater Heater	Extraction Steam Flow t/h	Extraction Steam Parameters		
			Extraction Pressure, ata	Temperature °C	Enthalpy kcal/kg
100%	HP HTR 6	48.89	38.35	385	760.11
	HP HTR 5	21.76	14.29	227	708.11
	Deaerator	32.63	7.234	193	675.84
	LP HTR 3	18.99	2.183	122	630.4
	LP HTR 2	27.06	1.058	101	606.12
	LP HTR 1	10.71	0.189	58	555.52
75%	HP HTR 6	32.58	28.72	363	752.12
	HP HTR 5	14.69	10.76	249	701.69
	Deaerator	23.07	5.447	179	670.47
	LP HTR 3	13.44	1.664	114	626.31
	LP HTR 2	20.16	0.809	93	602.56
	LP HTR 1	6.09	0.147	30	553.26
50%	HP HTR 6	18.62	19.05	337	742.95
	HP HTR 5	8.71	7.152	228	694.07
	Deaerator	13.77	3.665	161	664.16
	LP HTR 3	8.21	1.123	102	621.69
	LP HTR 2	13.01	0.548	83	598.63
	LP HTR 1	1.41	0.104	46	551.4
25%	HP HTR 6	5.15	9.107	331	745.31
	HP HTR 5	-	-	-	-
	Deaerator	8.0	9.0	500	832.6
	LP HTR 3	3.48	0.584	85	626.57
	LP HTR 2	3.8	0.3	33	604.28
	LP HTR 1	-	-	-	-

5.3.4 Capital Cost

Capital cost estimates have been developed for the new Unit 6 installation. Some of the cost for equipment were obtained from Ukrainian or Russian sources, and some of them were developed from either U.S. vendor information or from Burns and Roe in-house data. The total estimated capital cost for the Unit 6 turbine generator is $10,457,800. This figure includes the steam turbine, the electric generator, the excitation system, gland steam condenser, steam jet air ejectors lube oil storage tank, lube oil conditioner and oil coolers, lube oil pumps, stop and regulating valves, non-return valves for extraction lines, turbine programmatic control system, and various automatic safety features as well as the turbine turning gear.

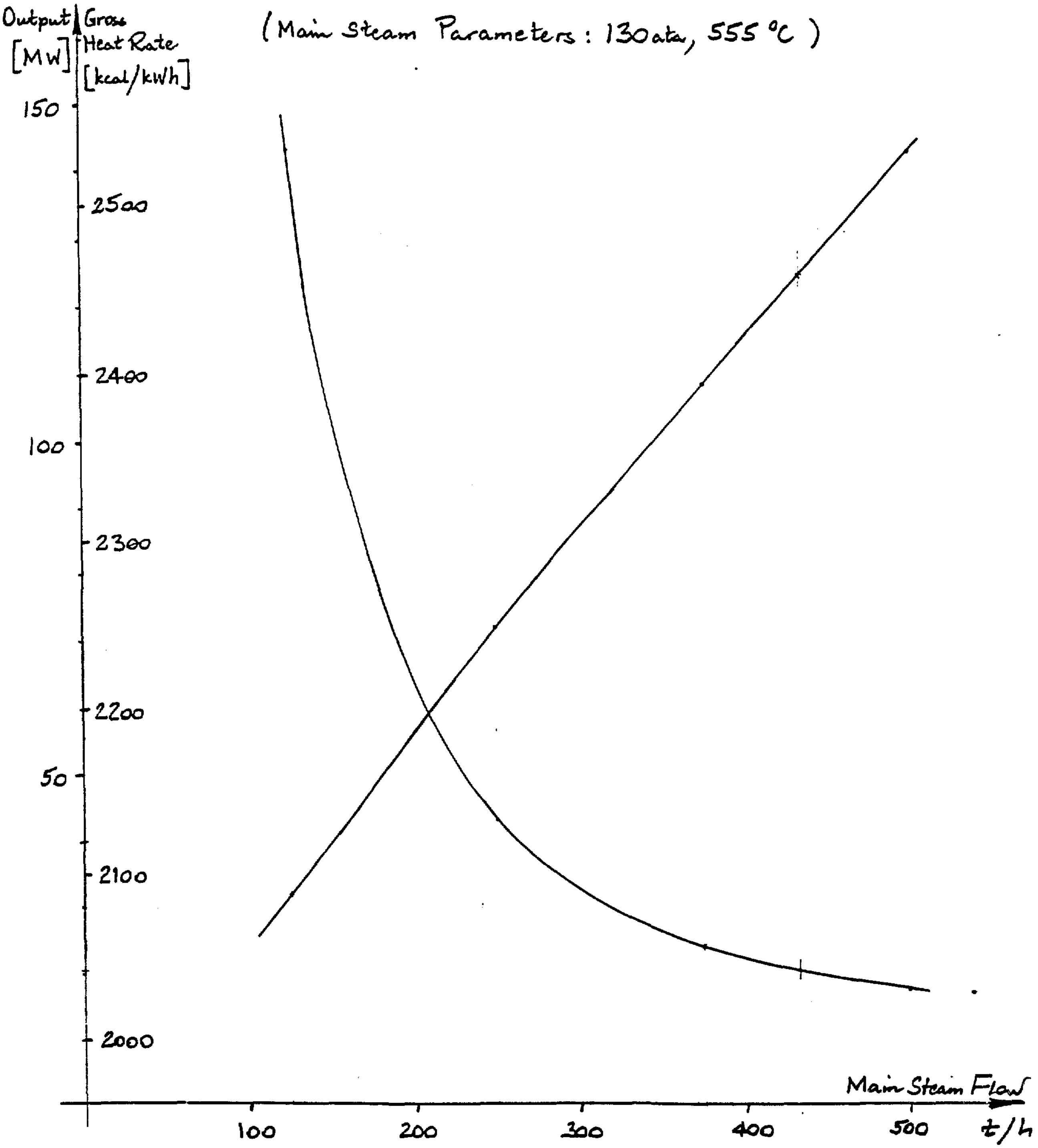


Figure 5.3-1 Gross Performance of the KT-125/115-128 Turbine

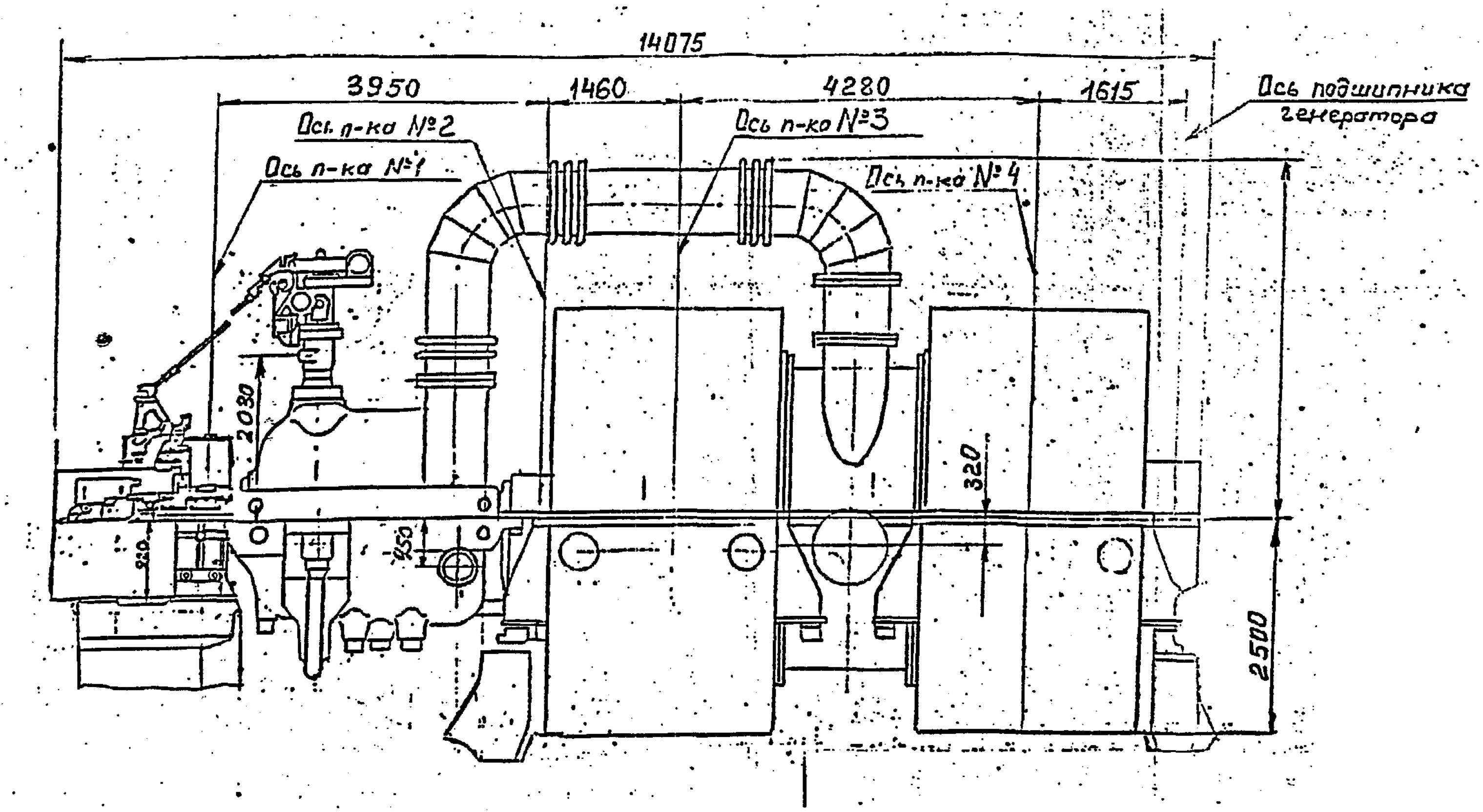
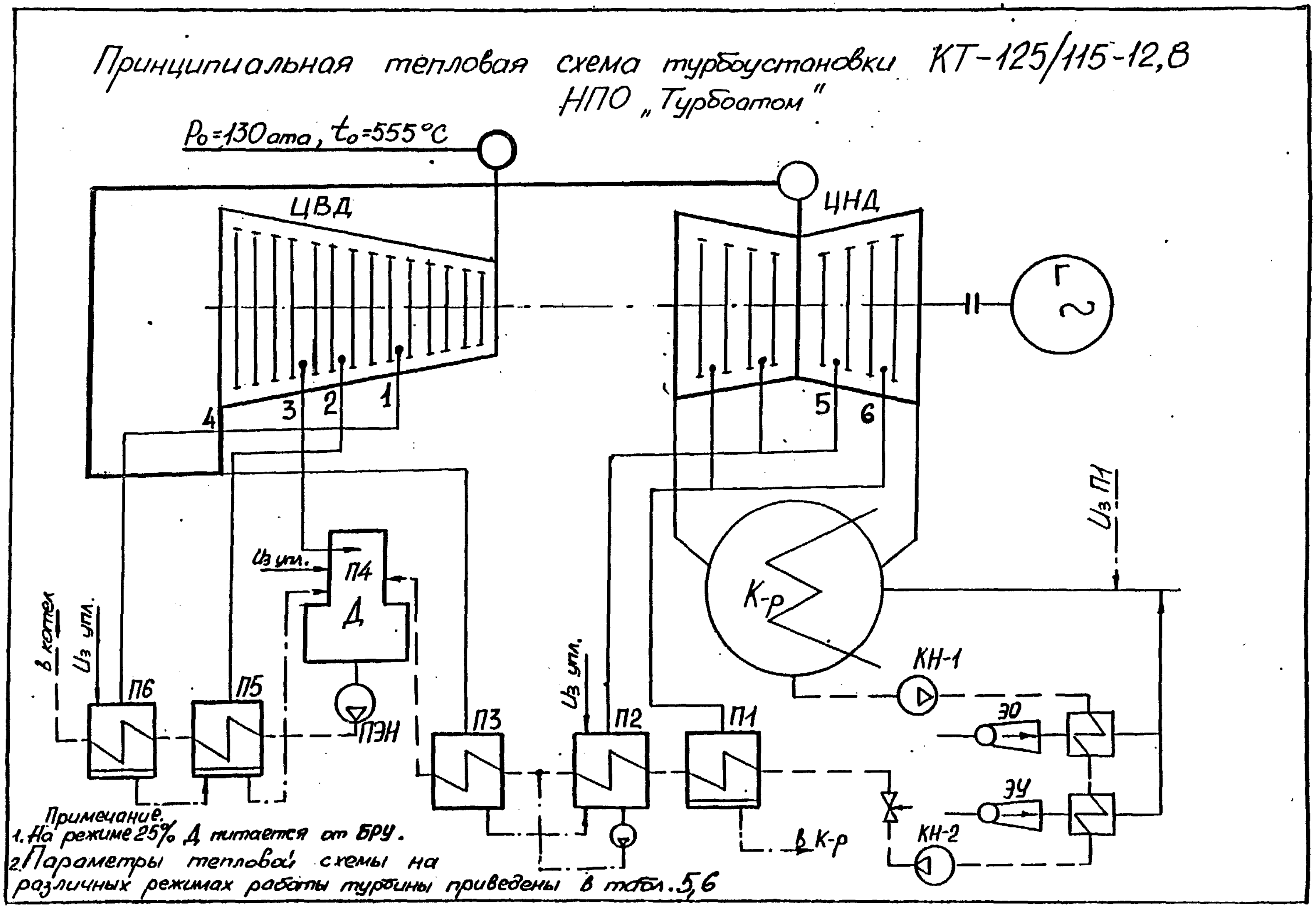


Figure 5.3-2 Outline of 125 MW Turbine



Принципиальная тепловая схема турбоустановки КТ-125/115-12,8
НПО „Турбоатом"

Примечание.
1. На режиме 25% Д питается от БРУ.
2. Параметры тепловой схемы на различных режимах работы турбины приведены в табл. 5,6

Figure 5.3-3 Heat Cycle Diagram for the 125 MW Turbine

5.4 MECHANICAL SYSTEMS AND EQUIPMENT

5.4.1 Systems And Equipment Requiring Replacement

Based upon the condition of the Phase 1 plant equipment associated with Boilers Nos. 13 & 14 and Turbine No. 6, addition of the CFB units will require installation of all new Balance of Plant (BOP) equipment required to support the steam cycle associated with the new K-125/115 turbine unit. Existing cycle equipment and piping systems will require removal and disposal.

5.4.2 Conceptual Design and Cost Impact

The following is a description of the conceptual design of the major mechanical fluid systems and equipment required for the new 125 MWe unit. These items, along with their associated costs, are summarized in Table 5.4.1. Refer to drawing No. SM100, "Flow Diagram, 125 MW Turbine Cycle" for an overview of the cycle concept. For layout of the equipment, refer to drawings Nos. SM203 and SM024, "General Arrangement, Unit 6 Upgrade". These drawings are in Appendix D.

Main and Extraction Steam

The Main Steam System will convey high pressure, high temperature steam from the two CFB boilers to the Turbine main stop valve. The system will also include a main steam dump line to the condenser. Main Steam piping will be designed with adequate drainage to prevent water from entering the turbine. A drain will be installed at each low point in the Main Steam piping and branch lines, from the boiler outlet to the turbine generator stop valves. Each branch line to the turbine stop valves will also be provided with a drain just before the stop valve. The power-operated drain valves will open automatically on turbine trip and will also be remotely operated from the control room. During normal operation the Main Steam System will operate at varying loads dictated by the turbine generator demand. The steam flow will be controlled by maintaining a constant steam chest pressure when in the constant throttle pressure mode. A change in the turbine generator demand will result in a change in the position of the turbine generator control valves. The resulting change in flow will alter the steam chest pressure which is compensated for by a change in the boiler steam generation rate.

The Extraction Steam System will supply steam to three stages of low pressure feedwater heating, one deaerating feedwater heater, and two stages of high pressure feedwater heating. The steam used for feedwater heating is extracted from progressively lower pressure stages of the main turbine casings.

The Extraction Steam System will operate over a range of turbine generator loads, from the lowest acceptable to the turbine generator system, to the maximum loading conditions at turbine valves wide open (VWO) plus 5% overpressure. All heaters must be in service to obtain the unit's capability at designed efficiency. The Extraction Steam System is designed to permit operation with selected heaters out of service.

TABLE 5.4.1

Mechanical B.O.P. Equipment for Stage I Rehabilitation - CFB Boiler Plant

Item No.	Title	Qty.	Price Per Unit-$(US)	Total Price-$(US)
1	Surface Condenser Package	1	$1,600,000	$1,600,000
2	Condenser Cleaning System ("Technos", two twin line system)	1	$300,000	$300,000
3	LP Feedwater Heater No. 1+ Drain Cont'l Valves	1	$70,000	$70,000
4	LP Feedwater Heater No. 2 + Drain Cont'l Valves	1	$70,000	$70,000
5	LP Feedwater Heater No. 3 + Drain Cont'l Valves	1	$70,000	$70,000
6	HP Feedwater Heater No. 5 + Drain Cont'l Valves	1	$150,000	$150,000
7	HP Feedwater Heater No. 6 + Drain Cont'l Valves	1	$150,000	$150,000
8	Boiler Feed Pump (2 x 100%)	2	$300,000	$600,000
9	Condensate Pump (3 x 50%)	3	$50,000	$150,000
10	Condensate Booster Pump (2 x 100%)	2	$90,000	$180,000
11	Heater Drains Pump (2 x 100%)	2	$15,000	$30,000
12	Deaerator	1	$100,000	$100,000
13	Intermittent Blowdown Tank	1	$8,000	$8,000
14	Continuous Blowdown Tank	1	$5,000	$5,000
15	Air Compressor	2	$70,000	$140,000
16	Air Receiver	1	$8,000	$8,000
17	Boiler Chemical Feed Package	1	$60,000	$60,000

TABLE 5.4-1 (Cont'd)

18	Circ. Water Pumphouse #1 Modifications - Pumps - 2 x 50% capacity), (1600 mm piping), (Screens)	1	$650,000	$650,000
19	Turbine Main L.O. Pumps	2	$2,400	$4,800
20	Turbine Emergency L.O. Pump	1	$4,000	$4,000
21	Turbine Regulator Oil Syst. S/U Pump	1	$5,000	$5,000
22	Turbine Regulator Oil Syst. Pressurizing Pump	1	$4,000	$4,000
23	Misc. Mechanical Equipment (not stated above)	1	$800,000	$800,000
24	Turbine Hall Piping Package (Valves, fittings, insul, for Steam, Air, Cond, Water)	1	$500,000	$500,000
25	Remaining Piping (Instmt. Air, etc.)	1	$231,882	$231,882

Since the Extraction Steam System is a major path of potential turbine water induction, the system will include equipment for prevention of water damage to the steam turbine. Typical causes for excess water accumulation are (a) Leaking feed water heater tube(s) (b) Failure or inadequacy of heater condensate level controls (c) Water accumulation in extraction lines. A motor-operated isolation valve followed by one or more reverse current valves will be installed in each extraction line. These valves will be installed as close to the turbine as possible, and they will close when high-high water level is experienced in the heater. The valve closing speed will depend on the excess water flow to the heater and the volume between high-high level and the shut off valve.

Extraction line drains will be used during system warm-up to prevent thermal shock and minimize stress. The drain lines will be equipped with air-operated valves and will be situated at the low points between the turbine and the extraction motor-operated isolation valve and at low points between the reverse current valve and the heater. The air-operated drain valves will open automatically upon closure of the motor-operated extraction steam line isolation valve upon heater high-high level. All extraction line drains will be routed separately to the condenser.

Feedwater System

The Feedwater System will provide feedwater in the quantity, quality, pressure, and temperature required by the boilers at various operating loads. The system will draw deaerated condensate from the Deaerator Storage Tank and deliver it to the boilers. During this process the feedwater will be heated in a string of two (2) High Pressure Feedwater Heaters (HP-5, HP-6) to improve cycle efficiency.

The Feedwater Pumps will be 2 x 100% capacity, electric motor driven, multistage barrel type units, with variable speed control. Pump capacity will be 580 m^3/hr at 195 kg/cm^2 head. Flow variation will be controlled by the feedwater flow control system automatically regulating the pump speed to respond to the steam-feedwater flow demand. Feedwater pump minimum flow protection is provided by flow controlled recirculation back to the deaerator based upon pump suction flow metering.

The High Pressure Feedwater Heaters will be vertical shell-and-tube heat exchangers. Feedwater flows through the tubes and is heated by high-pressure turbine extraction steam which condenses in the shell side of the feedwater heaters. The heaters will be provided with individual by-passes with manual operated gate valves. The heaters will have, depending on the specific heat duty characteristics, integral drain cooler and desuperheating sections, as applicable. The water temperature leaving the heaters will be as follows:

- HP-5 heater: 190.3 ^{0}C (374.5 F)
- HP-6 heater: 242.4 ^{0}C (468.3 F)

The Feedwater System will include all piping, valves and specialties between the Deaerator Storage Tank and the CFB boiler economizer inlets. The material for the feedwater system piping

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will be carbon steel equivalent to the ASTM specifications A 106 Gr. B and A 335 P22.

Condensate System

The Condensate System will provide condensate in quantity, quality, pressure, and temperature required to supply the Feedwater System and other miscellaneous systems at various unit operating loads. The system will draw condensate from the condenser hotwell and delivers it to the feedwater system. During this process the condensate will be heated, deaerated, chemically treated, and if required, cleansed of impurities. Condensate heating will improve the plant cycle efficiency. The condensate is heated by turbine extraction steam in a string of three Low Pressure Feedwater Heaters and a Deaerating Feedwater Heater. Deaeration of the condensate will remove oxygen and other noncondensible gases to minimize corrosion and gas accumulation in equipment. Condensate deaeration occurs in both the condenser and the deaerator. The condensate system will also be the source of water for other miscellaneous systems requiring high purity water. Condensate losses will be replenished with make-up water from the Demineralized Water System in the Water Treatment Plant.

The Condenser will be a two section, shell-and-tube heat exchanger designed to condense the turbine exhaust steam. The steam will condense inside the condenser shell as it is cooled by circulating river water flowing through the tubes. The condensate collects in a hotwell at the bottom of the condenser, from which it will be withdrawn by the main condensate pumps. The condenser operates under a vacuum which is a function of the circulating water temperature. To maintain vacuum, noncondensible gases and air leakage into the condenser are withdrawn by the Condenser Air Evacuation System. The Condenser will be located below the new KT-125/115 turbine at the turbine pedestal formerly occupied by the 100 MWe turbine, No. 6.

Condensate pumping will be accomplished by use of main and booster condensate pumps. The Main Condensate Pumps will be 3 x 50% capacity, single stage, vertical centrifugal pumps with constant speed electric motor drives. Their capacity will be 200 m3/hr at a head of 99 meters (w.c.).The pumps will discharge through the Gland Steam and Steam Jet Air Ejector Condensers from which the Booster Condensate Pump takes suction. The Gland Steam System condenser condenses steam exhausted from turbine shaft seals and stop valve stem packing. The condenser shell will be maintained at a slight vacuum by a blower which exhausts air and non-condensables to the atmosphere.

The Condensate Booster Pumps will be 2 x 100% capacity, vertical, centrifugal pumps with constant speed electric motor drives. Their capacity will be 500 m3/hr at a head of 150 meters (w.c.). The booster pumps will discharge through the three stages of Low Pressure Heaters. The heaters will be provided with individual, manually operated by-passes.

The Low Pressure Feedwater Heaters will be specified to handle extraction steam flows consistent with the by-pass arrangement and the turbine generator capability to operate with the heaters out of service. The heaters will have, depending on the specific heat duty characteristics, integral drain cooler and desuperheating sections, as applicable. Motor-operated valves, which are automatically actuated by high water level switches in the drain reservoirs, will be provided to assure that a means is available to prevent water from being induced into the turbine in the event of tube failure. The water temperature leaving the feedwater heaters, at 100% load, will be as follows:

- Heater LP- 1 : 54.3 ^{0}C (129.7 ^{0}F)
- Heater LP- 2 : 94.9 ^{0}C (202.8 ^{0}F)
- Heater LP- 3 : 119.4 ^{0}C (247 ^{0}F)

After leaving heater LP-1, the condensate flow will pass to the Deaerator. The Deaerator unit will consist of a deaerating heater section mounted on top of a deaerator storage tank. The deaerating heater will be an open type, direct contact, heat exchanger in which condensate is mixed with turbine extraction steam causing the steam to condense as it loses heat to the condensate. The condensate will be heated to the saturation temperature corresponding to the steam pressure. In the process of heating the condensate oxygen and other noncondensible gases will be released from the condensate and vented to atmosphere. The resulting feedwater temperature leaving the Deaerator will be 162.1 ^{0}C (324 ^{0}F).

The Condensate System will include all piping, valves and specialties between the condenser hotwell outlet and the Deaerator. The material for the Condensate System piping will be carbon steel, equivalent to the ASTM A 106 Gr. B or seamless A 53 Gr. B specification.

Circulating Water System

The Circulating Water System will provide a continuous supply of cooling water, on a once through basis, to the new main condenser providing the heat sink for the turbine over its full range of its operating loads. The current primary source of Circulating Water to the Phase 1 area of the Lugansk plant originates at Pumphouse No.1. However; crossconnections exist from the circulating water systems supplied from Pumphouses No's. 2 & 3. The amount of circulating water required by the new condenser for the 125 MWe turbine cycle is 11,000 m^3/hr. Several alternatives were considered for supplying circulating water to the repowered Stage I units. These alternatives are as follows:

Alternative 1- If it is assumed that the current design basis for the rehabilitation of Stage I is based upon only the one 125 MWe unit defined in the Scope of Work (S.O.W.), the required circulating water may be supplied via the cross-connections from the Pumphouse 2 & 3 circulating water systems. In this case modifications to the system would be minimal, consisting only of replacement of the four 1200 mm inlet/outlet leads to the condenser with two 1400 mm inlet/outlet leads to accommodate the new condenser.

Alternative 2 - If it is assumed that Rehabilitating of Phase 1 units will eventually go beyond the one unit defined in the S.O.W., it will be necessary to rehabilitate the Pumphouse No. 1 circulation water system. Due to the age and current condition of the components of this system significant rehabilitation would be required. The extent of rehabilitation depends upon how many Phase 1 units would be rehabilitated. If it is assumed that a total of three new 125 MWe turbines will eventually be installed (the current one plus two more) Pumphouse No.1 will have to be modified to replace three of the existing eight pumps with new pumps (Model 96VD4.5/23)

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having a capacity of 16200 m^3/hr each. Additionally, the intake screens will have to be upgraded and the two 2500 mm diameter steel supply lines to the Phase 1 area will have to be replaced. The replacement pipelines would be 1600 mm diameter and the two leads to the new condensers would be 1400 mm.

Alternative 3 - If it is assumed that all seven Phase 1 units will be rehabilitated eventually, it would be necessary to remove and replace all eight existing pumps with six new pumps (Model 96VD4.5/23) and all intake screens would have to be replaced. The replacement pipelines would be 2100 mm diameter and the condenser leads would be 2000 mm.

Option 1, although feasible, was felt to present a potential operational/maintenance constraint for the facility. Use of only the circulating supply lines from Pumphouses 2 & 3 results in a reduction in the operational flexibility provided by the original design since the system separation valves allowed all units to remain in operation (during most seasonal variations) if maintenance is required on any one of the six water supply lines.

The design basis selected for inclusion in the Unit 6 rehabilitation work of this report is a variation of Options 2 and 3. In this regard it includes installation of two new 8100 m^3/hr circulating water pumps (74% of the design flow to one 125 MW turbine condenser or half the flow of one Model 96VD4.5/23), intake screen modifications to accommodate these pumps and replacement of the existing 2500 mm/1200 mm supply lines/condenser leads with the 1600 mm/1400 mm, respectively, lines and leads described in Option 2.

It was felt that additional pumping capacity can be added in the future if additional units are added therefore only the pumping capacity required to accommodate the current 125 MW addition will be provided. Since excavation is required for the pipeline replacements, it is felt that installation of a larger pipe size, which allows for future capacity, is a prudent expense at this time to avoid the cost of reexcavating in the future.

Heater Drains And Vents System

The Heater Drains and Vents System (HDVS) will consist of all equipment, piping, valves, instruments, and control components required to perform the following major functions:

- Drain and recover condensed extraction steam from feedwater heaters and miscellaneous heat exchangers.
- Vent noncondensible gases from the same.
- Recover drain heat content by cascading drains from higher pressure to lower pressure heaters.
- Provide protection against water induction into the turbine through the heater extraction steam lines in case of inadequate heater drainage or heater tube rupture.

The HDVS will service all feedwater heaters and miscellaneous steam condensing heaters. To recover heat, the drains from high pressure heaters will be cascaded to lower pressure heaters. Each heater will be provided with two drains. A normal (cascading) drain and an alternate drain to the condenser. Control valves will be provided in these drains lines to maintain level in the heaters. The deaerator is the terminal receiver of drains cascading from the high pressure heaters, and the condenser is the terminal receiver of drains cascading from the low pressure heaters. A low pressure heater drain pump will be installed for pumping forward the drains from the L.P. Heater No. 2.

The HDVS system will operate through all ranges of turbine generator load, including plant transients, and when one or more heaters are out of service. During normal operation heaters will drain through their primary drains. Under abnormal conditions, when the capacity of the primary drains is exceeded, the excess flow will be drained to the condenser through the alternate drains which will be actuated by high water level in the heater shells. When a heater is out of service, the heater drains which normally cascade to this heater will drain through its alternate drain to the condenser. The alternate drain will also used whenever the normal drain is not available for service.

As applicable, closed feedwater heaters will be provided with an internal drain subcooling zone. In this zone the extraction steam condensate will be subcooled close to the saturation temperature of the heater into which it is draining. Subcooling will prevent flashing in the drain piping upstream of the control valve, reduce flashing downstream of the control valve, and improve cycle thermal efficiency.

Since gases trapped in heat exchangers will degrade heat transfer, cause corrosion, eventually block the steam flow to the heater, each feedwater heater will be provided with two types of vents for removal of noncondensible gases, start-up vents and continuous vents. Start-up vents will be used during start-up to vent the heater fast and during maintenance to purge the heater. Continuous vents will continuously remove noncondensible gases during normal operation. Continuous vents from the high pressure heaters discharge to the Deaerator. Continuous vents from the low pressure heaters will discharge to the condenser. Start-up vents from the high pressure heaters will discharge to the atmosphere. Start-up vents from the low pressure heaters will discharge to the condenser. Each continuous vent is equipped with an isolation valve and a restriction orifice. Deaerator continuous and start-up vents will discharge to atmosphere through a common header.

The heater drains pump from L.P. Heater No. 2 will be 2 x 100% capacity centrifugal, constant speed, electric motor driven, pumps. Each pump will be provided with a temporary suction strainer to be used during initial pump operation to prevent construction debris from damaging the pump. The strainer element may be removed after initial system flush or retained for added protection.

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Instrument and Plant Air Systems

An Instrument Air System will be added to the unit to provide high purity, oil-free, dry compressed air in sufficient quantity and adequate pressure for the new instrumentation and pneumatic control devices being added to the unit. The Plant Air system will be provided to supply compressed air in sufficient quantity, quality, and pressure for various equipment, pneumatic tools and systems in the plant.

The air receiver will be equipped with a safety valve to protect it from overpressurization. The inlet and discharge piping to the receiver will be at opposite ends to assure flow through the receiver volume. Moisture drops carried-over from the moisture-separator will be collected at the bottom of the receiver and trapped to a drain. The drain piping will be piped to an open floor drain.

The Instrument and Plant Air systems will contain the following major equipment:

- Two rotary compressors with inlet filter/silencer.
- Compressor aftercooler/moisture separator.
- Two air receivers.
- Air Dryer with pre-filter and after-filter.

5.5 ELECTRICAL SYSTEMS AND EQUIPMENT

5.5.1 Systems and Equipment Requiring Replacement

Essentially, the entire electrical system requires demolition/replacement. Equipment includes all 3.3kV and 400V switchgear, 400V Motor Control Centers and all associated raceways, medium and low voltage power and control and instrumentation cables, 220kV circuit breakers, disconnect switches, potential transformers, surge arresters, protective relay system, turbine control system, and DC system. The existing cable tunnel can be utilized to route the new cables on a new tray system.

Table 5.5.1 lists electrical systems and equipment for Units 6 that will be replaced.

Table 5.5.1

Item No.	Equipment Considered For Replacement
1)	220 kV Circuit Breaker
2)	220 kV Disconnect Switches
3)	220 kV Potential Transformers & Lightning Arrestors
4)	3.3 kV Switchgear
5)	400V Switchgear
6)	400 V Switchgear Transformers
7)	3.3 kV Cable Bus
8)	220 V DC Battery Chargers and Batteries
9)	220 V DC Switchboard
10)	All Power, Control and Instrument Cables
11)	All Cable Trays and Conduits
12)	Protective Relay Boards
13)	Electrical Control Board
14)	Lighting System
15)	Fire Detection System

5.5.2 Performance

Power plant performance can be greatly improved if the obsolete and degraded electrical equipment are replaced with new equipment. Section 5.5.3 describes the conceptual design criteria and brief descriptions of new electrical equipment.

The new equipment will be of modern design. It will have smaller probability of failure, thus allowing the plant to achieve a higher capacity factor. It will require reduced operation and maintenance cost. It will be designed to modern design criteria providing safety to plant personnel.

Operating and maintenance will be reduced for the new electrical equipment; especially for the motors which are prone to faults on the windings and existing electromechanical protective relays which require a great deal of maintenance.

5.5.3 Conceptual Design

5.5.3.1 General

Reference Drawings (in Appendix D)

SE001	Conceptual Main One-Line, Units 6, 10 and 13
SE003	6.3 kV and 416V System One-Line, Unit 6 Upgrade
SE005	General Arrangement, 6.3 kV Switchgear and 416V Unit Substation, Unit 6

Drawings SE001 and SE003 are single line diagrams indicating major equipment recommended for upgrade or replacement. Drawing SE005 shows preliminary locations and space requirements for equipment within the existing rooms.

Major equipment that can be supplied from the Ukraine include 400V switchgear transformers, all medium and low voltage power, control and instrumentation cables and cable raceways. The new equipment that will be supplied from foreign sources include 220kV circuit breakers, potential transformers, and surge arresters, 6.3kV switchgear, 400V switchgear, motor control centers, DC system, UPS system and plant protective relays.

Major new electrical equipment required for Unit 6 will include the following:

- Turbine Generator with Static Exciter; 125MW,10.5kV, 0.85 Power Factor, Air Cooled.
- 10.5 kV Generator Circuit Breaker
- Generator Step-Up Transformer (Unit XFMR): 160MVA, 242/10.5kV
- Auxiliary Transformer: 25MVA 10.5 / 6.3 - 6.3 kV, 3 phase, 3 wire
- Generator Leads to Unit Transformer (Non-Segregated Phase Bus)

- Leads to Auxiliary Transformer
- Excitation Transformer
- Leads to Excitation Transformer
- 220 kV Circuit Breaker, 40 kA
- 220 kV Potential Transformers
- 220 kV Disconnect Switches
- 220 kV Surge Arrestors
- 6.3 kV Switchgear
- 400V Unit Substation
- Motor Control Centers
- 220 V DC Batteries, Chargers and Switchboard
- 220 V AC Uninterruptible Power Supply
- All Power, Control and Instrument Cables
- All Cable Trays and Conduit
- Lighting System
- Grounding System
- Cathodic Protection System
- Communication System
- Fire Protection and Detection System
- Protective Relays Panel with Solid State Relays
- Circulating Water Pump Motors (Quantity - 3)
- Electrically Operated Valves
- New Cables for Circulating Water Pump Motors
- Air Conditioning for Control Room

The new 125MW, 10.5kV generator will be connected through non-segregated phase bus duct to a 10,000A, SF6 generator circuit breaker. The generator circuit breaker will be connected to the 220/10.5kV, 160MVA step-up transformer via non-segregated phase bus duct up to the building wall and by cable bus from the building wall to the step-up transformer. The step-up transformer will be connected to the switchyard 220kV busses through a 220kV SF6 circuit breaker.

Auxiliary power will be supplied from a 10.5/6.3-6.3kV, 25MVA unit auxiliary transformer. The auxiliary power system will consist of two 6.3kV switchgear buses designated 6A and 6B. Power to the switchgear will be supplied either through the auxiliary transformer under normal conditions or through the reserve buses. The 6.3kV switchgear will feed the 400V unit substations. Unit substations will feed the motor control centers.

Existing cable tunnels will be reused along with reserve transformers and non-segregated phase reserve power busses. The existing cables and racks will be removed from the tunnels and new cable trays and cables will be installed. A new fire detection system will be installed in the cable tunnels.

New electrical system and equipment that will be used for the 125MWe Unit No. 6 are briefly described herein under the headings switchyard, turbine island, boiler island and miscellaneous systems. The selection criteria and description for some of these equipment and systems are similar to that which is described in Section 4.6.3.

5.5.3.2 Switchyard

New electrical equipment in the switchyard includes 220 kV circuit breakers, potential transformers, disconnect switches and surge arrestors, generator step-up transformer, auxiliary transformer, leads to the auxiliary transformer, step-up transformer and to the excitation transformer.

The existing circuit breakers in the switchyard are of the air-blast type. These breakers will be replaced with SF6 type breakers with short circuit rating of 40kA. The SF6 circuit breakers will be of the dead tank design.

The abandoned potential transformers surge arrestors and disconnected switches in the switchyard will be replaced with new equipment.

Transformers

The generator step up transformer will be rated 160MVA, 242/10.5kV. The unit auxiliary transformer will be rated 25MVA 10.5/6.3-6.3 kV. Power transformers will be of a low loss, core form, oil-filled design. The transformers will have a high voltage tap changer suitable for operation from ground level when transformers are deenergized with full load taps of 2 - 2 1/2% above and 2 - 2 1/2% below nominal kV rating.

Excitation Transformer

A new excitation transformer will be installed required for the 125MW generator with a rating of 1000kVA.

6.3kV Cable Bus

The leads to the generator step-up transformer, auxiliary transformer and to the excitation transformer will be cable bus installed on existing structures. Leads to the auxiliary transformer will be sized for maximum plant auxiliary load. Leads to the excitation transformer will be sized for maximum excitation load.

5.5.3.3 Turbine Plant

New electrical equipment associated with the turbine island include the turbine generator, neutral grounding transformer, PTs and surge suppressor, generator leads up to turbine building wall, leads to 6.3kV switchgear, generator circuit breaker, 6.3kV switchgear, 400V unit substation, 220V DC batteries, chargers and switchboard, 220V AC uninterruptible power supply, protective relays, motor control centers and power distribution panels.

Generator

The generator will be nominally rated at 10.5 kV, 125 MW 0.85 power factor, 3 phase, 50 Hz, air cooled.

Generator Circuit Breaker

The generator circuit breaker will be of the SF6 type and rated to withstand maximum fault current. The generator circuit breaker will be rated 10,000A continuous and 41kA interrupting capacity.

Non-Segregated Phase Bus Duct

The leads from the generator to the generator circuit breaker and from the generator circuit breaker to the building wall will be non-segregated bus duct. Leads from the generator to the step-up transformer will be sized to carry the maximum generator output.

Cable Bus

The leads from the building wall to the step-up transformer will be cable bus. Cable bus will be sized to carry the maximum generator output.

6kV Cable Bus

The leads from the secondary of the auxiliary transformer to the 6.3kV switchgear will be cable bus. Cable bus will be sized to carry the maximum plant auxiliary load and will be routed in the existing cable tunnels.

6.3kV and 400V Switchgear

The 6.3kV and 400V switchgear will consist of vertical sections mounted side by side and connected mechanically and electrically together. Auxiliary compartment(s) will be provided to mount potential transformers, surge arrestors, control power transformers, etc.

6.3kV circuit breakers will be vacuum type mounted two(2) per vertical stack and will consist of electrically operated removable vacuum circuit breaker elements.

The unit substation dry-type transformers for 400V switchgear will be rated 1000kVA.

The circuit breakers for 400V switchgear will be three-pole, single throw, air break, electrically operated, drawout type rated 600 volts. Breakers will be operated by motor-charged, spring-type stored energy mechanism.

400V Motor Control Centers

Motors from 1/2kW to 100kW will be fed from motor control centers (MCC's). The 400V motor control centers will be provided to feed all turbine-related low voltage loads. MCC's will consist of one or more vertical sections and will be of the non-ventilating type.

220V DC Power System

The DC system will consist of two battery chargers, batteries and DC power distribution switchboard. The DC system will supply power to all DC loads including emergency oil pumps, uninterruptible power supply, and switchgear control.

DC power distribution switchboard will contain molded case circuit breakers. All breakers will be 2-pole. Batteries will consist of 98 cells and will be rated 220V at the required ampere-hours.

220V AC Uninterruptible Power Supply

The UPS will provide regulated, transient-free sine wave 220V AC power to plant distributed control system (DCS) and other selected loads operating during both normal and abnormal conditions. It will consist of a rectifier, inverter, static transfer switch, manual bypass switch, bypass transformer and accessories. DC power will be provided by the 220V DC station batteries.

Protective Relays and Metering

Protective relaying will be provided for the turbine generator, step-up transformer, unit auxiliary transformer, reserve transformers, and 220kV lines. Protective relays will be of solid state design.

5.5.3.4 Boiler Plant

Electrical equipment associated with the boiler island includes the 400V unit-substations, motor control centers and power distribution panels.

400V unit-substations and motor control centers will be provided to feed all turbine-related low voltage loads. This equipment will be similar to those as specified in Section 5.5.3.3.

5.5.3.5 Miscellaneous Systems

Electrical equipment included in the miscellaneous systems are power, control and instrument cables, cable trays and conduits, lighting system, grounding system, cathodic protection system, communication system, fire detection system, and new motors for circulating water pumps.

Power, Control and Instrument Cable

All medium and low voltage power control and instrumentation cables will be replaced. Cables will be asbestos free.

Cable Trays

Separate cable trays will be provided for each of the following classifications of circuits: 6kV power cables, 400V single conductor and multiconductor power cables (220V DC), power cables, control cables (220V AC and 220V DC), and instrumentation cables. Cable trays for power and control cables will be ladder type. Instrumentation trays will be solid bottom (steel) with solid covers. Cable tray will be installed in the existing cable tunnel and other plant areas where required.

Lighting System

Lighting system will consist of normal plant lighting, lighting panels and transformers, and an emergency lighting system. Lighting will be designed to minimize glare and meet required illumination levels for plant operation.

Grounding System

Grounding will be provided to insure safety to personnel and equipment in case of electrical equipment failures. A complete grounding system will be provided. All equipment enclosure and or equipment ground busses will be grounded through the plant's ground loop. All major electrical equipment, including medium voltage motors and all other motors 30 kw and above will be directly connected to the ground grid.

Cathodic Protection System

The cathodic protection system will provide corrosion protection for all buried metallic systems and structures.

Communications System

A multi-channel communications system with paging capability will be installed as part of plant refurbishment. The basic plant communications system will be a combined public address (paging) and party line telephone system.

Fire Protection System

A new fire protection system will be provided.

Motors and Cables to Circulating Water Pump House

Motors associated with circulating water pumps that will supply circulating water to new Unit No. 6, will be replaced along with power and control cables between the plant and the motors.

5.5.3.6 Equipment not Requiring Replacement

Equipment which will not require replacement include the reserve transformers and reserve buses, steel structures for cable leads from generator to transformers and the cable tunnels.

5.6 INSTRUMENTATION AND CONTROLS SYSTEMS AND EQUIPMENT

5.6.1 Systems and Equipment Requiring Replacement

Replacement of the existing control systems with a state-of-the-art distributed type control system will be employed to achieve the most efficient combustion and co-ordinated control of feedwater flow, fuel feed, air flow and the electro-hydraulic turbine governor in all modes of operation.

5.6.2 Performance

Utilization of modern digital Distributed Control System (DCS) will result in improved unit performance, realized through improved reliability, availability and downtime reduction due to easy maintenance. Unit efficiency will come primarily from boiler efficiency which is due to most efficient combustion. Efficient combustion will be attained with the help of sophisticated controls.

5.6.3 Conceptual Design

5.6.3.1 Unit Control System

Reference Drawing (in Appendix D)

SI002 - Control System Block Diagram - Boilers 13 and 14, and Turbine 6

Control systems aids the operator in achieving safe, reliable and economical power from fuel, while relieving the operator of continually regulating the process.

Instrumentation and control systems include safety systems which will automatically alarm and execute preprogrammed actions in cases where unsafe or fault situations are likely to imminent, or as the result of an occurrence. Systems interlocks will prevent initiation of system operations in an unsafe sequence.

Operation of the boiler, turbine-generator and plant auxiliaries will be accomplished from a centralized control area located in the main control room. All signals routed to the main control room and electrical equipment room cabinets will be electrical, either directly wired or multiplexed.

Local control systems may be electrical or pneumatic, depending on the specific applications.

Redundant design will be utilized in critical control loops (e.g. furnace pressure, drum level).

The main unit control system will provide the coordinated regulation of feedwater flow, fuel feed, air flow, and the electro-hydraulic turbine governor in all modes of operation. The control system will maintain desired unit generation, proper throttle steam pressure, and proper excess air, as well as desired drum and deaerator levels.

This self-balancing control system will operate the turbine-generator and the boiler as an integrated unit. It will apply control actions in a coordinated manner so as to minimize interactions between the controlled variables of unit generation, throttle steam pressure, and flue gas oxygen by appropriate operation of the manipulated variables of fuel, air, and governor.

The combustion control system, an integral part of the coordinated control system, will control all feeders, and damper drives to supply the proper amount of fuel and air. Master manual/auto stations, and manual/auto stations will be provided in the DCS to permit biasing units as required.

All low level instrumentation wiring (e.g. thermocouples, RTD's, 4-20 maDC, etc.) will be shielded twisted pairs or equivalent with single point grounding. Where instrumentation is grouped together on rack, multipair cables will be utilized wherever possible. Where multipair cables are used for low level signals, each twisted pair or equivalent shall be individually shielded.

Analog signal transmission levels will, in general, be 4-20 mAdc or 3-15 psig.

Soft manual-automatic control stations will be provided for final control elements of all major systems. Transfer from auto mode of operation to manual and vice-versa will be bumpless.

5.6.3.2 Process System Control

Turbine-Generator and Auxiliaries

The Turbine Control System will be non-redundant microprocessor based. The primary operator interface shall be provided by the unit distributed control system (DCS) communicating over a data link to the turbine control system. A separate operator interface will be provided for start-up, engineering and maintenance purposes. The turbine will be fully controllable from either location.

All inputs required for control will be input directly to the Turbine Control System. Miscellaneous monitoring points will be available for input to the unit Distributed Control System. All interconnections to the turbine will be to prewired junction boxes on the turbine skid. Interconnections will utilize prefab plug-in cable where possible. A free standing local turbine gauge panel will be provided.

The turbine supplier will also make provisions for the monitoring functions listed below. All required field devices and the vibration monitoring system will be furnished by the turbine supplier. Remote temperature signals will be connected directly to the unit DCS for:

- remote bearing temperature monitoring
- remote vibration monitoring
- remote metal temperature monitoring
- local oil flow indication
- local bearing drain temperatures

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Steam Generator and Auxiliaries

The steam generator supplier will provide the burner management controls and, as a separate package, the soot blower controls. The supplier will also furnish the required primary measuring elements and final drives for steam temperature and combustion control.

The burner safety and interlock system will be of the programmable solid state type with provisions for remote-manual operation of lightoff and for hardwired master fuel trip push buttons located in the control room. The system will include timed purging and a complete fuel safety arrangement incorporating a system of interlocks and permissives for fail-safe operation. The burner management system will be furnished in complete compliance with the steam generator manufacturers' requirements. Operator interface with the system will be implemented through a communication interface with the plant DCS which will provide the operator all required control capability and status and alarm information via the DCS console. Since the power supply feed is subject to voltage dip, frequency shift and power interruption, the burner management system shall be designed to react with a predictable and safe response in those instances. Requirements of NFPA 85C and 85H will be observed.

The Steam Temperature Control System will be provided in the unit DCS in complete compliance with the Steam Generator manufacturers' requirements.

F.D. and I.D. fan and damper interlock logic and control will be in accordance with NFPA 85C.

The following categories of draft measurements will be transmitted to the unit DCS.

- Air pressures at air heaters.
- Gas pressures at air heaters, superheaters, economizers, baghouse and system.
- Furnace and wind box pressures.
- Fan pressures.
- Pressures associated with feeders, primary and secondary air, etc.

The devices provided for drum level monitoring will as a minimum be furnished and installed in accordance with the applicable requirements of Section I of the ASME Boiler and Pressure Vessel Code. The following drum level instrumentation will be provided:

- One illuminated water gauge glass at each end of the boiler.
- Two drum level transmitters for feedwater flow control and high and low alarms.
- One drum pressure transmitter for pressure compensation of drum level transmitter signals.

- Two direct reading remote level indications. These indications will be visible in the control room.
- A highly reliable drum level measurement system to be used for primary high and low drum level sensing. Backup high and low level alarms will be developed by alternate devices such as the transmitters or other devices.

Local control panels will be furnished for air heater support systems.

A soot blower insert panel will be provided, mounted on an auxiliary panel in the main control room.

The furnace draft control system will ensure that pressure inside the furnace shall remain at the desired setpoint. This will be accomplished by regulation of the I.D. fan flow control devices.

Feedwater System

The feedwater system will be a conventional, combination, 3-element/single-element system using feedwater flow, steam flow, and steam generator drum level to control feedwater flow. The feedwater flow signal will have temperature compensation. The main steam flow signal will be the same as used for combustion control.

Condensate System

A combination 3-element/single-element control system using feedwater flow, condensate flow and the deaerating heater storage tank level, will function to maintain the deaerator storage tank level within limits by means of a condensate flow control valve. The condensate flow signal will have temperature compensation.

Water Treatment

Instrumentation and controls including local panels and racks will be provided as part of water treatment system. Panels will contain electrical devices such as control switches, annunciators, PLCs, indicators and recorders.

Pollution Control System

The baghouse and flyash transfer will be controlled locally from stand-alone control panels, containing PLC's, a graphic mimic, complete status indicators, control switches, alarm annunciators and other devices to allow the operator to monitor and manipulate the system as necessary. These systems will have the capability to communicate with the DCS. Primary elements, local indication, and final control elements, drives and linkages are to be provided as part of the fly-ash system. All interfacing wiring will be brought to the Boiler Area DCS I/O Cabinets.

Flue Gas Analysis

A continuous emissions monitoring system (CEM) will be provided to analyze, record, alarm, process data, and generate reports for the concentrations of SO_2, No_x, O_2 and/or CO_2 and particulate of stack effluents in accordance with criteria set by the Environmental Protection Agency and other cognizant regulatory bodies. Isolated outputs for alarms and monitored variables will be provided to the main plant control system (DCS). A control room insert and report generation equipment will be provided for operator interface to the analyzers which will be installed in an analyzer house located near the base of the stack.

An oxygen analyzer system separate from the CEM will be provided as a trim for the Combustion Control System. Oxygen trim will ensure that proper excess air level is maintained.

Uninterruptible Power Supplies (UPS)

An uninterruptible power supply will be provided for the following systems. Details of the system are provided in section 5.5.3.

a) Burner Management System

b) Control System for Main Turbine-Generator

c) Distributed Control System

d) CEM Data Acquisition System

5.6.3.3 Area Arrangements

The instrument panels will be located in different areas of the plant according to the following:

a) The main operator interface controls shall be located in the Central Control Room.

b) An Electronics Room will be provided in addition to the Central Control room. Electronic equipment cabinets, not requiring direct operator interface, will be located here. This may include turbine control equipment cabinets, DCS electronics, DCS I/O cabinets, relay cabinets (if applicable) and other electronic or electrical cabinets. This room will be air conditioned and maintained at a slight positive pressure.

c) All local control panels will be located in accessible areas containing necessary utilities and will be physically close to the equipment they control and monitor.

5.6.3.4 Instrumentation System

The control system will allow unit start up, operation and shutdown under normal and upset conditions from the main control room. Local control with control room alarming will be utilized where conditions permit sufficient reaction time without undue jeopardy to equipment or the ability to maintain unit output.

Most plant control will be accomplished through the implementation of a distributed type control system (DCS) in conjunction with direct hardwired controls of emergency and critical functions. Control of packaged equipment will be incorporated into this system to the greatest reasonable extent possible without jeopardizing system safety, performance, and economics.

Operating Concept

The DCS will perform all major control, indication and alarming functions for the unit. Hardwired interfaces will be used for critical and emergency duties and selected subvendor control that cannot be incorporated into the system.

The DCS equipment will interface with the operator in the main control room via:

- Multiple CRTs capable of displaying status, alarm and trend and archive information and computed performance results and with the ability for auto/manual open and closed loop control

- Printers

Additionally, the DCS will process and archive the sequence of events (SOE) records, even if these are generated by a separate device.

All normal electric motor and actuator control will be via the CRT and associated keyboard.

Control Room Instrumentation

The main control room layout and environment will be in accordance with the best human factors engineering practice.

Operation of the unit will be from the operator's console. This console will include as a minimum, multiple CRTs and keyboards.

A vertical board will also be provided for mounting of additional components such as recorders, miscellaneous alarms and specialized inserts (including T/G and electrical controls and boiler trip pushbuttons) will be located here.

Vertical control board will incorporate selected hardwired interfaces to give the operator direct control of emergency and critical functions, independently of the DCS equipment.

Hardwired devices shall include:

- Burner Management emergency trip

- Turbine emergency trip

- Miscellaneous electrical devices

Distributed Control System

With the exception of selected vital and emergency functions as previously detailed, the DCS will form the major interface with unit sensors, actuators, switchgear and other input/output devices, as well as forming the major operator interface via CRTs in the main control room. The DCS equipment will incorporate:

- For each cabinet, power supply auctioneering from at least two incoming sources, one of which will be from a UPS system
- Redundant data highways
- Redundant highway controllers

The DCS will have the capability to acquire unit analog and digital information, perform limit checking (including configurable deadband and out-of-range), prioritize and initiate alarms, perform logic operations/interlocking; drive bistable outputs and perform open and closed loop control. Comprehensive operator interfacing, including loop auto/manual control, trending, sequence of events, archiving and logging will be included.

Interactive CRT's and keyboards located in the control room will be utilized for plant operation. Multiple printers will provide hard copies of alarms, logs and other selected information. All operator interface components including printers will be backed up such that a failure of one component will not limit operation or result in the loss of information.

Additional equipment such as input/output and electronics cabinets associated with the DCS system will be isntalled in the Electronics Room.

5.6.3.5 Field Instrumentation

a) Transmitters

Transmitters will be used for control, indication, recording, data acquisition and to avoid the exposure of the Control room to high pressure or temperature fluids and fuel oil

Measuring elements for measured variables such as flow, level, pressure, and differential pressure transmitters will be of the electronic force-balance or capacitance type.

b) Thermocouples/RTD

Temperature measurements for control and computer inputs will be with chromel-constantan thermocouples and/or resistance temperature detectors (RTD); except that chromel-alumel thermocouples will be used for the furnace temperature probes and tube temperature sensors. Thermocouples and RTD's will be of the dual element type.

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c) Pressure and Temperature Switches

Pressure and temperature switches will be of the snap action type; and will include at least DPDT contacts or equivalent, unless the application requires types furnished only as SPDT because of dead-band requirement. In such a case, contacts will be multiplied by relays.

d) Level Switches

All level switches will be of the packless type. This includes the feedwater heater high level switches used to trip the turbine extraction line valves. Contact requirements will be the same as for pressure and temperature applications.

5.7 STRUCTURAL SYSTEMS

5.7.1 Systems Requiring Refurbishment

The structure housing the existing boilers and coal bunkers will require redesign to accommodate the new CFB technology. The structural systems in the area which housed Boiler No. 14A will require complete rehabilitation to accommodate the new ancillary equipment for the CFB technology.

The structural systems within the Turbine Hall will require only minor modification.

The existing Circulating Water System requires major rehabilitation work that includes rebuilding portions of the pumphouse and replacing portions of the pipeline.

Structural support of the existing Induced Draft Fans, Forced Draft Fans, Emission Control Technology and exhaust ductwork will require complete redesign.

5.7.2 Conceptual Design

Conceptually, the basis of design is to locate the new CFB boiler supports on the existing foundations of Units No. 13 and 14. The CFB technology selected for this upgrade allows for the existing foundations to be utilized with only minor modification. The limestone storage and preparation equipment will be located in the area that originally housed Boiler No. 14A.

The new 125 MW Turbine Generator will be located on the existing Turbine Pedestal. Only minor modification to the pedestal will be required because the new 125 MW Turbine has the same configuration and dimensions as the existing 100 MW Turbine. The new condenser will also fit within the space of the existing condenser.

The new Emission Control Equipment, Induced Draft Fans and Flue Gas Ductwork will require complete new structural and foundation supports. This equipment will be lcaoted within the area of the existing equipment.

The Circulating Water Pump House Structure will be redesigned to accommodate new traveling screens, new pumps and new valving. In addition, the piping will be replaced as necessary.

6. REHABILITATION OF COMMON PLAN SYSTEMS

6.1 MAKEUP WATER TREATMENT AND WATER/STEAM ANALYSIS

6.1.1 Present Water Treatment

Water supply to the Lugansk GRES is from the Donets River, and is fairly brackish with a significant amount of hardness and alkalinity. It is first treated in four clarifiers with a total capacity of 500 t/h (three 100 t/h and one 200t/h) where lime is added to precipitate hardness and alkalinity from solution and remove silica. Either iron or aluminum sulfate is added to coagulate suspended solids and promote setting of these in the clarifiers. The plant also has equipment for adding soda ash and magnesium chloride. Effluent from the clarifiers overflows by gravity to two 100 cubic meter storage tanks.

From the above storage tanks, clarified water is pumped through eleven 2600 mm diameter pressure filters with 2-5 mm anthracite media and a capacity of 50 t/h each. Continuing under pressure, water then passes through thirteen first stage ion exchange softener vessels. Ten of these are 2000 mm and three are 3000 mm in diameter. As much as 150 t/h of the effluent from the first stage ion exchange softener vessels may be used for district heating without any further treatment. The remainder is treated in seven 2000 mm diameter second stage ion exchange softener vessels and forced draft degasifiers.

After the forced draft gasifiers, water is pumped to evaporators in each of the eight operating 200 megawatt units. Each of these evaporators has a capacity of 20-25 t/h and evaporator distillate is pumped into a deaerator operating at a pressure of 6 atmospheres in each generating unit. The evaporators have evidently been able to supply enough water to the units to compensate for a boiler blowdown rate of approximately 7.3% even though the plant was originally designed for a 3% blowdown rate.

6.1.2 Design Basis for New Water Treatment Equipment

Problems with the present water treatment equipment as described by plant personnel are listed below:

- clarifiers, filters, and ion exchange softeners are too small
- transfer pumps are old
- on-line and analytical instruments are lacking
- boiler blowdown rate is high
- consumption of chemicals for regenerating the ion exchange softeners is high
- too much maintenance is required for the evaporators

- loss of ion exchange material is high
- mixing tanks and chemical dosing equipment is in poor condition.

A high boiler blowdown rate could be caused by either cooling water leakage in the condensers or poor quality makeup water form the evaporators or both. This creates too much demand for makeup water so that the clarifiers, filters and softeners would seem too small; consumption of chemicals would seem high, and additional maintenance of the evaporators would be needed. Since the ion exchange materials used in this plant are inefficient, a high demand for makeup water means that a large quantity of clarified and filtered water is consumed in regenerating the ion exchange softener units. This would also make the clarifiers and filters seem too small.

The design basis for the new water treatment system is to supply the requirements for one new 125 megawatt unit and two existing 200 megawatt units.

6.1.3 Recommended New Water Treatment Arrangement

6.1.3.1 Use of Existing Equipment

As the system is now operated, a raw water hardness of approximately 12 milligram equivalents per liter (600 ppm as $CaCO_3$) is reduced to about 6 milligram equivalents per liter (325 ppm as $CaCO_3$) by lime softening in the clarifiers. If soda ash is used together with lime, clarifier effluent hardness can be reduced to about 2.3 milligram equivalents per liter (115 ppm as $CaCO_3$) as shown on Table 6.1-1.

This would reduce the demand for clarified and filtered water because the ion exchange softeners would require fewer regenerations. Not only would the hardness concentration going into the ion exchange softeners be reduced by about 65%, but influent to the new water treatment equipment would not need any ion exchange softening, and so the flowrate through the ion exchange softeners would also be reduced. For these reasons, replacement of the soda ash feed equipment is recommended.

Repair of the condenser tubes in each of the existing eight 300 megawatt units to minimize cooling water leakage into the condensate is also recommended. Since cooling water leakage increases the boiler blowdown rate and thereby increases the demand for makeup water repair of these tubes will reduce the need for additional water treatment equipment.

6.1.3.2 Recommended New Equipment

Figure 6.1-1 shows the arrangement of new equipment with existing equipment at the plant and the flowrates which would be required for each. New equipment to supply makeup water to two 200 megawatt units and one 125 megawatt unit would be rated for 66 t/h based on the following:

(25 t/h per 200 MW unit XZ) + (25 t/h x 125/200) = 66 t/h

As shown on Figure 6.1-1, influent to the new system would be 80 t/h to produce an effluent of 66 t/h.

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Based on the recommendations in section 6.1.3.1 above, the existing clarifiers, mechanical filters, and ion exchange softeners would be sufficient to meet all power plant and district heating requirements as shown on Figure 6.1.1. No additional equipment of these types is recommended.

To treat clarified, lime and soda ash softened, and filtered water for boiler makeup to two 200 megawatt existing units and one new 125 megawatt unit, the system shown on Figure 6.1.2 is recommended.

This system includes two (2) 100% cartridge filters so that one can be in service while the filter elements are being charged in the other. Sulfuric acid and sodium hexametaphosphate would be added to prevent scaling on membrane surfaces. Two (2) 50% reverse osmosis trains are provided because the 66 t/h system rating is based on a boiler blowdown rate of about 3%. Since boiler blowdown will generally be about 1%, one train will generally provide more than enough makeup water.

Reverse osmosis product water will go to the permeate tank and be pumped through mixed bed demineralizers into an 800 cubic meter demineralized water storage tank. Three 50% mixed bed demineralizers are included so that two can be in operation while one is being regenerated. One of two 100% transfer pumps would supply demineralized water through a new pipeline to two 200 megawatt existing units and one new 125 megawatt unit.

The recommended new water treatment system would provide boiler makeup with zero hardness, zero iron, and 0.01 ppm of silica as SiO_2. By comparison, makeup from the existing evaporators contains 1.0 microgram equivalent per kilogram (50 ppb) of hardness, 25 micrograms per kilogram (25 ppb) of iron, and 27 microgram equivalents per kilogram (1.35 ppm) of silica. The difference in silica concentration could significantly reduce the boiler blowdown rate of the units served.

The recommended new water treatment system will consume a significant amount of electrical power because of the high pressure reverse osmosis feed pumps. However, discontinuing operation of the evaporators in two existing 200 megawatt units will increase the electrical output of those units, and a comparison provided elsewhere in this report shows that there would be a significant net increase in available electrical power.

Although some reverse osmosis systems require a high degree of maintenance due to membrane fouling, the type of pretreatment already in existence at the Lugansk GRES will prevent this. The lime softening process removes colloidal suspended solids better than many other pretreatment processes and is a very effective biocide; and thereby prevents two of the primary causes of membrane fouling. Maintenance is expected to be far less than required for the presently used evaporators. With less maintenance of the boiler makup water treatment system, availability of the generating units will be increased.

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TABLE 6.1-1

	Raw Water	Lime Softened	Lime/Soda Ash Softened	1st Stage Ion Exchange Softened	2nd Stage Ion Exchange Softened
Ca (ppm as $CaCO_3$)	530	325	35	25	1
Mg (ppm as $CaCO_3$)			80		
Na (ppm as $CaCO_3$)	427	427	637	727	751
Total Cations	957	752	752	752	752
Alkalinity (ppm as $CaCO_3$)	240	35	35	35	35
Cl (ppm as $CaCO_3$)	412	412	412	412	412
SO_4 (ppm as $CaCO_3$)	305	305	305	305	305
Total Anions	957	752	752	752	752
Silica (ppm as SiO_2)	13.1	8	6	6	6

6.1.4 Present Water/Steam Analysis

At present, water and steam sampling and analysis is performed by taking grab samples to a laboratory at the plant. The laboratory lacks analytical instruments needed to adequately monitor water and steam chemistry throughout the boiler-turbine cycles, and grab samples can only indicate water and steam chemistry at certain specific times.

6.1.5 Recommended Water/Steam Analysis Equipment

A sampling and analysis panel including continuous analyzers for the following is recommended for each generating unit:

boiler water - silica, pH, specific conductivity and phosphate

saturated steam - cation conductivity and silica

superheated steam - cation conductivity and silica

condensate - cation conductivity and specific conductivity

feedwater - oxygen, pH

6.2 FUEL SYSTEMS

6.2.1 Coal Handling System

The Coal Handling System has an outdoor coal storage capacity of 520,000 tons. The system consists of three car dumpers, crushers, a system of conveyors located in underground galleries and on trestles, transfer stations and a coal thawing facility for 26 railroad cars. The plant coal preparation systems are fed by two coal supply channels: one for the Phase 1 area and the other for the Phase 2 and 3 areas. The coal storage area is serviced by two crane-reloaders with a 76.2 meter span and a 400 t/hr output.

The coal handling equipment is operational and can adequately serve the rehabilitated units.

6.2.2 Coal Preparation System

The Coal Preparation System of each 200 Mwe unit is equipped with a two-train pulverizer system which is positioned in the new feed hopper-deaerator area between building column lines "B" and "V" of the main building. The systems, as originally designed, were of an open design with an intermittent hopper for pulverized coal. Coal is transported from the coal storage area to elevation 33 m of the main building by a system of belt conveyors. From this point it is fed through a horizontal belt conveyor to the raw coal hoppers of each boiler. From these hoppers, the coal is delivered by a belt conveyor to the inlet of a ball mill where it is crushed.

In the original design, drying and transportation of the air-pulverized coal mixture was performed by supplying hot air from a boiler tubular air heater to the mill inlet. In this design, the coal-air mix is drawn into the mill by a mill fan and then to a classifier where coarse particles are removed and returned to the mill and a cyclone where air and dust are separated with a 95% efficiency. The pulverized coal is dumped into a common pulverized coal hopper and the slightly dust-laden air is vented by a mill fan to the boiler furnace. From the pulverized coal hopper the coal is transported by a coal feeder to pulverized coal ducts and then by the primary air fans to a primary air duct and through the 16 coal feeding ducts to the burners.

A pulverized coal screw conveyor, between pulverizing systems of adjoining units, permits the feeding of pulverized coal from an operational system of one unit to the coal hopper of the adjoining unit.

During the life of the plant the systematic increase of coal moisture content led to a reduction of coal mill drying capacity. As a result, the original "open" design was converted to a "half-open" design by the addition of a heating system consisting of heaters with mazut fired burners. This system increases mill drying capacity by increasing the temperature of the drying agent and the retention time of coal in the drying zone. Recirculation of part of the coal-air mixture reduces the cold air venting to the boiler furnace.

Additionally, the conveyor belts were replaced with wider belts with DC motors to allow mill capacity control by varying belt speed with fixed coal layer instead of by varying the coal layer thickness.

6.2.3 Fuel Oil System

The plant Fuel Oil System consists of four major components:

- Oil Storage Area containing an 8000 m^3 storage capacity and an oil unloading trestle.
- Two step oil pumping station.
- Station fuel oil supply headers.
- Fuel oil piping at boiler burner fronts.

The oil pumping station contains a holding capacity of 4000 tons of oil comprised of 4 x 1000 ton tanks connected in groups of two tanks. The oil is withdrawn from these tanks with immersion pumps and pumped through fine filters and heaters after which it is subsequently pumped via booster pumps (40 kg/cm^2 pressure) to the boiler building.

Station oil supply headers are sectionalized into two parts, one to feed boilers No. 8 - 11 and one to feed boilers No. 12 - 15, with a section valve between boilers 11 and 12. Fuel oil operating conditions are 100° C and 30 kg/cm^2. The boilers are equipped with 1 to 3 t/h capacity mechanical oil atomizers.

In addition to the high pressure fuel system, the station is equipped with a low pressure header to supply the Phase I area of the facility at a pressure below 10 kg/cm^2. This system was originally the primary system prior to fuel oil becoming a primary fuel at the station.

No problems have been reported in the operation of the station Fuel Oil System components and no rehabilitation is anticipated.

6.2.4 Fuel Gas System

The station receives natural gas from a main supply line through a gas-distribution station located behind the plant fence near the fuel oil storage area. Gas at 6 kg/cm^2 supply pressure is regulated to, and controlled at, a pressure of 1.2 kg/cm^2 by a regulating station on the plant property.

Gas from the regulating station is directed through three main lines to a common header. The three lines contain shut-off and regulating valves (2 per line). The station is equipped with two bypass lines, relief valves, and gas vents. From the common header gas is directed through two main lines to the boiler areas. One line supplies the Phase I area and boilers No. 8 - 11 of the Phase II area. The second line supplies boiler No.12 -15. The capacity of the gas regulating station is 500,000 m^3/hr of natural gas.

Gas supply to individual boilers is divided into two halves per boiler. Boiler gas supply capacity is up to 60,000 m^3/hr at a pressure of 1 kg/cm^2.

No problems have been reported in the operation of the station Fuel Gas System components and no rehabilitation is anticipated.

6.3 Ash Handling

6.3.1 Phase 1

The ash/slag handling equipment for the units of the Phase 1 plant areas is no longer operational. However the sluice system in this area is still functional and will be used for the new boilers. Bed ash purged from the new CFB boilers will be cooled and controlled by water-cooled screws. After cooling, the bed ash is mechanically conveyed to the existing ash sluice system.

Flyash will be pneumatically vacuum conveyed to a flyash collection bin which will be equipped with a top mounted ash receiver. The collected ash will pass through the Flyash Collection Bin hopper and be sluiced to the ash storage pond along with the boiler bed ash.

6.3.2 Phases 2 & 3

As currently designed, the Ash/Slag Handling System serving the Phase 2 & 3 units is of a closed-circuit design and will be used for the refurbished units. Ash and slag pulp is pumped out of the boilers and fly ash removal systems using dredger (slag) and slurry (ash) pumps at three dredger pump stations as follows:

Pump Station No. 1 (Units 8 thru 11)

- 3 Dredger Pumps, pumping slag pulp from under the boilers.
- 3 Slurry Pumps, pumping ash pulp from below the scrubbers.

Pump Station No. 2 (Units 12 thru 15)

- 3 Dredger Pumps, pumping slag pulp from under the boilers.

Electrostatic Precipitator (ESP) Pump Station (Units 12 thru 15)

- 2 Slurry Pumps, pumping ash pulp from under the ESPs.

Ash/Slag from these stations is pumped to receiving tanks in a remotely located, second phase, pumping station consisting of 6 dredger pumps and 3 slurry pumps. Ash and slurry are pumped separately from this station to the ash and slag sections of Ash Pond No. 2.

Water for the ash/slag removal system is clarified water from the clarified water pump station at Pond No. 2. The water is pumped to the inlet of the sluice and ash/slag removal system pumps where it is supplied to the sluice and high pressure water distribution headers which are the source of supply for each boiler. There are two sluice and ash/slag removal system pump stations in the boiler building as follows:

Station I

- 2 pumps for ash/slag removal
- 2 sluice pumps - Units 8 thru 11

Station II

- 2 pumps for ash/slag removal
- 2 sluice pumps - Units 12 thru 15

This arrangement permits the exchange of ash/slag pumps and sluice pumps. There is a separate water supply for units 8 thru 11 and units 12 thru 15. Water supply pressure for the ash/slag removal system is 7 to 8 kg/cm^2. Make-up water to the ash ponds and ash/slag removal system is supplied from the circulating water system by 2 pumps located at Unit 8 and 3 pumps at Unit 12. These pumps discharge water to the sluice and high pressure water distribution headers.

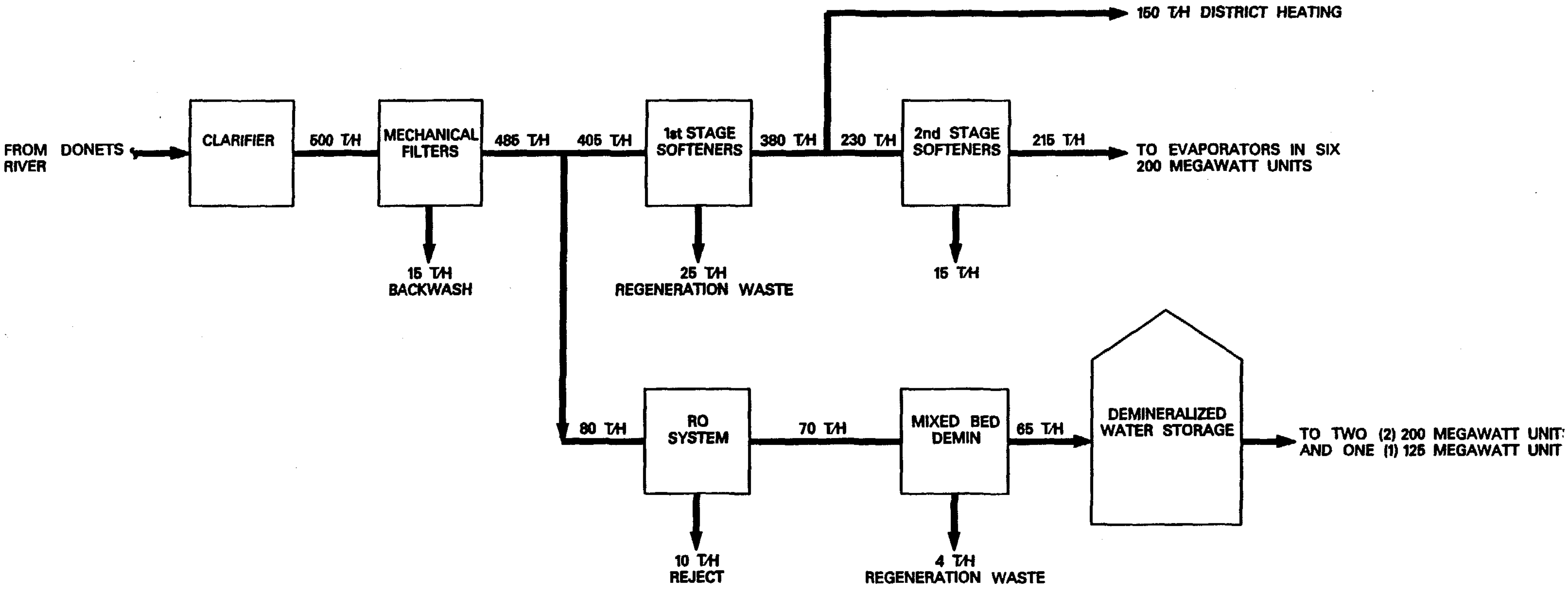

FIGURE 6.1.1

WATER TREATMENT SYSTEM BLOCK FLOW DIAGRAM

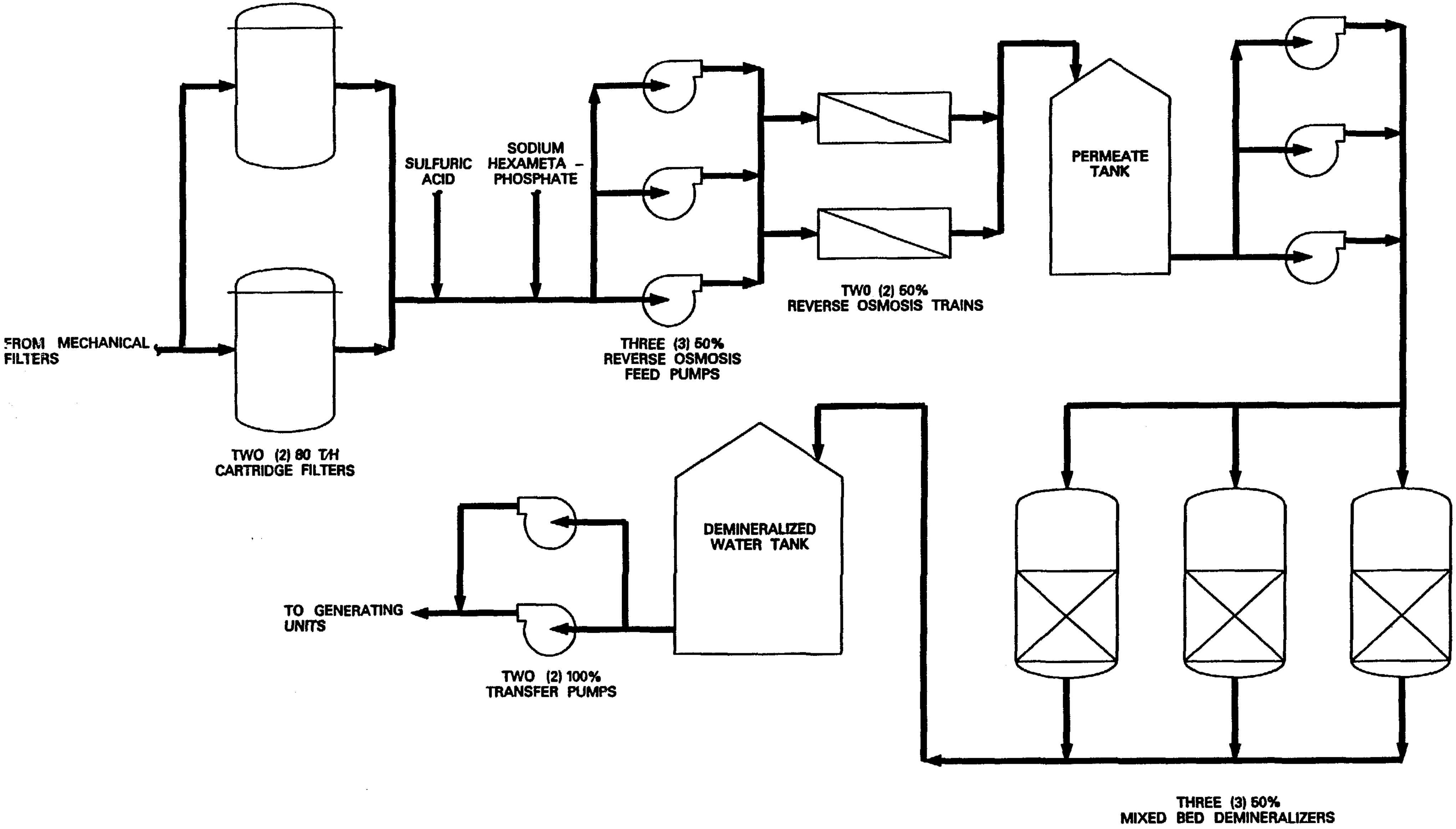

FIGURE 6.1.2

NEW WATER TREATMENT EQUIPMENT
SCHEMATIC PROCESS DIAGRAM

7. ENVIRONMENTAL IMPACT

This section addresses environmental impacts associated with the rehabilitation and replacement projects described in the earlier sections of this report. Environmental improvements and negative impacts, as well as the mitigation measures planned in this report, are discussed below.

7.1 ENVIRONMENTAL IMPROVEMENTS

The Lugansk plant rehabilitation project (Unit Nos. 10 & 13, 200 MWe each, in the Phase 2 and Phase 3 respective sections of the plant) will improve air emissions. Similarly, there will be a significant improvement in the quality of air emissions with the replacement project (50MWe Boiler Units Nos. 13 and 14, along with 100 MWe Turbine No. 6, in the Phase 1 section of the plant, replaced by two 62.5 MWe CFB boilers and a 125 MWe turbine generator). The quality of air emissions from these projects is discussed in Section 4.3 of this report.

7.2 NEGATIVE IMPACTS

Negative impacts associated with the rehabilitation and replacement projects are identified as follows:

NEGATIVE IMPACT	BOILER	TURBINE	MECHANICAL SYSTEMS	ELECTRICAL SYSTEMS	STRUCTURAL (CONSTRUCTION/DEMOLITION)	COMMON PLANT SYSTEMS
ASBESTOS INSULATION	X	X	X	X	X	
DUST (COAL AND ASH)	X					
TOXIC GASES	X					
WASTE LUBE OIL	X	X				
WASTE OIL (TRANSFORMER AND SWITCHGEAR)				X	X	
NOISE		X				
WATER TREATMENT WASTES						X

Negative impacts include asbestos insulation, dust from coal and ash, toxic gases, waste lube oil, waste oil from transformers and switchgear, noise, and water treatment wastes. Project work areas, as broken-down in this report, include the boiler and boiler auxiliaries, the turbine generator, mechanical systems and equipment, electrical systems and equipment, structural systems (construction and demolition), and common plant systems. There is no negative environmental impact associated with the proposed instrumentation and controls systems and equipment.

During rehabilitation and replacement construction there is a potential for human health effects associated with airborn asbestos resulting from insulation removal and disposal operations associated with the boiler, turbine, mechanical, electrical, and demolition work. Also, during this period there is a

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potential for toxic effects associated with disposal of waste lube oil, and waste oil from transformers and switchgear. These oils are generated in the boiler, turbine, electrical, and demolition work areas.

During operation of the rehabilitation and replacement projects workers are potentially exposed to dust from ash and coal, as well as toxic gases, in the boiler work. Similarly, during this period workers are potentially exposed to excessive noise in the turbine area.

Also, disposal of regeneration wastes and general flush wastes is a negative impact associated with operation of the water treatment facilities common to the plant. Concentrated brine from the new reverse osmosis unit is not listed as a negative impact since it is similar to the existing evaporator waste, and does not require treatment prior to discharge to the river.

Each of the negative impacts described above is avoided or mitigated by measures already planned as part of the rehabilitation and replacement projects.

7.3 MITIGATION MEASURES

Plans included in this report for avoiding and mitigating negative impacts associated with the rehabilitation and replacement projects are as follows:

Impact	Mitigation
Asbestos Insulation	Use suppression techniques such as wetting, plastic wraping, and bagging, to keep asbestos from becoming airborn. Monitor airborn asbestos concentrations during insulation removal and disposal operations, and as necessary, issue and require workers to wear protective clothing. Issue and require workers to use breathing protection devices as necessary.
Dust (Coal and Ash)	Provide dust collector equipment. Maintain dust levels below 10 mg/m^3. Provide and require that workers use dust masks when level is exceeded.

Impact	Mitigation
Toxic Gases	Protect workers from exposure to boiler gases by maintaining the boilers properly, and

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	monitoring concentrations with levels not to exceed 5 ppm SO_2, 50 ppm CO, and 5 ppm NO_2.
Waste Lube Oil, Waste Oil (Transformer and Switchgear)	Dispose of waste oil will be by recycling if possible. Disposal to the environment will be properly controlled to avoid soil and groundwater contamination. Clean-up and properly dispose any spills.
Noise	Maintain noise levels below 90 dBA, or provide ear protection.
Water Treatment Wastes	Wastes from regeneration of the mixed-bed demineralizer will be batch-treated by neutralization, and discharged to the river.

8. SCHEDULING, PROCUREMENT AND CONSTRUCTION

8.1 PROJECT SCHEDULING

Schedules for the engineering and construction activities for each of the Unit 10 and 13 options and for the replacement Boiler 13 and 14/Turbine 6 unit are shown in the following figures:

Figure 8.1-1 Units 10 and 13 - Option 1A and 1B (Minimum Refurbishment/Minimum Emission Control)

Figure 8.1-2 Units 10 and 13 - Option 2A and 2B (Minimum Refurbishment/Improved Emission Control)

Figure 8.1-3 Units 10 and 13 - Option 3A and 3B (Conversion to Arch Firing/Improved Emission Control

Figure 8.1-4 Units 10 and 13 - Option 4A and 4B (Extensive Refurbishment/Improved Emission Control)

Figure 8.1-5 Boilers 13 and 14, and Turbine No. 6

These schedules are based on an EPC type contract, with preparation of tender documents started in the second quarter of 1995. Work on all units is assumed to be concurrent.

8.2 BASIS OF ESTIMATE

The project cost estimate was developed based on Burns and Roe providing conventional Architect/Engineer and Construction Management Service. In that regard, the project was broken down into three phases.

Phase I of the project will involve the detailed engineering work necessary to produce demolition concepts and workplans, equipment and material procurement specifications and construction bid packages.

Phase II of the project includes the procurement of the major equipment and materials, and the evaluation/selection of the major subcontractors for the project. (I.e. Demolition/Civil/Structural, Mechanical, Electrical).

Phase III of the Project will include the management of the actual construction on-site, operational training for the new equipment and start-up of the new equipment.

Equipment and Material Costs have been developed from a number of sources. The Capital Cost Estimates identify the pricing source for each item of work. Below is a table which identifies each of the pricing sources.

UKR-	This designation identifies the material and/or equipment cost component as provided by the Ukrainian engineering company, Kharkov Central Design Office, UNPO Energoprogress.
US -	This designation identifies the material and/or equipment cost components as provided by quotes from U.S. manufacturers.
B&R -	This designation identifies the material and/or equipment cost component as developed from Burns and Roe's in-house data from projects similar in nature or size to that referenced in the estimate.

8.2.1 Domestic Procurement (Ukraine)

Particular emphasis was placed on obtaining current pricing for equipment and material from suppliers within the Ukraine. In that regard Burns and Roe met with staff members of Kharkov Central Design Office UNPO Energoprogress during the June, 1995 visit to Lugansk GRES Power Plant to determine which Ukrainian material and equipment suppliers had the technical capability to provide new equipment to the project. Based on those discussions and subsequent phone conferences a comprehensive list of equipment and material pricing was obtained from Ukrainian manufacturers and suppliers by Kharkov Central Design Office. This cost information was provided to Burns and Roe for use in developing the cost estimates for various options contained in Appendix A, B and C.

8.2.2 Foreign Procurement (Non Ukrainian)

Equipment and materials which were not available from Ukrainian manufacturers were priced from U.S. or European manufacturers where possible. Those portions of the estimate are identified with a "US" designation on the estimates contained in Appendix A, B, and C.

8.2.3 Construction Labor

Labor costs were generated by using U.S. Gulf Coast manhour estimates for the work to be performed and applying a productivity factor. The productivity factor was developed based on Burns and Roe's observations at the site, its previous studies performed in NIS countries and information provided by Kharkov Central Design Office. Average hourly rates were derived from wage rates provided during the site visit in June of 1995 and the wage rates of specialists required for certain portions of the project. Based on our site visit, we expect the skilled labor required to complete the project to be available locally to the project and within the Ukraine.

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8.2.4 Project Indirect Costs

Incorporated in the cost of construction Support Facilities are office trailer space and staffing for Construction Engineering and Inspection, Project Management, material and equipment storage, and subcontractor temporary facilities (i.e. change trucks etc.).

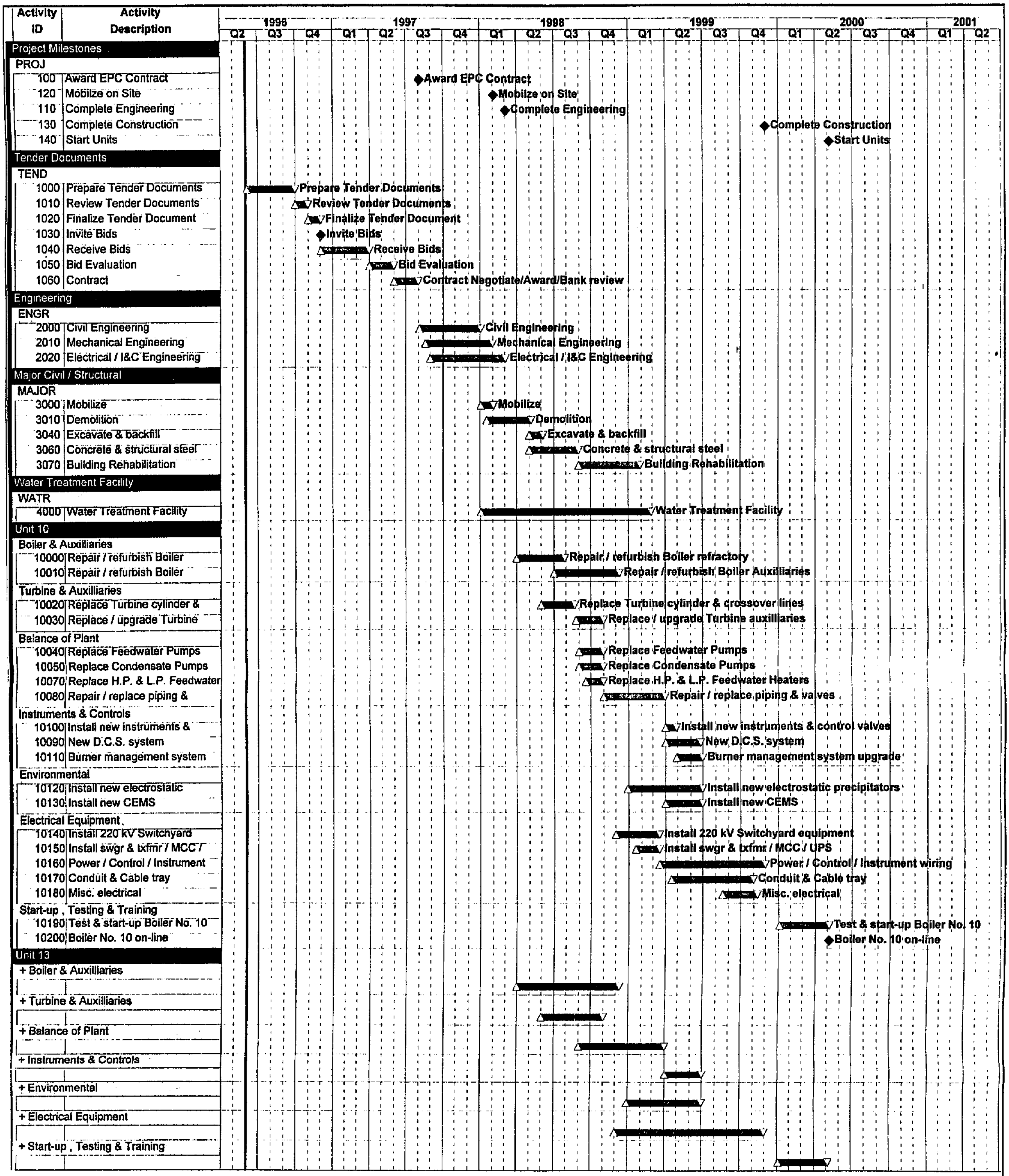
It is assumed that construction utility water and power are available at the site at no cost to the project.

Construction Equipment of the type, quantity and size required for the project appears to be available within the Ukraine from discussions with Kharkov Central Design Office and the Plant Management Personnel.

Ocean freight costs and insurance have been included for those items not manufactured or supplied by Ukraine. Also included is a small amount of freight costs for those items manufactured within the Ukraine.

Contingency is added to the estimate to provide for risks and uncertainties associated with the scope of work at the conceptual stage in design.

Contingency, at various percentages were applied to the direct labor and material costs in addition to the indirect portions of the project costs.



Activity ID	Activity Description
Project Milestones	
PROJ	
100	Award EPC Contract
120	Mobilize on Site
110	Complete Engineering
130	Complete Construction
140	Start Units
Tender Documents	
TEND	
1000	Prepare Tender Documents
1010	Review Tender Documents
1020	Finalize Tender Document
1030	Invite Bids
1040	Receive Bids
1050	Bid Evaluation
1060	Contract
Engineering	
ENGR	
2000	Civil Engineering
2010	Mechanical Engineering
2020	Electrical / I&C Engineering
Major Civil / Structural	
MAJOR	
3000	Mobilize
3010	Demolition
3040	Excavate & backfill
3060	Concrete & structural steel
3070	Building Rehabilitation
Water Treatment Facility	
WATR	
4000	Water Treatment Facility
Unit 10	
Boiler & Auxiliaries	
10000	Repair / refurbish Boiler
10010	Repair / refurbish Boiler
Turbine & Auxiliaries	
10020	Replace Turbine cylinder &
10030	Replace / upgrade Turbine
Balance of Plant	
10040	Replace Feedwater Pumps
10050	Replace Condensate Pumps
10070	Replace H.P. & L.P. Feedwater
10080	Repair / replace piping &
Instruments & Controls	
10100	Install new instruments &
10090	New D.C.S. system
10110	Burner management system
Environmental	
10120	Install new electrostatic
10130	Install new CEMS
Electrical Equipment	
10140	Install 220 kV Switchyard
10150	Install swgr & txfmr / MCC /
10160	Power / Control / Instrument
10170	Conduit & Cable tray
10180	Misc. electrical
Start-up, Testing & Training	
10190	Test & start-up Boiler No. 10
10200	Boiler No. 10 on-line
Unit 13	
+ Boiler & Auxilliaries	
+ Turbine & Auxilliaries	
+ Balance of Plant	
+ Instruments & Controls	
+ Environmental	
+ Electrical Equipment	
+ Start-up, Testing & Training	

Project Start	01JUN95
Project Finish	29DEC00
Data Date	01JUN96
Plot Date	26OCT95

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▨ Early Bar
▨ Progress Bar
■ Critical Activity

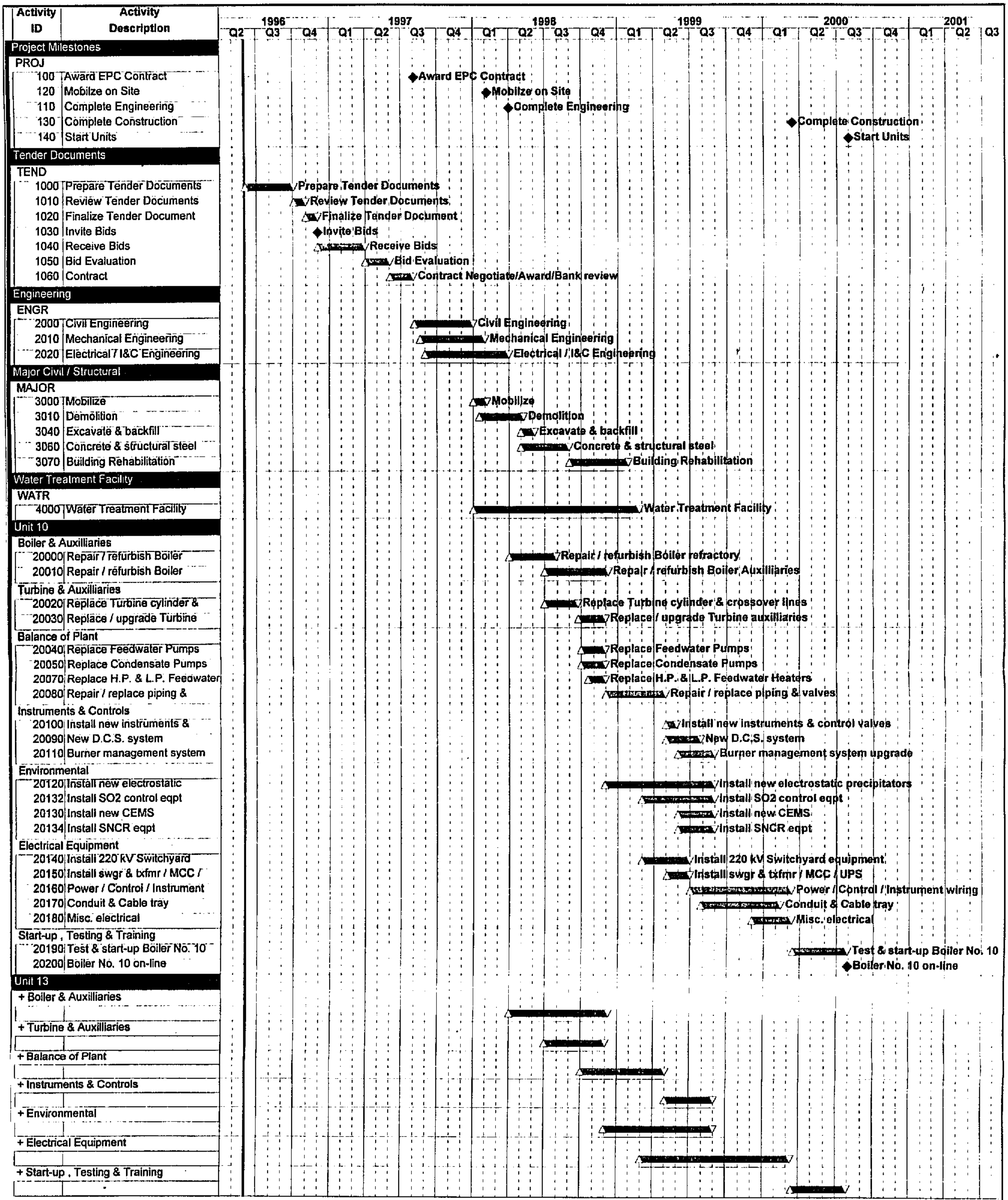
LUGA

Sheet 1 of 1

FIGURE 8.1-1

LUGANSK GRES OPTION 1 - UNITS 10 &13

Uncleaned & Cleaned Coal



Activity ID	Activity Description
Project Milestones	
PROJ	
100	Award EPC Contract
120	Mobilze on Site
110	Complete Engineering
130	Complete Construction
140	Start Units
Tender Documents	
TEND	
1000	Prepare Tender Documents
1010	Review Tender Documents
1020	Finalize Tender Document
1030	Invite Bids
1040	Receive Bids
1050	Bid Evaluation
1060	Contract
Engineering	
ENGR	
2000	Civil Engineering
2010	Mechanical Engineering
2020	Electrical / I&C Engineering
Major Civil / Structural	
MAJOR	
3000	Mobilize
3010	Demolition
3040	Excavate & backfill
3060	Concrete & structural steel
3070	Building Rehabilitation
Water Treatment Facility	
WATR	
4000	Water Treatment Facility
Unit 10	
Boiler & Auxilliaries	
20000	Repair / refurbish Boiler
20010	Repair / refurbish Boiler
Turbine & Auxilliaries	
20020	Replace Turbine cylinder &
20030	Replace / upgrade Turbine
Balance of Plant	
20040	Replace Feedwater Pumps
20050	Replace Condensate Pumps
20070	Replace H.P. & L.P. Feedwater
20080	Repair / replace piping &
Instruments & Controls	
20100	Install new instruments &
20090	New D.C.S. system
20110	Burner management system
Environmental	
20120	Install new electrostatic
20132	Install SO2 control eqpt
20130	Install new CEMS
20134	Install SNCR eqpt
Electrical Equipment	
20140	Install 220 kV Switchyard
20150	Install swgr & txfmr / MCC /
20160	Power / Control / Instrument
20170	Conduit & Cable tray
20180	Misc. electrical
Start-up , Testing & Training	
20190	Test & start-up Boiler No. 10
20200	Boiler No. 10 on-line
Unit 13	
+ Boiler & Auxilliaries	
+ Turbine & Auxilliaries	
+ Balance of Plant	
+ Instruments & Controls	
+ Environmental	
+ Electrical Equipment	
+ Start-up , Testing & Training	

Project Start	01JUN95
Project Finish	29DEC00
Data Date	01JUN96
Plot Date	26OCT95

- Early Bar
- Progress Bar
- Critical Activity

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FIGURE 8.1-2

LUGANSK GRES OPTION 2 - UNITS 10 &13

Uncleaned & Cleaned Coal

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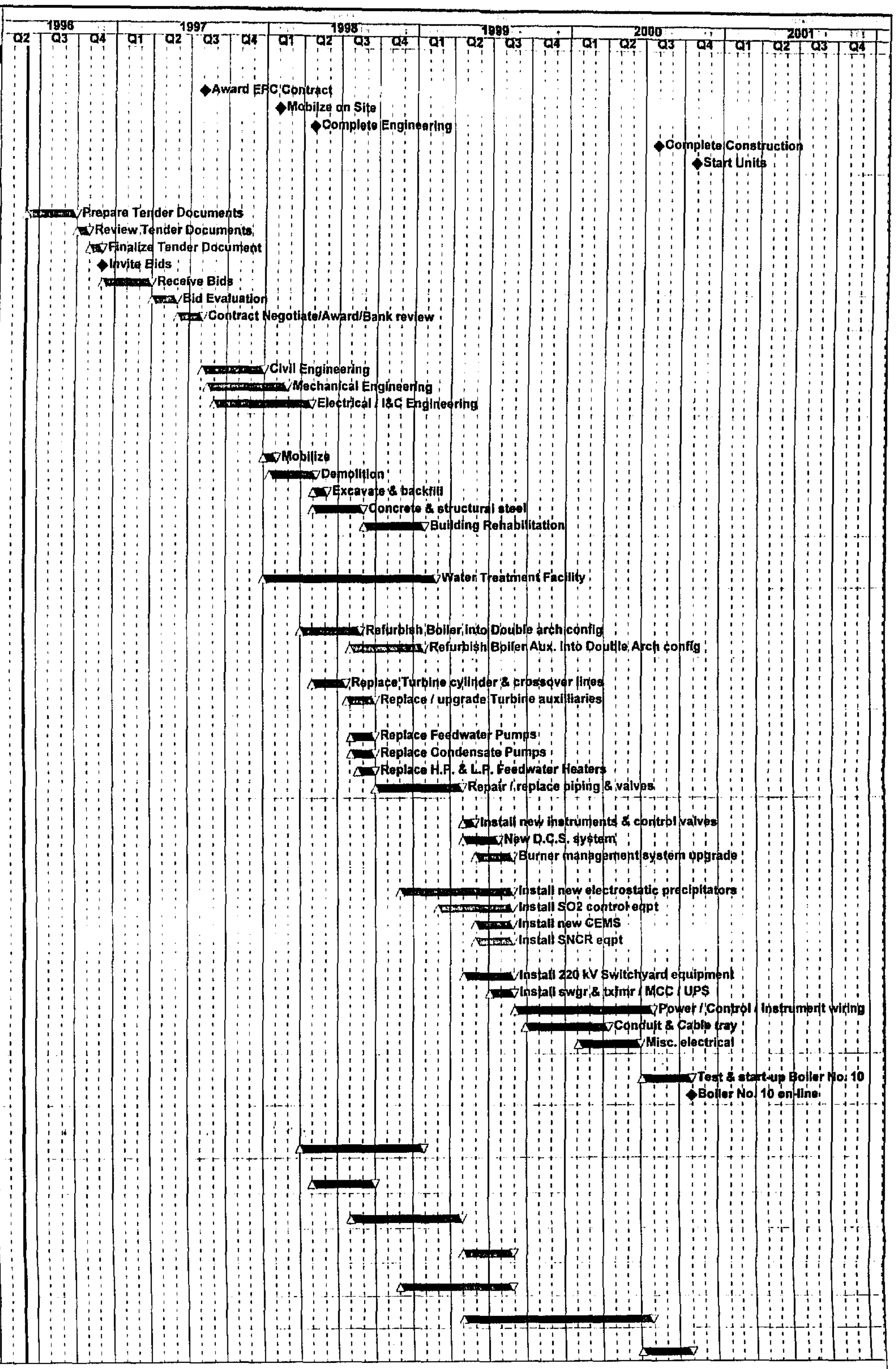
Activity ID	Activity Description
Project Milestones	
PROJ	
100	Award EPC Contract
120	Mobilze on Site
110	Complete Engineering
130	Complete Construction
140	Start Units
Tender Documents	
TEND	
1000	Prepare Tender Documents
1010	Review Tender Documents
1020	Finalize Tender Document
1030	Invite Bids
1040	Receive Bids
1050	Bid Evaluation
1060	Contract
Engineering	
ENGR	
2000	Civil Engineering
2010	Mechanical Engineering
2020	Electrical / I&C Engineering
Major Civil / Structural	
MAJOR	
3000	Mobilize
3010	Demolition
3040	Excavate & backfill
3060	Concrete & structural steel
3070	Building Rehabilitation
Water Treatment Facility	
WATR	
4000	Water Treatment Facility
Unit 10	
Boiler & Auxilliaries	
30000	Refurbish Boiler into Double
30010	Refurbish Boiler Aux. Into
Turbine & Auxilliaries	
30020	Replace Turbine cylinder &
30030	Replace / upgrade Turbine
Balance of Plant	
30040	Replace Feedwater Pumps
30050	Replace Condensate Pumps
30070	Replace H.P. & L.P. Feedwater
30080	Repair / replace piping &
Instruments & Controls	
30100	Install new instruments &
30090	New D.C.S. system
30110	Burner management system
Environmental	
30120	Install new electrostatic
30140	Install SO2 control eqpt
30130	Install new CEMS
30150	Install SNCR eqpt
Electrical Equipment	
30160	Install 220 kV Switchyard
30170	Install swgr & txfmr / MCC /
30180	Power / Control / Instrument
30190	Conduit & Cable tray
30200	Misc. electrical
Start-up , Testing & Training	
30210	Test & start-up Boiler No. 10
30220	Boiler No. 10 on-line
Unit 13	
+ Boiler & Auxilliaries	
+ Turbine & Auxilliaries	
+ Balance of Plant	
+ Instruments & Controls	
+ Environmental	
+ Electrical Equipment	
+ Start-up , Testing & Training	



Project Start	01JUN95
Project Finish	29DEC00
Data Date	01JUN96
Plot Date	26OCT95

▨ Early Bar
▬ Progress Bar
■ Critical Activity

LUGA

Sheet 1 of 1

FIGURE 8.1-3

LUGANSK GRES OPTION 3 - UNITS 10 &13

Uncleaned & Cleaned Coal

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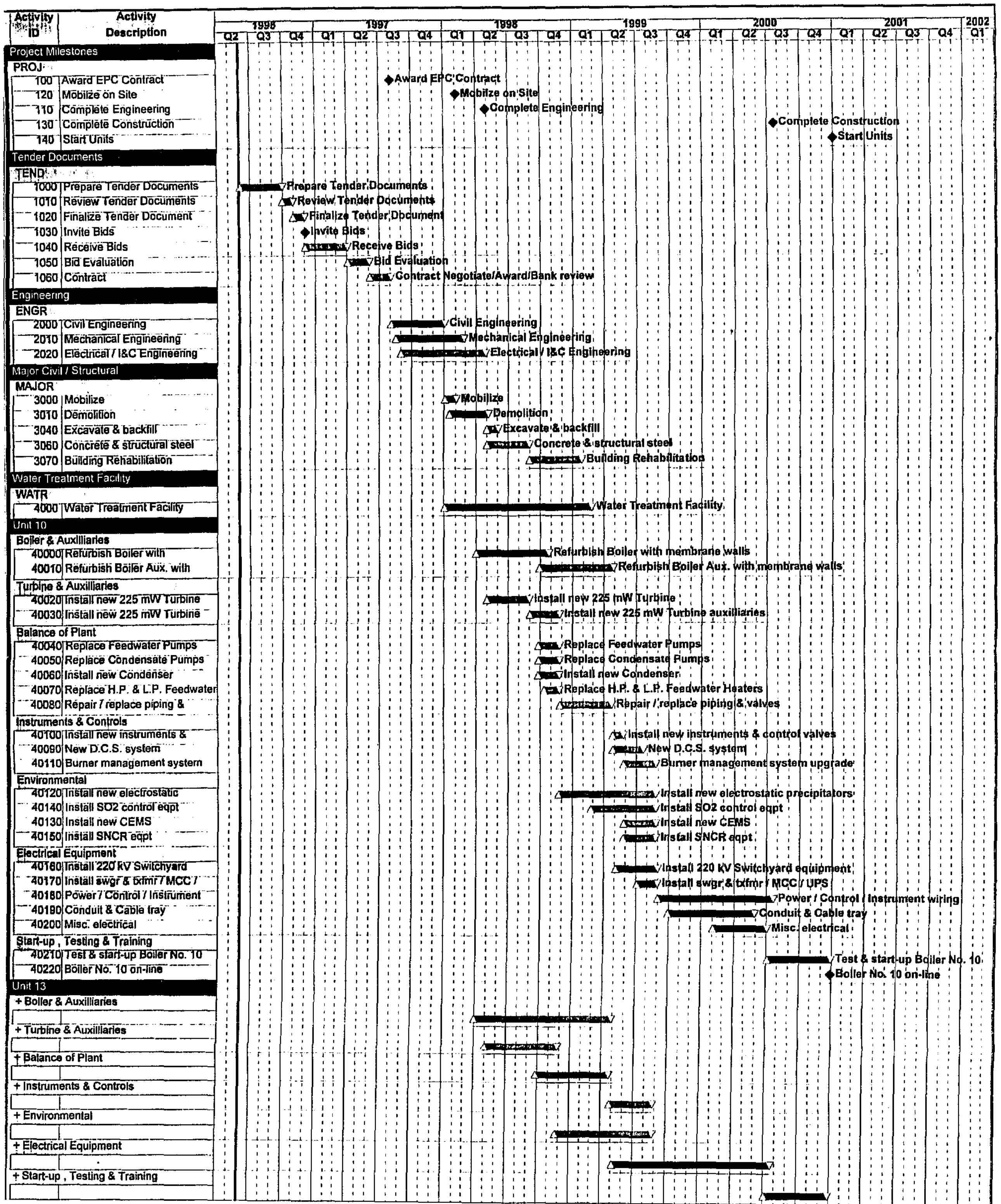
BEST AVAILABLE COPY



Activity ID	Activity Description
Project Milestones	
PROJ	
100	Award EPC Contract
120	Mobilize on Site
110	Complete Engineering
130	Complete Construction
140	Start Units
Tender Documents	
TEND	
1000	Prepare Tender Documents
1010	Review Tender Documents
1020	Finalize Tender Document
1030	Invite Bids
1040	Receive Bids
1050	Bid Evaluation
1060	Contract
Engineering	
ENGR	
2000	Civil Engineering
2010	Mechanical Engineering
2020	Electrical / I&C Engineering
Major Civil / Structural	
MAJOR	
3000	Mobilize
3010	Demolition
3040	Excavate & backfill
3060	Concrete & structural steel
3070	Building Rehabilitation
Water Treatment Facility	
WATR	
4000	Water Treatment Facility
Unit 10	
Boiler & Auxiliaries	
40000	Refurbish Boiler with
40010	Refurbish Boiler Aux. with
Turbine & Auxilliaries	
40020	Install new 225 mW Turbine
40030	Install new 225 mW Turbine
Balance of Plant	
40040	Replace Feedwater Pumps
40050	Replace Condensate Pumps
40060	Install new Condenser
40070	Replace H.P. & L.P. Feedwater
40080	Repair / replace piping &
Instruments & Controls	
40100	Install new instruments &
40090	New D.C.S. system
40110	Burner management system
Environmental	
40120	Install new electrostatic
40140	Install SO2 control eqpt
40130	Install new CEMS
40150	Install SNCR eqpt
Electrical Equipment	
40160	Install 220 kV Switchyard
40170	Install swgr & txfmr / MCC /
40180	Power / Control / Instrument
40190	Conduit & Cable tray
40200	Misc. electrical
Start-up , Testing & Training	
40210	Test & start-up Boiler No. 10
40220	Boiler No. 10 on-line
Unit 13	
+ Boiler & Auxilliaries	
+ Turbine & Auxilliaries	
+ Balance of Plant	
+ Instruments & Controls	
+ Environmental	
+ Electrical Equipment	
+ Start-up , Testing & Training	

Project Start	01JUN95	▲	Early Bar
Project Finish	29DEC00	▲	Progress Bar
Data Date	01JUN96	■	Critical Activity
Plot Date	26OCT95		

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FIGURE 8.1-4

LUGASNK GRES OPTION 4 - UNITS 10 &13

Uncleaned & Cleaned Coal

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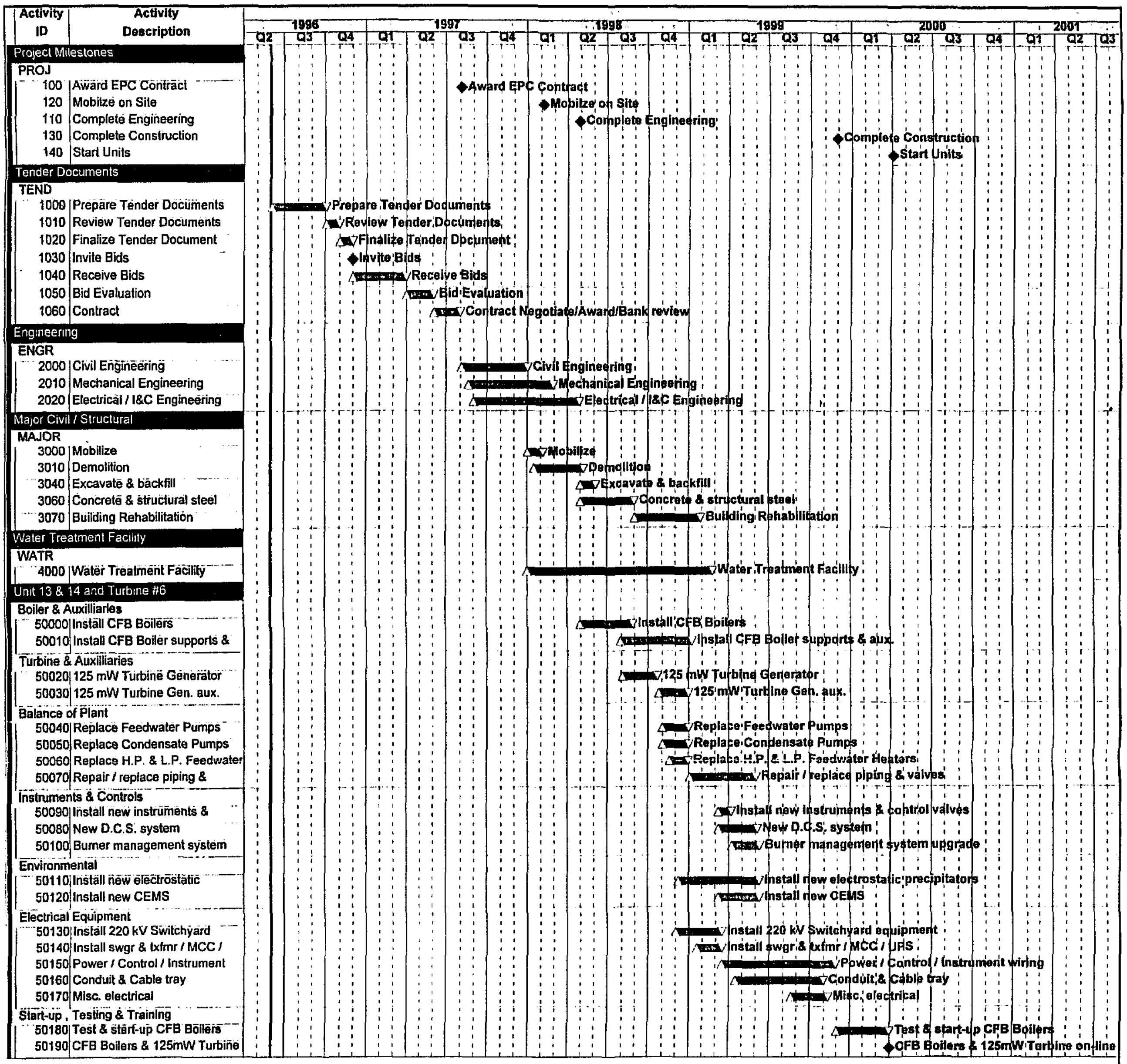

Activity ID	Activity Description
Project Milestones	
PROJ	
100	Award EPC Contract
120	Mobilize on Site
110	Complete Engineering
130	Complete Construction
140	Start Units
Tender Documents	
TEND	
1000	Prepare Tender Documents
1010	Review Tender Documents
1020	Finalize Tender Document
1030	Invite Bids
1040	Receive Bids
1050	Bid Evaluation
1060	Contract
Engineering	
ENGR	
2000	Civil Engineering
2010	Mechanical Engineering
2020	Electrical / I&C Engineering
Major Civil / Structural	
MAJOR	
3000	Mobilize
3010	Demolition
3040	Excavate & backfill
3060	Concrete & structural steel
3070	Building Rehabilitation
Water Treatment Facility	
WATR	
4000	Water Treatment Facility
Unit 13 & 14 and Turbine #6	
Boiler & Auxilliaries	
50000	Install CFB Boilers
50010	Install CFB Boiler supports &
Turbine & Auxilliaries	
50020	125 mW Turbine Generator
50030	125 mW Turbine Gen. aux.
Balance of Plant	
50040	Replace Feedwater Pumps
50050	Replace Condensate Pumps
50060	Replace H.P. & L.P. Feedwater
50070	Repair / replace piping &
Instruments & Controls	
50090	Install new instruments &
50080	New D.C.S. system
50100	Burner management system
Environmental	
50110	Install new electrostatic
50120	Install new CEMS
Electrical Equipment	
50130	Install 220 kV Switchyard
50140	Install swgr & txfmr / MCC /
50150	Power / Control / Instrument
50160	Conduit & Cable tray
50170	Misc. electrical
Start-up , Testing & Training	
50180	Test & start-up CFB Boilers
50190	CFB Boilers & 125mW Turbine

Project Start	01JUN95	▭ Early Bar	LUGA
Project Finish	29DEC00	▭ Progress Bar	
Data Date	01JUN96	■ Critical Activity	
Plot Date	26OCT95		

Sheet 1 of 1

FIGURE 8.1-5

LUGANSK GRES Rehabilitation Of

Boilers No. 13, 14 and Turbine No. 6

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 10

MINIMAL BOILER UPGRADE / MIMIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	587,840		15,000			120,568	723,408
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**805,880**	**0**	**129,000**	**0**	**1,250,000**	**436,976**	**2,621,856**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	78,000		623,400			84,168	785,568
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
REFURBISH EXISTING FUEL INJECTORS	B & R	10,240		450,000			55,229	515,469
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**627,240**	**0**	**9,539,400**	**1,545,000**	**0**	**1,405,397**	**13,117,037**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 10

MINIMAL BOILER UPGRADE / MIMIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNING & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
CONTROLS & INSTRUMENTS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			300,000		48,915	375,015
TOTAL CONTROLS & INSTRUMENTS		**149,300**	**0**	**0**	**1,765,000**	**0**	**245,945**	**2,160,245**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**171,200**	**0**	**0**	**2,850,000**	**0**	**302,120**	**3,323,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 10

MINIMAL BOILER UPGRADE / MIMIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**2,880,200**	**0**	**22,269,900**	**10,511,820**	**1,250,000**	**4,463,108**	**41,375,028**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 10

MINIMAL BOILER UPGRADE / MIMIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	B & R							1,311,269
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,609,669**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					2,068,751	103,438	2,172,189
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,318,751**	**340,938**	**5,659,689**
TOTAL ESTIMATED PROJECT COSTS								**51,644,386**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 10

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	587,840		15,000			120,568	723,408
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		805,880	0	129,000	0	1,250,000	436,976	2,621,856
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	78,000		623,400			84,168	785,568
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
REFURBISH EXISTING FUEL INJECTORS	B & R	10,240		450,000			55,229	515,469
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		627,240	0	9,539,400	1,545,000	0	1,405,397	13,117,037

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 10

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			300,000		48,915	375,015
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,765,000**	**0**	**245,945**	**2,160,245**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**171,200**	**0**	**0**	**2,850,000**	**0**	**302,120**	**3,323,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 10

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**2,880,200**	**0**	**22,269,900**	**10,511,820**	**1,250,000**	**4,463,108**	**41,375,028**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 10

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS UPGRADE

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	B & R							1,311,269
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,609,669**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					2,068,751	103,438	2,172,189
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,318,751**	**340,938**	**5,659,689**
TOTAL ESTIMATED PROJECT COSTS								**51,644,386**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	587,840		15,000			120,568	723,408
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**805,880**	**0**	**129,000**	**0**	**1,250,000**	**436,976**	**2,621,856**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	78,000		623,400			84,168	785,568
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,200,000		147,456	1,376,256
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**645,800**	**0**	**9,089,400**	**2,745,000**	**0**	**1,497,624**	**13,977,824**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	UKR	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			300,000		48,915	375,015
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,765,000**	**0**	**245,945**	**2,160,245**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
INSTALL SO2 CONTROL EQUIPMENT	US	210,000			6,400,000		661,000	7,271,000
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**409,200**	**0**	**0**	**10,230,000**	**0**	**1,063,920**	**11,703,120**

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING		628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT		16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY		178,000		630,000			121,200	929,200
GROUNDING SYSTEM		4,800		67,500			10,845	83,145
CATHODIC PROTECTION		10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION		11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**3,136,760**	**0**	**21,819,900**	**19,091,820**	**1,250,000**	**5,317,135**	**50,615,615**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS UPGRADE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES						1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS						1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS						225,000	27,000	252,000
FREIGHT								1,636,469
VENDOR REPS/TRAINING/MANUALS						200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,934,869**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES						2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT						2,530,781	126,539	2,657,320
START-UP, TESTING & TRAINING						750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,780,781**	**364,039**	**6,144,820**
TOTAL ESTIMATED PROJECT COSTS								**61,695,304**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	587,840		15,000			120,568	723,408
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**805,880**	**0**	**129,000**	**0**	**1,250,000**	**436,976**	**2,621,856**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	78,000		623,400			84,168	785,568
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,200,000		147,456	1,376,256
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**645,800**	**0**	**9,089,400**	**2,745,000**	**0**	**1,497,624**	**13,977,824**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			300,000		48,915	375,015
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,765,000**	**0**	**245,945**	**2,160,245**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
INSTALL SO2 CONTROL EQUIPMENT	US	252,000			8,150,000		840,200	9,242,200
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,980,000**	**0**	**1,243,120**	**13,674,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING		628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT		16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY		178,000		630,000			121,200	929,200
GROUNDING SYSTEM		4,800		67,500			10,845	83,145
CATHODIC PROTECTION		10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION		11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**3,178,760**	**0**	**21,819,900**	**20,841,820**	**1,250,000**	**5,496,335**	**52,586,815**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 10

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES						1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS						1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS						225,000	27,000	252,000
FREIGHT								1,706,469
VENDOR REPS/TRAINING/MANUALS						200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**5,004,869**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES						2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT						2,629,341	131,467	2,760,808
START-UP, TESTING & TRAINING						750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,879,341**	**368,967**	**6,248,308**
TOTAL ESTIMATED PROJECT COSTS								**63,839,992**

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THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	875,840		35,000			182,168	1,093,008
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	138,400		88,000			45,280	271,680
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,192,000**	**0**	**218,000**	**0**	**1,250,000**	**532,000**	**3,192,000**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	872,000		9,650,000			1,262,640	11,784,640
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	32,400		1,125,000			138,888	1,296,288
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
INSTALL NEW BURNERS	B & R	32,400			1,400,000		171,888	1,604,288
INSTALL NEW BOTTOM ASH SYSTEM	B & R	25,200			485,000		61,224	571,424
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,525,200**	**0**	**18,648,000**	**3,430,000**	**0**	**2,832,384**	**26,435,584**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	UKR	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD, CASING SUPPORTS AND EXPANSION JOINT	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	210,000			6,950,000		716,000	7,876,000
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**409,200**	**0**	**0**	**10,780,000**	**0**	**1,118,920**	**12,308,120**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,667			57,400	440,066
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,167**	**0**	**0**	**575,545**	**4,412,511**
TOTAL DIRECT COSTS		**4,402,280**	**0**	**31,467,667**	**20,376,820**	**1,250,000**	**6,809,444**	**64,306,210**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,073,779
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,235,699**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,215,311	160,766	3,376,076
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,515,311**	**455,766**	**7,971,076**
TOTAL ESTIMATED PROJECT COST								**78,512,986**

NOTE:

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THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR UKR	LABOR OTHER	MATERIAL UKR	MATERIAL OTHER	SUBCONTRACT $	CONTINGENCY $	TOTAL $
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	875,840		35,000			182,168	1,093,008
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	138,400		88,000			45,280	271,680
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,192,000**	**0**	**218,000**	**0**	**1,250,000**	**532,000**	**3,192,000**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	872,000		9,650,000			1,262,640	11,784,640
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
INSTALL NEW BURNERS	B & R	32,400			1,400,000		171,888	1,604,288
INSTALL NEW BOTTOM ASH SYSTEM	B & R	25,200			485,000		61,224	571,424
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,510,800**	**0**	**18,068,000**	**3,430,000**	**0**	**2,761,056**	**25,769,856**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE H.P. & I.P. TURBINE CYLINDERS & CROSSOVER LINES	UKR	31,200		5,150,000			518,120	5,699,320
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	UKR	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD, CASING SUPPORTS AND EXPANSION JOINT	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**233,320**	**0**	**9,612,500**	**1,705,000**	**0**	**1,227,922**	**12,778,742**
MISC ITEMS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL MISC ITEMS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	226,800			7,115,000		734,180	8,075,980
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**10,945,000**	**0**	**1,137,100**	**12,508,100**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,404,680**	**0**	**30,887,500**	**20,541,820**	**1,250,000**	**6,756,271**	**63,840,271**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 10

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,057,173
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,219,093**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,192,014	159,601	3,351,614
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,492,014**	**454,601**	**7,946,614**
TOTAL ESTIMATED PROJECT COST								**78,005,978**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	898,000		35,000			186,600	1,119,600
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	148,800		94,000			48,560	291,360
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,224,560**	**0**	**224,000**	**0**	**1,250,000**	**539,712**	**3,238,272**
BOILER REPAIR WORK								
REFURBISH BOILER INTO MEMBRANE WALL DESIGN	B & R	671,600		6,820,000			898,992	8,390,592
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	32,400		1,125,000			138,888	1,296,288
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,200,000		147,456	1,376,256
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,324,200**	**0**	**16,115,000**	**2,745,000**	**0**	**2,422,104**	**22,606,304**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,582,800**	**1,050,000**	**0**	**1,992,480**	**21,038,880**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	252,000			7,305,000		755,700	8,312,700
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,135,000**	**0**	**1,158,620**	**12,744,820**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220 KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,456,120**	**0**	**36,910,800**	**19,391,820**	**1,250,000**	**7,211,109**	**69,219,849**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,252,105
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,414,025**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,460,992	173,050	3,634,042
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,760,992**	**468,050**	**8,229,042**
TOTAL ESTIMATED PROJECT COST								**83,862,916**

NOTE:

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THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	898,000		35,000			186,600	1,119,600
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	148,800		94,000			48,560	291,360
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASEESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,224,560**	**0**	**224,000**	**0**	**1,250,000**	**539,712**	**3,238,272**
BOILER REPAIR WORK								
REFURBISH BOILER INTO MEMBRANE WALL DESIGN	B & R	671,600		6,820,000			898,992	8,390,592
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	72,000		545,000			74,040	691,040
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,200,000		147,456	1,376,256
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,363,800**	**0**	**15,535,000**	**2,745,000**	**0**	**2,357,256**	**22,001,056**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,582,800**	**1,050,000**	**0**	**1,992,480**	**21,038,880**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	252,000			7,530,000		778,200	8,560,200
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,360,000**	**0**	**1,181,120**	**12,992,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,667			57,400	440,066
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,167**	**0**	**0**	**575,545**	**4,412,511**
TOTAL DIRECT COSTS		**4,495,720**	**0**	**36,330,967**	**19,616,820**	**1,250,000**	**7,168,786**	**68,862,292**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 10

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,237,911
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,399,831**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,443,115	172,156	3,615,270
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,743,115**	**467,156**	**8,210,270**
TOTAL ESTIMATED PROJECT COST								**83,472,394**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	65,000		519,000			70,080	654,080
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	7,200		45,000			6,264	58,464
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
REFURBISH EXISTING FUEL INJECTORS	B & R	20,400		655,000			81,048	756,448
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**625,600**	**0**	**9,650,000**	**1,545,000**	**0**	**1,418,472**	**13,239,072**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,462,500**	**1,715,000**	**0**	**710,842**	**7,090,862**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**171,200**	**0**	**0**	**2,850,000**	**0**	**302,120**	**3,323,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**2,876,320**	**0**	**17,235,500**	**10,571,820**	**1,250,000**	**3,973,315**	**35,906,955**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1A - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	UKR							1,112,293
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,410,693**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					1,795,348	89,767	1,885,115
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,045,348**	**327,267**	**5,372,615**
TOTAL ESTIMATED PROJECT COSTS								**45,690,263**

NOTE:

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THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	65,000		519,000			70,080	654,080
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	7,200		45,000			6,264	58,464
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
REFURBISH EXISTING FUEL INJECTORS	B & R	20,400		655,000			81,048	756,448
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**625,600**	**0**	**9,650,000**	**1,545,000**	**0**	**1,418,472**	**13,239,072**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,462,500**	**1,715,000**	**0**	**710,842**	**7,090,862**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**171,200**	**0**	**0**	**2,850,000**	**0**	**302,120**	**3,323,320**

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**2,876,320**	**0**	**17,235,500**	**10,571,820**	**1,250,000**	**3,973,315**	**35,906,955**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 1B - UNIT 13

MINIMAL BOILER UPGRADE / MINIMAL EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	UKR							1,112,293
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,410,693**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					1,795,348	89,767	1,885,115
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,045,348**	**327,267**	**5,372,615**
TOTAL ESTIMATED PROJECT COSTS								**45,690,263**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR UKR	LABOR OTHER	MATERIAL UKR	MATERIAL OTHER	SUBCONTRACT $	CONTINGENCY $	TOTAL $
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	65,000		519,000			70,080	654,080
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	7,200		45,000			6,264	58,464
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	37,600			1,900,000		232,512	2,170,112
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**642,800**	**0**	**8,995,000**	**3,445,000**	**0**	**1,569,936**	**14,652,736**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING EQUIPMENT	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,462,500**	**1,715,000**	**0**	**710,842**	**7,090,862**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
INSTALL SO2 CONTROL EQUIPMENT	US	210,000			6,400,000		661,000	7,271,000
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**409,200**	**0**	**0**	**10,230,000**	**0**	**1,063,920**	**11,703,120**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**3,131,520**	**0**	**16,580,500**	**19,851,820**	**1,250,000**	**4,886,579**	**45,700,419**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2A - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	B & R							1,457,293
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,755,693**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					2,285,021	114,251	2,399,272
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,535,021**	**351,751**	**5,886,772**
TOTAL ESTIMATED PROJECT COSTS								**56,342,884**

NOTE:

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THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
BOILER REPAIR WORK								
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	B & R	65,000		519,000			70,080	654,080
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	7,200		45,000			6,264	58,464
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	18,000		545,000			67,560	630,560
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	37,600			1,900,000		232,512	2,170,112
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
TOTAL BOILER WORK		**642,800**	**0**	**8,995,000**	**3,445,000**	**0**	**1,569,936**	**14,652,736**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING EQUIPMENT	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,462,500**	**1,715,000**	**0**	**710,842**	**7,090,862**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
INSTALL SO2 CONTROL EQUIPMENT	US	252,000			8,135,000		838,700	9,225,700
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,965,000**	**0**	**1,241,620**	**13,657,820**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**3,173,520**	**0**	**16,580,500**	**21,586,820**	**1,250,000**	**5,064,279**	**47,655,119**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 2B - UNIT 13

MINIMAL BOILER UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
FREIGHT	B & R							1,526,693
VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**4,825,093**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
CONSTRUCTION MANAGEMENT	B & R					2,382,756	119,138	2,501,894
START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**5,632,756**	**356,638**	**5,989,394**
TOTAL ESTIMATED PROJECT COSTS								**58,469,606**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	875,840		35,000			182,168	1,093,008
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	138,400		88,000			45,280	271,680
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,192,000**	**0**	**218,000**	**0**	**1,250,000**	**532,000**	**3,192,000**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	872,000		9,650,000			1,262,640	11,784,640
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	32,400		1,125,000			138,888	1,296,288
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
INSTALL NEW BURNERS	B & R	32,400			1,400,000		171,888	1,604,288
INSTALL NEW BOTTOM ASH SYSTEM	B & R	25,200			485,000		61,224	571,424
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,525,200**	**0**	**18,648,000**	**3,430,000**	**0**	**2,832,384**	**26,435,584**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,462,500**	**1,715,000**	**0**	**710,842**	**7,090,862**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	210,000			6,935,000		714,500	7,859,500
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**409,200**	**0**	**0**	**10,765,000**	**0**	**1,117,420**	**12,291,620**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,371,480**	**0**	**26,317,500**	**20,371,820**	**1,250,000**	**6,290,839**	**58,601,639**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3A - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							1,867,573
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,029,493**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					2,930,082	146,504	3,076,586
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,230,082**	**441,504**	**7,671,586**
TOTAL ESTIMATED PROJECT COST								**72,302,718**

NOTE:

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THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	875,840		35,000			182,168	1,093,008
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	138,400		88,000			45,280	271,680
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,192,000**	**0**	**218,000**	**0**	**1,250,000**	**532,000**	**3,192,000**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	872,000		9,650,000			1,262,640	11,784,640
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	32,400		545,000			69,288	646,688
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
INSTALL NEW BURNERS	B & R	32,400			1,400,000		171,888	1,604,288
INSTALL NEW BOTTOM ASH SYSTEM	B & R	25,200			485,000		61,224	571,424
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,525,200**	**0**	**18,068,000**	**3,430,000**	**0**	**2,762,784**	**25,785,984**

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
REPLACE L.P. TURBINE LAST STAGE BLADING	UKR	15,200		1,000,000			101,520	1,116,720
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
REPLACE GOVERNING SYSTEM	US	2,000			500,000		50,200	552,200
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140
REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
IMPROVE H2 SEALING SYSTEM	UKR	1,200		20,000			2,120	23,320
CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
ADD CONDENSER CLEANING SYSTEM	UKR	9,600			220,000		22,960	252,560
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
INSTALL NEW STEAM SAMPLING SYSTEM	UKR	8,400		32,000			4,040	44,440
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		650,000			145,680	874,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**202,520**	**0**	**4,494,500**	**1,590,000**	**0**	**701,542**	**6,988,562**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	226,800			7,115,000		734,180	8,075,980
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**10,945,000**	**0**	**1,137,100**	**12,508,100**

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR UKR	LABOR OTHER	MATERIAL UKR	MATERIAL OTHER	SUBCONTRACT $	CONTINGENCY $	TOTAL $
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,388,280**	**0**	**25,769,500**	**20,426,820**	**1,250,000**	**6,231,619**	**58,066,219**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 3B - UNIT 13

ARCH FIRED BOILER / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							1,847,853
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,009,773**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					2,903,311	145,166	3,048,476
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,203,311**	**440,166**	**7,643,476**
TOTAL ESTIMATED PROJECT COST								**71,719,468**

NOTE:

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THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	898,000		35,000			186,600	1,119,600
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	148,800		94,000			48,560	291,360
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,224,560**	**0**	**224,000**	**0**	**1,250,000**	**539,712**	**3,238,272**
BOILER REPAIR WORK								
REFURBISH BOILER INTO MEMBRANE WALL DESIGN	B & R	671,600		6,820,000			898,992	8,390,592
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	72,000		1,125,000			143,640	1,340,640
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	37,600			1,900,000		232,512	2,170,112
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,372,600**	**0**	**16,115,000**	**3,445,000**	**0**	**2,511,912**	**23,444,512**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		20,000			2,720	29,920
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,588,300**	**1,050,000**	**0**	**1,993,030**	**21,044,930**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	226,800			7,305,000		753,180	8,284,980
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**11,135,000**	**0**	**1,156,100**	**12,717,100**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,479,320**	**0**	**36,916,300**	**20,091,820**	**1,250,000**	**7,298,947**	**70,036,387**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4A - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,280,325
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,442,245**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,501,819	175,091	3,676,910
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,801,819**	**470,091**	**8,271,910**
TOTAL ESTIMATED PROJECT COST								**84,750,542**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	898,000		35,000			186,600	1,119,600
EXCAVATION & BACKFILL	B & R	51,600		23,000			14,920	89,520
CONCRETE & STRUCTURAL STEEL	B & R	148,800		94,000			48,560	291,360
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,224,560**	**0**	**224,000**	**0**	**1,250,000**	**539,712**	**3,238,272**
BOILER REPAIR WORK								
REFURBISH BOILER INTO MEMBRANE WALL DESIGN	B & R	671,600		6,820,000			898,992	8,390,592
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	59,200		1,150,000			145,104	1,354,304
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REPLACE EXISTING BALL MILLS	B & R	32,400		545,000			69,288	646,688
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	37,600			1,900,000		232,512	2,170,112
REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**1,333,000**	**0**	**15,535,000**	**3,445,000**	**0**	**2,437,560**	**22,750,560**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		20,000			2,720	29,920
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,588,300**	**1,050,000**	**0**	**1,993,030**	**21,044,930**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING PRECIPS WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	226,800			7,530,000		775,680	8,532,480
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**11,360,000**	**0**	**1,178,600**	**12,964,600**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**4,439,720**	**0**	**36,336,300**	**20,316,820**	**1,250,000**	**7,247,095**	**69,589,935**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 4B - UNIT 13

EXTENSIVE BOILER & TURBINE UPGRADE / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,685,000	202,200	1,887,200
SUPPORT LABOR & FIELD OFFICE	B & R					1,456,000	174,720	1,630,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					325,000	39,000	364,000
FREIGHT	B & R							2,266,125
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,716,000**	**445,920**	**6,428,045**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,479,497	173,975	3,653,472
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**7,779,497**	**468,975**	**8,248,472**
TOTAL ESTIMATED PROJECT COST								**84,266,451**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and TURBINE NO. 6
2- CFB BOILERS WITH 125 MW TURBINE

ITEM	PRICING SOURCE	LABOR UKR	LABOR OTHER	MATERIAL UKR	MATERIAL OTHER	SUBCONTRACT $	CONTINGENCY $	TOTAL $
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	352,400		68,000			84,080	504,480
EXCAVATION & BACKFILL	B & R	106,000		43,000			29,800	178,800
CONCRETE & STRUCTURAL STEEL	B & R	490,000		1,495,000			397,000	2,382,000
BUILDINGS REHABILITATION	B & R	172,000		450,000			124,400	746,400
ROADWAYS / PARKING / FENCING	B & R	60,000		57,000			23,400	140,400
NEW STACK LINER & DUCTWORK	US	272,000		421,000			138,600	831,600
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R					1,350,500	270,100	1,620,600
REPAIR CIRCULATING WATER PUMPHOUSE	UKR	157,000		295,000			90,400	542,400
TOTAL CIVIL/STRUCTURAL		**1,609,400**	**0**	**2,829,000**	**0**	**1,350,500**	**1,157,780**	**6,946,680**
CFB BOILER & MECH EQUIP								
CFB BOILER SYSTEM INCLUDING STRUCTURAL SUPPORTS	UKR	914,800		27,500,000			2,841,480	31,256,280
INDUCED DRAFT FANS & F.D. BLOWERS	UKR	26,000		1,160,000			118,600	1,304,600
ASH CONVEYOR AND SILO	UKR	26,800		420,000			44,680	491,480
COAL FEEDING EQUIPMENT	US	32,000		1,200,000			123,200	1,355,200
NEW COAL CONVEYORS	B & R	20,800			549,000		56,980	626,780
NEW COAL CRUSHER SYSTEM	US	18,800			214,300		23,310	256,410
NEW COAL BUNKERS	B & R	30,000		305,000			33,500	368,500
LIME PREPERATION AND STORAGE SYSTEM	US	41,800			1,650,000		169,180	1,860,980
BOILER FEED PUMPS	UKR	8,000		600,000			60,800	668,800
125 MW TURBINE GENERATOR	UKR	54,000		10,457,800			1,051,180	11,562,980
SURFACE CONDENSER	UKR	31,600		1,600,000			163,160	1,794,760
CONDENSER CLEANING SYSTEM	US	12,800			300,000		31,280	344,080
NEW CIRCULATING WATER PUMPS & PIPING	UKR	90,220		545,000			63,522	698,742
NEW INSTRUMENT & SERVICE AIR COMPRESSORS	B & R	9,600			140,000		14,960	164,560
L.P. FEEDWATER HEATERS	UKR	21,200		210,000			23,120	254,320
H.P. FEEDWATER HEATERS	UKR	22,000		300,000			32,200	354,200
CONDENSATE PUMPS	UKR	8,800		150,000			15,880	174,680
CONDENSATE BOOSTER PUMPS	UKR	6,000		180,000			18,600	204,600
PIPING & VALVES	UKR	67,200		750,000			163,440	980,640
HEATER DRAIN PUMPS	UKR	2,000		30,000			3,200	35,200
DEAERATOR & BLOWDOWN EQUIPMENT	B & R	5,200			155,000		16,020	176,220
CHEMICAL FEED SYSTEM	B & R	16,800			60,000		7,680	84,480
TOTAL CFB BOILER & MECH EQUIPMENT		**1,466,420**	**0**	**45,407,800**	**3,068,300**	**0**	**5,075,972**	**55,018,492**

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and *TURBINE NO. 6*
2- CFB BOILERS WITH 125 MW TURBINE

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	*OTHER*	UKR	*OTHER*	$	$	$
INSTRUMENTS & CONTROLS								
DCS SYSTEM	US	75,600			760,000		83,560	919,160
INSTUMENTS & CONTROLS	B & R	37,000			418,000		68,250	523,250
TOTAL INSTRUMENTS & CONTROLS		**112,600**	**0**	**0**	**1,178,000**	**0**	**151,810**	**1,442,410**
ENVIRONMENTAL SYSTEMS								
BAGHOUSE SYSTEM	US	50,000			3,800,000		385,000	4,235,000
CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**77,200**	**0**	**0**	**4,050,000**	**0**	**412,720**	**4,539,920**
ELECTRICAL WORK								
[illegible]20 KV SWITCHYARD EQUIPMENT	US	43,200			831,020		87,422	961,642
[illegible] & AUXILIARY TRANSFORMERS & ASSOCIATED EQUIPMENT	US	16,000			2,291,888		230,789	2,538,677
SWITCHGEAR & BUS	US	4,000			1,452,000		145,600	1,601,600
GENERATOR CIRCUIT BREAKER	US	4,800			540,000		54,480	599,280
GENERATOR TO TRANSFORMER NON-SEG. BUS	US	2,000			599,000		60,100	661,100
MOTOR CONTROL CENTERS	US	10,000			275,000		28,500	313,500
BATTERIES & CHARGERS	US	4,800			71,500		7,630	83,930
PROTECTIVE RELAYS	US	3,000			165,000		16,800	184,800
UPS SYSTEM	US	1,200			44,000		4,520	49,720
MAIN & AUXILIARY PANELS	US	2,400			375,000		37,740	415,140
TOTAL ELECTRICAL WORK		**91,400**	**0**	**0**	**6,644,408**	**0**	**673,581**	**7,409,389**
MISC ELECTRICAL								
DUCT BANK	B & R	24,000		251,000			41,250	316,250
EQUIPMENT INSTALLATION	B & R	64,000		0			9,600	73,600
POWER/CONTROL/INSTRUMENT WIRING	B & R	122,000		762,000			132,600	1,016,600
BUILDING LIGHTING/PANELS/RECEPT	B & R	40,000		356,000			59,400	455,400
CONDUIT & CABLE TRAY	B & R	128,000		678,900			121,035	927,935
GROUNDING SYSTEM	B & R	16,000		209,500			33,825	259,325
CATHODIC PROTECTION	B & R	7,200		22,500			4,455	34,155
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	14,400		95,600			16,500	126,500
TOTAL MISC ELECTRICAL		**415,600**	**0**	**2,375,500**	**0**	**0**	**418,665**	**3,209,765**
TOTAL DIRECT COSTS		**3,772,620**	**0**	**50,612,300**	**14,940,708**	**1,350,500**	**7,890,528**	**78,566,656**
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					2,845,000	341,400	3,186,400

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and TURBINE NO. 6
2- CFB BOILERS WITH 125 MW TURBINE

ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
		UKR	OTHER	UKR	OTHER			
SUPPORT LABOR & FIELD OFFICE COSTS	B & R					2,795,000	335,400	3,130,400
CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					500,000	60,000	560,000
FREIGHT	B & R							3,933,180
VENDOR REPS/TRAINING/MANUALS	B & R					625,000	75,000	700,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**6,765,000**	**811,800**	**11,509,980**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
[illegible] DESIGN SERVICES	B & R					9,000,000	450,000	9,450,000
CONSTRUCTION MANAGEMENT	B & R					3,928,333	196,417	4,124,749
[illegible], TESTING & TRAINING	B & R					1,500,000	225,000	1,725,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**14,428,333**	**871,417**	**15,299,749**
TOTAL ESTIMATED PROJECT COSTS								**105,376,386**

NOTE: THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

REHABILITATION OF LUGANSK GRES

ADDENDUM TO REPORT

April 1996

Contents

I. QUESTIONS ON REPORT AND RESPONSES

Document No.	Contents
1.	"Ukraine and World Bank Questions for Response and Addition to Report" (undated)
1R.	Response
2.	Extractions from "Comments on (preliminary) draft report", H. L. Falkenberry, 11/4/95
2R.	Response
3.	Comments from I. Dobozi, World Bank, 11/12/95
3R.	Response
4.	Comments from V. Vucetic, World Bank, 11/15/95
4R.	Response
5.	Comments from Ministry of Power Industry and Electrification of Ukraine (undated)
5R.	Response
6.	"Stack Parameters for Lugansk GRES Options, M. Blinn, 11/16/95
6R.	Response
7.	"Additional Question concerning Options 1 and 2, M. Blinn, 11/28/95
7R.	Response

UKRAINE AND WORLD BANK QUESTIONS FOR RESPONSE AND ADDITION TO REPORT

RESPONSE IS DUE IN UKRAINE ON NOVEMBER 20, 1995, FOR QUESTIONS MARKED WITH AN "*". ALL CLARIFICATIONS AND CHANGES ARE DUE PRIOR TO A MEETING IN KIEV ON DECEMBER 11-12, 1995. THE FORM IN WHICH THE REQUESTED MATERIAL IS PRESENTED, EITHER AS AN ADDENDUM TO THE ORIGINAL DRAFT OR BY INCORPORATION INTO A REVISED FINAL REPORT, IS TO BE DISCUSSED BY BRE AND PETC PERSONNEL.

Note: In most of the questions that follow, the desire is for learning the basis upon which a statement is made. The strongest substantiation for any statement in the draft report would probably be citation of experience with a relevant commercial boiler/turbine unit burning a similar coal. The ability to do this is limited. We expect more often BRE will have to cite boiler/turbine sets and fuels that are in some way similar to the boiler/turbines that are the subject of rehabilitation/repowering and the intended fuels. This is acceptable. The idea is to give an indication of the basis upon which a professional judgment was formed.

*1. Discuss where ammonia or urea is introduced to the system and slip of these substances. Provide documentation.

*2. What are the levels of unburned carbon that would be achieved with each option.

*3. Discuss use of support fuels and the expected levels required for each option. Provide supporting details where judgments are made. For example, cite specific examples where prior knowledge serves as a basis for use of the specific natural gas levels given.

*4. Identify Lugansk GRES emissions at current operating conditions. This is interpreted to signify the current uncontrolled emissions. Give references to material obtained from Lugansk and other engineers. (It is recognized that emissions will vary with sulfur content of feed coal, extent of support fuel use, load, and possibly other variables. There is not a single answer to the question. Present any data you have together with suitable caveats concerning forming generalizations based on the data.)

*5. Explain the basis for use of a baghouse instead of an ESP with the CFB units.

*6. The World Bank requested an explanation of why the Option 1 steaming rate increased by such a large amount in going from uncleaned to cleaned coal (400 tph vs 640tph).

7. Modify water treatment system and costs to include 70% organics removal. (The Ukrainians claimed to have experience that showed reverse osmosis was not effective in controlling organics at the level they are encountered in Lugansk.)

8. The World Bank has suggested new maximum atmospheric emission limits for TP-100 boilers that are rehabilitated in this project. Their acceptability will probably depend upon the effect upon ambient air quality, as determined by local environmental officials, making use of Ukrainian plume dispersion models. Mr. Yatskevich of Minenergo accepted this approach in principle, breaking a deadlock on the proper approach to environmental protection. The World Bank's Bill Lane will be traveling to Ukraine in two weeks to conduct necessary evaluations. The World Bank recommendations for emission limits for rehabilitated boilers are:

- SOx: 1200 mg/nM^3
- NOx: 800 mg/nM^3

Particulate emissions limits are unchanged.

Please identify appropriate emissions control technology, specify equipment and estimate its cost to reflect the above limits for use in the upgrade options for TP-100 boiler sets.

QUESTIONS FOR RESPONSE BUT NOT NECESSARILY TO BE INCLUDED IN THE REPORT:

9. Provide details regarding the European standard of 1300 mg/nM^3 for NOx.

10. The World Bank inquired about why Refaco's CFB unit was not considered in the BRC work. The response could be based upon the SOW as identified by DOE/PETC.

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1. RESPONSE TO "UKRAINE AND WORLD BANK QUESTIONS FOR RESPONSE AND ADDITION TO REPORT"

1. Ammonia and urea - introduction to system and slip

With the Selective Non-Catalytic Reduction (SNCR) process for controlling NOx emissions, ammonia or urea is injected into the combustion gases at locations where temperatures are between 1600-2100°F (870-1150°C). Other chemicals can be added to expand this temperature window.

The emission of ammonia which results from incomplete reaction of the NOx reducing agent is known as ammonia slip. Excessive amounts can cause plugging of the air heater, contamination of fly ash, and odor in the vicinity of the plant. Ammonia slip is controlled by proper design of the injection system to provide appropriate reagent distribution into regions of the furnace where conditions (temperature and residence time) for the SNCR reaction exist.

Attached are the following documents providing more details on the SNCR process and ammonia slip:

2. Predicted levels of unburned carbon

The quantity of unburned carbon in the existing furnace configuration is greatly influenced by the amount of supplementary support fuel firing. This effect is less strong for the double-arch, down-fired furnace configuration. The amount of mineral matter and volatiles also affect the quantity of unburned carbon.

The predicted levels of unburned carbon are included in the following table, along with the assumed amounts of mineral matter and volatiles:

Option	**Coal**	**Unburned Carbon, %**	**Mineral Matter, %**	**Volatile Matter, %**
1a	Uncleaned	15	36	4.5
1b	Cleaned	15	18	4.5
2a	Uncleaned	20	36	4.5
2b	Cleaned	20	18	4.5
3a	Uncleaned	6	36	4.5
3b	Cleaned	6	18	4.5
4a	Uncleaned	12	36	4.5
4b	Cleaned	12	18	4.5

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3. Background to predicted supplementary fuel quantities

Current operation: 35 percent of full load heat input must be supplied by supplementary fuel (natural gas) while burning the present (38% ash) coal, resulting in 29-30 percent carbon in ash.

Option 1a - Minimal Refurbishment, Coal Presently Fired

Prediction: 30 percent heat input from supplementary fuel.

Basis of prediction: Visual observations of boiler operation, analysis of boiler design and fuel, and extensive discussions with plant personnel.

It is concluded that patching the furnace/boiler setting will not radically address the air ingress problem. This repair should improve the situation slightly; however, the high mineral content of the fuel, together with the diluted furnace gas temperature, will continue to cause both ignition and combustion problems. A conservative estimate of the resulting supplementary fuel requirement is 30 percent to achieve carbon in ash less than 30 percent by weight.

Option 1 B - Minimal Refurbishment, Cleaned Coal

Prediction: 15 percent heat input from supplementary fuel

Basis of prediction: Station records indicate that during the 1963-1970 operating period, no supplementary fuel was required while firing an anthracite shtib with an average LHV of approximately 5500 kcal/kg. Information received concerning operation of the Varna (Bulgaria) power plant supports this evidence.

As this minimal refurbishment will not restore the furnace/boiler to its as-new condition and considering the above expected mineral content of the cleaned shtib, a conservative estimate of the supplementary fuel requirements is 15 percent, in order to reduce carbon in ash to a figure nearer the design 16 percent by weight.

Option 2a & 2b - Minimal Refurbishment, Both Coals

Prediction: Same supplementary fuel as in Options 1a & 1b.

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Basis of Prediction: The retrofit of new low NOx burners together with bulk furnace air staging, i.e. overfire air use, will increase the furnace zone adiabatic fluegas temperatures, due to the near-stoichiometric combustion conditions in the burner zone. This would, theoretically, help to stabilize combustion, but could result in some furnace tubewall slag accumulation. Therefore, there is no basis to alter the conservative estimates of Options 1a and 1b if the carbon in flyash percentages are to be kept below the present 30% by weight and approach the design 16%.

Option 3a & 3b - Arch Firing, Both Coals

Burns and Roe believes that this option is the correct engineering solution for the efficient/safe combustion of low reactivity anthracite:

Double arch/down-fired furnace
Monowall type furnace tubewall construction
Strategically placed refractory on fireside lower furnace tubes
Carefully metered, gradual injection of combustion air
Increased concentration of PC in PA/PC mixture

<u>Coal Presently Fired</u>

Prediction: 5 percent heat input from supplementary fuel

Basis of prediction: Recent discussions with Foster Wheeler technical executives. (Foster Wheeler indicated a willingness to guarantee 5 percent, with carbon in ash not more than 16 percent by weight.)

Burns and Roe past design experience with low reactivity Korean and Spanish anthracite.

<u>Cleaned Coal</u>

Prediction: No supplementary fuel required

Basis of prediction: Foster Wheeler's expectation that even with the presently fired shtib, no supplementary fuel would be required (although its guarantee would be 5 percent). Therefore, an estimate of zero supplementary fuel for the cleaned shtib is reasonable.

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Option 4 - Extensive Refurbishment, Both Coals

Predictions: 15 percent supplementary fuel with present shtib
5 percent supplementary fuel with cleaned shtib

Bases of predictions: Refurbishments will provide marked improvement, but basic problems of original design remain: unsuitable furnace configuration, too short flame path, too short particle residence time.

Above predictions are required to limit carbon in flyash to not more than 16 percent. They are conservative and could be reduced if fireside refractory coverage is effective and if a high density PA/PC mixture could be developed.

4. Background to identification of emissions at current operating conditions.

Information provided to Burns and Roe

- Nominal characteristics of uncleaned shtib were provided to Burns and Roe by DOE. Fuel characteristics included moisture (8 wt%), fixed carbon (50-53 wt%), ash (36 wt%), sulfur (2.9 wt%), volatiles (3-6 wt%), and heating value (4400 kcal/kg).
- Steam production rate and quality were provided by Lugansk engineers and were used to estimate heat input to boiler (kcal/hr). Estimated value was 370 million kcal/hr.
- Present mix of fuels fired (coal/gas) was provided by Lugansk engineers.
- Estimated excess combustion air was provided by Lugansk engineers (60% due to inleakage). Combustion calculations were performed by Burns and Roe to estimate the volume of flue gas produced (m^3/hr). Estimated flue gas volume was 632,070 N m^3/hr.
- NOx emission estimates were provided by Lugansk engineers. Estimated value for current operation was 1,600 mg/N m^3.

Development of estimates of SO_2 and particulate emissions

- SO_2 emissions (kg/hr) were calculated from coal firing rate and fuel sulfur content. Assumption was made that all sulfur in fuel is converted to SO_2. Calculated emissions are 3,410 kg/hr SO_2 (6,660 mg/N m^3 @ 40% excess air).

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- Particulate emissions (kg/hr) were calculated from coal firing rate and fuel ash content. Assumption was made that 80% of ash in fuel is converted to fly ash and that the fly ash contains 15% unburned carbon. Estimates of present emissions were made based on the following equipment dust collection efficiency information provided by Lugansk engineers:

  i) Unit 10 - Design flue gas pressure drop for the scrubber is about 125 mm water and design efficiency has been stated to have been only about 95% which would result in an estimated particulate emission of 1,500 to 2,000 mg/Nm^3

  ii) Unit 13 - The expected ESP particulate collection efficiency for this design is about 96%-97% when firing the uncleaned coal at the reduced boiler steam production rate. Estimated particule emissions are 1300 mg/Nm^3 (at 40% excess air).

5. Use of fabric filter instead of ESP for each CFB boiler

The manufacturers solicited for CFB boiler information have almost exclusively used fabric filter technology for particulate collection. Furthermore, considerable experience has been gathered by these manufacturers with fabric filters used for the combustion of waste fuels in Pennsylvania which are similar to those anticipated for Lugansk. Although European experience has been with ESP's, many European users are considering switching to fabric filter technology due to its inherent advantages listed below:

- Fuel Flexibility - Changes in fuel quality have little impact on fabric filter performance.
- Higher Collection Efficiency - Fabric filters typically can filter out greater percentages of particulate matter
- Fines Collection - Fabric filters exhibit greater capability in collecting particulates less than 10 microns in size.
- Flexibility in Design - In the event other gas cleaning technologies are employed, fabric filters are more readily adaptable to these changes.
- Pollution Reduction - In the event the collected particulate is alkaline by nature, further pollution reduction (i.e., SO_2) can be realized when using fabric filter technology.

6. Increase in Option 1 steaming rate: uncleaned to cleaned fuel

Lugansk GRES personnel produced documents showing that during the operating period from 1963 to 1970, when firing an anthracite shtib with an average LHV of 5500 kcal/kg (mineral matter content of approx 20% by wt.), each new boiler was

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able to generate the full design steaming rate of 640 t/h. Burns and Roe expects that each of the refurbished boilers, firing the cleaned coal, will be able to produce this design steaming rate, as had been requested by the Lugansk GRES personnel. Please note, however, that only 564 t/h is required to generate the 200 MW rated output and Burns and Roe is very confident that this will be achieved.

Regarding the basis for the prediction of 400 t/h maximum steaming rate with uncleaned coal: Burns and Roe believes that the present derated steam output of approximately 400 t/h will not be improved with the minimal modifications of Option 1, considering the additional 15 year expected service life. Air ingress remains the chief problem and will not be radically corrected by patching the furnace/boiler setting, as stated in Item 3 of this letter, under Option 1a. There is a limit to the volume of flue gas which can be passed through the backpass sections of the boiler and the draft system. As this volume will be a combination of air in-leakage and combustion gases, boiler load will tend to be restricted. Also, the incentive to achieve a high load by passing the maximum volume must be tempered, considering the erosive effect of high velocities of ash-laden flue gas. Metal loss is very sensitive to velocity.

7. Modify water treatment system and costs to include 70% organics removal

We had been informed by the Ukrainians (through answer No. 21 in our questionnaire) that circulating water oxidizability is 5.32 mg/kg. This indicates that a low level of organics is present in the Donets River. Many U.S. electric generating stations supplied by rivers with much higher levels of organics make use of the same makeup water treatment system as proposed for the Lugansk GRES.

Even if a significant amount of organics were present, the existing pretreatment system at the Lugansk GRES (lime softening and coagulation in clarifiers, followed by mechanical filters) has been found to be a very effective method for reducing organics. A reverse osmosis membrane will reject all remaining organics which are present as suspended solids. It will also reject almost all dissolved organics with a molecular weight at 500 or higher and a significant percentage of dissolved organics with molecular weights between 100 and 500. The remaining low molecular weight organics which are introduced into the steam generators are not expected to have any significant effect.

In summary, we believe that the proposed water treatment system, coupled with the existing pretreatment system, will be adequate for treating Donets River water, even at times when it contains a significant amount of organics.

Comments on draft report

US/UKRAINE JOINT POWER PLANT UPGRADE PROJECT
REHABILITATION OF LUGANSK GRES

Submitted by
Burns and Roe Enterprises, Inc.
to
U.S. Department of Energy
Pittsburgh Energy Technology Center
October 1995

Comments submitted by
Harold L. Falkenberry, P.E.
4 November 1995

1. Report represents a generally thorough review of possible approaches. One omission: no lower cost, lower efficiency SO_2 alternatives discussed.

2. When completed, report should provide a valuable source of information for Lugansk rehabilitation, and should provide the Bank with much background information, including cost estimates, that may be used on a $/kW basis for Krivoi Rog rehab planning.

3. The Burns and Roe Enterprises (BREI) report provides four basic equipment rehab options with information on impact of coal quality on performance of each option. The options, as presented, are not directly comparable -- this is not a criticism in any way of either BREI or the report -- it is only to point out that the minimum rehabilitation option holds least financial risk of "stranded investment" if, in the future, a meaningful role for the rehabilitated plants does not materialize; conversely, the extensive refurbishment with emission controls option maximizes the financial risk of "stranded investment". The stranded investment risk would appear to be less for Krivoi Rog than for Lugansk, and it may be a very low probability risk for either since the many remaining unrehabilitated plants would become "stranded investments" first.

4. In the comparison of the options immediately following, I have tried to use rounded numbers to convey that these are approximations -- Any attempt at razor sharp comparisons at this stage could result in mis-information. Also, I believe the cost estimates in the BREI draft report do not include the complete costs of environmental protection equipment. I did not include the added costs of about $14 million that I believe will finally be reported. I did guess at the cost of a coal cleaning plant since the contractor's estimate is not yet available. What immediately follows is my characterization of the choices:

Option 1A (without coal cleaning): For about $48 to $52 million, depending on the specific unit, Donbasenergo gets about 130 MW (net) of dependable capacity good for about 15 years without any further major expenditures. Unit cost is $360 to $409/kW (net). Supplemental fuel consumption is estimated at 30%. If the supplemental fuel is natural gas, SO_2 emissions could be reduced. This capacity is equipped with high efficiency electrofilters, but does not include any

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equipment for reduction of NOx or SO_2 emissions. Selection of a lower sulfur coal, if available, could reduce SO_2 emissions. Whether this level of environmental protection will be found

acceptable by all parties is not known. Upon expiration of the new 15 year (approx) "new lease on life" Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant and probably for added environmental protection, for further significantly extending the plant lifetime.

Option 1B (with coal cleaning): For perhaps a little as $1 million more, and probably no more than $5 million per unit more, for a total of $49 to $57 million, (depending on which unit) Donbasenergo gets about 185 MW (net) of dependable capacity good for about 15 years without any further major expenditures. Unit cost is $260 to $300/kW (net). Maintenance of coal handling, gas path and ash handling equipment will be lower, coal transportation and ash disposal costs will be reduced and availability will be higher. Supplemental fuel consumption ~~fuel consumption~~ would be reduced to 15 %. This capacity is equipped with high efficiency electrofilters, but does not include any equipment for reduction of NOx or SO_2 emissions. Selection of a lower sulfur coal, if available, could reduce SO2 emissions. Whether this level of environmental protection will be found acceptable by all parties is not known. Upon expiration of the new 15 year (approx) "lease on life" Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant and probably for added environmental protection, for further significantly extending the plant lifetime.

Option 2A: (without coal cleaning) For approx $60 to $65 million, depending on the specific unit), Donbasenergo gets about 130 MW (net) of dependable generation with adequate equipment for protection of the environment for 15 years without any further major expenditures. Unit cost approximates $450 to $500/kW (net). Upon expiration of the 15 year (approx) life extension, Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant, for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Option 2B: (with coal cleaning) For perhaps as little as $1 million, and probably no more than $5 million more for a coal cleaning plant, or approx $64 to $73 million total, depending on the specific unit), Donbasenergo gets about 185 MW (net) of dependable generation with adequate equipment for protection of the environment for 15 years without any further major expenditures. Unit costs approximate $346 to $395/kW (net). Maintenance of coal handling, gas path and ash handling equipment will be lower, coal transportation and ash disposal costs will be reduced and availability will be higher. Supplemental fuel consumption fuel consumption would be reduced to 15 %. Upon expiration of the 15 year (approx) life extension, Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant, for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Option 3A: without coal cleaning) For approximately $76 to $83 million, Donbasenergo gets about 180 MW (net) of dependable generation with adequate equipment for protection of the environment for 15 years without any further major expenditures. Unit costs approximate $420 to $450/kW (net). Supplemental fuel consumption is reduced to about 5 %. Upon expiration of the 15 year (approx) life extension, Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant, for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Option 3B: (with coal cleaning) For approximately as little as $1 million, and probably no more than $5 million for a coal cleaning plant, or a total of $77 to $88 million, (depending on the specific unit), Donbasenergo gets about 185 MW (net) of dependable generation with adequate equipment for protection of the environment for 15 years without any further major expenditures. Unit costs will approximate $416 to $476/kW (net). Maintenance of coal handling, gas path and ash handling equipment will be lower, coal transportation and ash disposal costs will be reduced and availability will be higher. Supplemental fuel consumption, except for hot standby and startup, is projected to be near zero. Upon expiration of the 15 year (approx) life extension, Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant, for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Option 4A: without coal cleaning) For approximately $88 million, Donbasenergo gets about 180 MW (net) of dependable generation with adequate equipment for protection of the environment for 15 years without any further major expenditures. Supplemental fuel consumption will be reduced to about 15 %. Unit costs approximate $424/kW (net). Upon expiration of the 15 year (approx) life extension, Donbasenergo would have the options to either retire the plant or to expend additional funds, principally for the turbine generator plant, for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Option 4B: (with coal cleaning) For approximately as little as $1million, and probably no more than $5 million for a total of about 89 to $93 million, (depending on the specific unit), Donbasenergo gets about 180 MW (net) of dependable generation with adequate equipment for protection of the environment for at least 30 years without any further major expenditures. Unit costs approximate $430 to $450/kW (net). Maintenance of coal handling, gas path and ash handling equipment will be lower, coal transportation and ash disposal costs will be reduced and availability will be higher. Supplemental fuel consumption fuel consumption would be reduced to 5 %. Upon expiration of the approximate 30-year life extension, Donbasenergo would have the options to either retire the plant or to expend significant funds for a further significant extension of plant life. Probably no further major expenditures would be required for environmental protection.

Please note: It appears that the costs for environmental protection in the BREI report may not be complete. Under Costs (below) I comment that the costs for SO_2 removal equipment do not appear to be complete. I would likely defer to the final BREI numbers; until they complete their estimates, I suggest assuming about $20 million for the high removal efficiency SO_2 capture equipment, and about $5 million for the electrofilter at Lugansk. We don't have costs on coal cleaning equipment, and, until estimates from the contractor

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become available, I used numbers of $1 million for rehabilitating an existing coal cleaning plant to supply a single 200 MW Lugansk unit, and a maximum of $5 million for a new coal cleaning plant for the same service.

Time is running out, and I will not recalculate my estimated costs for the four rehabilitation options, but I would have used $5 million for the electrofilter and $20 million for SO_2 removal. It may be that the N0x control measures in the BREI may also be incomplete. BREI used $3 million for the electrofilter, $8 million for SO_2 removal and about $1 million for the hybrid flue gas N0x reduction system. I assume they will delete any cost items for low N0x burners except for the arch furnace case. So, pending some response from BREI, possibly correcting my assumptions, I suggest that all the options may need to be increased about $2 million for the electrofilter; and that all the options incorporating SO_2 removal may need to be increased by $12 million. Whether or not there is a need for increasing the cost of the hybrid flue gas N0x reduction system is a less important issue since, even if it is needed, it will be a considerably smaller number.

Following are comments based on a relatively brief review of the subject draft report.

None of the four cases evaluated by Burns and Roe Enterprises, Inc. (BREI) quite match the approach to rehabilitation being adopted by the World Bank, but this draft report provides much needed technical and cost information and data. The four rehabilitation options approaches described generally cover the range of options the Bank is likely to consider. Indeed, from the details provided on the four options, each of which is subdivided into separate cleaned and non-cleaned coal alternatives, it should be possible ~~to~~ for the interested participants to construct our own collage of the particular rehabilitation option that best meets the sometimes conflicting generation, environmental, economic and financial goals. The one area where we have limited choices is in lower cost and lower performance SO_2 removal systems, but that information can be readily estimated.

The major problem areas are boiler rehabilitation, environmental protection, and costs, and my comments are directed to these topics.

General

1. Options 1 and 2, as defined by BREI, involve minimal rehabilitation, e.g., sufficient to extend service life to about 15 years (without further rehabilitation/life extension work) and increase power generation above its present derated level, to improve efficiency and to control particulate emissions to prescribed limits. The parenthetical phrase immediately above is mine; I added it as a reminder that the lifetime of the units proposed for rehabilitation is not necessarily limited to only 15 years from completion of the specifically recommended rehabilitation. For Option 1 without coal cleaning, BREI does not propose to restore full rated capacity. In all other cases, the BREI options restore full rated boiler steaming capacity. The Bank has so far favored restoration of full rated capacity even with current coal quality.

2. Option 2 further includes equipment to control SO_2 and N0x emissions within quite strict limits and involves higher investment and higher operating cost because of the added emission controls..

3. Option 4 involves extensive rehabilitation of the entire power station, including replacement of the turbine generator set and main condensers with a 12.5 percent increase in generating capacity (25 MW) and with a life extension of a minimum of 30 years with the bulk of the capital expenditures "up front". (I didn't find this stated, but with this level of expenditures, clearly an added lifetime of this magnitude would be expected).

4. Option 3, conversion to a dry-bottom arch fired furnace with accompanying N0x-reducing burners and conversion to membrane furnace water walls, but without most of the major balance of plant improvements that are included in Option 4, has so far appeared to the Bank as more costly than would be preferred. Implicit in adopting this option would be the expectation of an operating lifetime considerably in excess of 15 years, but it permits deferring many major capital expenditures other than the boiler for a decade or longer.

5. The World Bank's approach thus far to rehabilitation of the anthracite fired power stations in Ukraine could be likened to Option 1.5 Plus; e.g., minimal rehabilitation with a high efficiency electrofilter and with reduction of SO_2 and possibly N0x emissions, but possibly not to the extent of the BREI Option 2 emission controls. Pending consultation with Krivoi Rog and Lugansk management The Bank may wish to include a component from Option 4; e.g., replacing the boilers non-welded furnace water walls with so-called membrane water walls. Membrane furnace water walls consist of closely spaced parallel water tubes with a narrow steel strip welded between all parallel tubes to form a gas-tight water cooled furnace inner casing. Heat absorbed by water walls of either type is beneficially utilized in generating steam.

6.. **Rehabilitation/life extension is a generally continuing process, not a single event; It is physically possible to undertake a single massive rehabilitation project designed for a lifetime of decades such as BREI Option 4. In the absence of a compelling need for performing all the work at one time, it may be found to be more financially prudent to plan the work to coincide with the physical need for major rehabilitation or replacement of a component. An obvious exception to this staged approach could be a situation in which the improved economics and probable increased generation is found to be the least cost system alternative, economics justify the action. For this to be true, an expected project lifetime of multiple decades is likely implicit.**

7. **For the Ukraine anthracite fueled power stations, at some time in the future there may not be the needed assurance of a multi-decade reliable and economic coal supply; in which case it could be prudent for the Bank and the generating companies to give some consideration to avoiding the fuel supply analog of "stranded investment". In view of the magnitude of the overall power sector restructuring and rehabilitation effort needed, the possibility of effective generation competition from outside Ukraine's borders that may accompany Ukraine's probable membership in an effective interconnected system, and further in view of future uncertainties such as the fuel supply question, the prudent**

investment minimizing approach the Bank, Minenergo, the hydro and thermal generating companies and the individual power stations have taken so far appears justified.

8. It is in the interest of all to look forward to the earliest possible restructuring and rationalizing of the coal industry so that, hopefully, there will soon be a more solid basis for strategic decisions which are dependent for their success on accurate long term resource and economic projections.

9. Rehabilitation/life extension efforts obviously rest on much stronger support where the available evidence suggests that the infrastructure and supply of economically available resources can support station operation over at least two or three decades and that a long term need for power from the plant exists.

10. The Bank's approach has been to include measures to improve protection of the environment, but not to incur costs for environmental protection at a level that would adversely affect the overall feasibility. Certainly in the U.S., and probably other Western countries, regulations acknowledge the economic problems of requiring large investments for emission controls on older plants in good operating condition, but a life extension undertaking can trigger a new source standards requirement; this has significantly curtailed U.S. power station life extension project initiatives.

11. The subject draft report includes a recommendation to install low N0x burners for the minimal rehabilitation case. For anthracite, I know of no such burners **with proven capabilities for significant N0x reduction except when used in an arch furnace, with or without cleaned** coal. I suggest the Bank avoid claiming N0x reduction for any wall burners without examining the technical basis and proven commercial experience supporting such a claim. As I understand the situation from US DOE, later drafts of subject report will not suggest that low N0x burners, with or without cleaned coal, can reduce N0x emission except for firing in the arch furnace configuration.

II. Costs

1. A quick comparison of the costs and work proposed for both Krivoi Rog and the 200 MW Starobeshevo units by KEMA/Comprimo, and by BREI for the 200 MW Lugansk units suggests that the estimated costs of boiler rehabilitation, when adjusted for MW capacity differences, are remarkably similar.

2. I didn't include the electrofilter in the boiler rehab cost comparison since it was in a separate category in the BREI report.

3. For SO_2 emission control equipment, the draft BREI report appears to report only the costs of certain equipment items that would have to be imported. The cost in US and probably western Europe for either the wet lime or limestone scrubber or the semi-dry scrubber would approximate $200/kw. The Bank and its contractors have generally estimated the cost of a component and its installation if manufactured in Ukraine would be about half the cost of a similar project in the

West. Even with all-local procurement, this would place the total cost of an approximately 90 % efficient SO_2 scrubber at about $100/kW, or about $20 million for a 200 MW Lugnask unit.

4. The same "50 % cost factor" would place the cost of a new high efficiency electrofilter at a 200 MW Lugansk unit at more like $5 million. The new electrofilter we walked by at Krivoi Rog was a 6-field electrofilter, designed, I believe, for 99% + dust removal efficiency. It would be helpful if we could obtain Krivoi Rog management's estimate of the cost of the completed installation. There is a fax machine at Krivoi Rog, but I failed to get the number.

5. As you know, until the BREI study draft became available, we had not heard anything about the design of the Lugansk, (and by inference only), the possibility that the same design is incorporated in the Krivoi Rog boiler furnace water walls. Based on the BREI report, if a compelling need for membrane water wall upgrading at Krivoi Rog should be demonstrated, the cost, ratioed to reflect the larger capacity Krivoi Rog boilers, could approximate $13 million based on capacity. There are other factors that would have to be taken into account such as ease of access and the fact that at Krivoi Rog there are the two 150 MW boilers per unit. This is an item that the next mission should discuss with Krivoi Rog and Lugansk staff, and perhaps with others. If membrane furnace water walls should be found desirable and worth the investment, this could add about $13 million to the currently estimated 22.7 million (excluding new electrofilter), for a total for boiler rehab of about $36 million for Krivoi Rog.

6. Attached is a form for a summary table of the options presented by BREI. It is incomplete, but, I think it could, in a single page, save a lot of searching and page turning for reviewers of the report.

END

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2. RESPONSE TO "COMMENTS ON DRAFT REPORT", H. L. FALKENBERRY, 11/4/95

1. "No lower cost, lower efficiency SO_2 alternatives discussed".
Response: Two lower cost alternatives were discussed: furnace sorbent injection and duct sorbent injection. They were not pursued due to their low removal efficiencies.

2. "Costs for environmental equipment (ESP and FGD) are not complete"
Response: The costs in the Draft Final Report, dated October, 1995 are complete. The equipment costs represent U.S. supply. We suspect that Mr. Falkenberry's estimate for the SO_2 removal equipment may be based on a full wet limestone FGD system instead of the spray dryer absorber system (semi-dry FGD) selected in the report.

3. "...the hybrid flue gas NOx reduction system"
Response: A selective non catalytic reduction system is used, together with low NOx burners for NOx reduction. The hybrid system is discussed in the report but is not used.

4. Capabilities of low NOx burners
Response: Several boiler/burner manufacturers offer double register low NOx burners for pulverized bituminous coal, for horizontal, opposed wall firing furnaces. These burners, when used in conjunction with bulk furnace air staging (overfire air) can reduce NOx emissions by 55 to 60 percent. Admittedly, their use with low volatile, high mineral matter content anthracite coal is not a well-established technology.

   Deutsche Babcock has developed and is in the process of testing its low NOx Type DS (swirl state) burner firing low volatile anthracite coal. Foster Wheeler reports that it intends to initiate a similar testing program shortly.

   We included low NOx burners together with SNCR for control of NOx emissions in our report, as we believe that suitable burners will have been developed by the time required for this project.

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Date: November 12, 1995
To: Howard Feibus, US Department of Energy
Fax: (301) 903-0243
From: Istvan Dobozi, World Bank
Re: Lugansk: Feasibility Study

Dear Howard,

Attached are my comments on the above. I have left out on purpose those issues where I expect my Bank colleagues to provide the feedback. I would have liked to pull together our comments in one note, but this was not feasible (I will be out of town from Nov. 13 to 17; back in office 11/20). I have asked them to send their comments directly to you by 11/15.

Sincerely,

Istvan

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Burns & Roe Study

1. Basis for the selection of units 10 and 13 should be provided. Why aren't both units from the most recent vintage (Phase 3)?

2. Life extension under alternative options: stating that "at least 15 years" is not adequate. This might be the reason why Parsons adopted a 15-year uniform service life across all options. If options 1-2 can achieve a 15-yr life extension, then options 3-4 should do better. Option 3-4 are loaded with new equipment: why not assume a 25-30 yr life extension? (This was suggested to me independently by Harold Falkenberry and another engineer guru in the Bank: the service life has a significant bearing on the economic/financial analysis.)

3. Emission limits: basis for the "prescribed limits" should be discussed. Who "prescribed" them? The difficulty of ascertaining applicable environmental requirements should be addressed. Design/cost consequences of the Bank's proposed middle-ground approach (see Bill Lane's comments, especially the suggested initial "working numbers"; NOx: 800; SO2: 1,200) should be identified.

4. Co-firing ratio: As I said at the Bank meeting, the Bank wouldn't accept this to be other than a second-order design criterion (a pre-ordained number, say 5%, would be seen as an extreme form of command and control; the utility should be able to choose the cost-minimizing fuel mix in response to changing relative fuel availability/prices).

5. FBC boiler:

(i) B&R should include a comparative analysis with a modern conventional boiler/turbine generator unit of the same output rating, with the external environmental benefits (or damage avoided) factored into the analysis. Otherwise, as Maistrenko suggested, we are comparing apples and oranges.

(ii) It would be desirable to obtain a quote from the Polish firm "Rafako," which is aggressively peddling its FBC boiler in Ukraine (allegedly, Rafako is offering the most competitive price among major vendors).

(iii) It looks that it will be difficult to justify FBC as part of a least-cost upgrade package. As I told you, given the high priority GOU ascribes to the FBC technology, we may justify it as a demonstration project in the interest of technology transfer. But in this case, one 62.5 MW unit would be adequate; and since it would be a boiler demo, no new turbine generator would be necessary--one of the existing 100 MW unit could be refurbished. B&R could examine the feasibility of this option. Total cost would presumably be in the range of $30-35m.

6. Cost estimates: The 20% import duty should be dropped from the cost estimates. All equipment under the Bank-financed project will be exempt from taxes.

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Parsons Analysis

1. General remark: The analytical framework and the parameters need to beefed up considerably before the report can be used for the screening of options. All assumptions (incl. conversion factors) used in the analysis should be reported in a special table(s), similar to the KEMA/Comprimo study (we called Parsons's attention to this early on).

2. Need for life-cycle costing: Using a uniform 15-yr service-extension life for all options (incl. FBC) is technically inappropriate. Thirty years should be used for FBC, while 25-30 ys could be considered for options 3 and 4 (esp. for the clean coal alternatives).

3. For the economic analysis, they should use "economic" prices. For coal this is the border price of Russian/Polish coal, not the "list prices," which suffer from serious distortions (cleaned coal is over-priced relative to uncleaned). Economic prices are significantly lower than the financial prices reported in the Parsons table ("Fuel Information"). I asked Heinz Hendriks (478-2887), our coal specialist on Ukraine, to provide you with the economic price of uncleaned and cleaned schtib. Waste coal (schlam): $7/t. For natural gas, the 1996 price is $80/tcm, $85 in 2000, and $110 in 2010. Fuel oil (mazut): 1996: $80/t, 2000: 85, 2010: 90.

4. Capital cost by year: the first year should be 1997 (not 1995--how can they assume expenditure for 1995?) and should be consistent with the suggested implementation schedule in the B&R report.

5. "Existing operating costs": it is not clear which units are covered by the reported figures (one or two?; aren't these plant-wide O&M numbers?--this should be clarified or amended, as appropriate). What is "Added Repl Fund"?

6. Why is levelized cost higher under option 4B (clean coal) than under option 4A, despite lower capital cost and higher efficiency of 4B? One would expect the opposite.

7. Capital costs should not contain import duties.

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3. RESPONSES TO COMMENTS ON BURNS AND ROE STUDY FROM I. DOBOZI, WORLD BANK, 11/12/95

1. Basis for selection of Units 10 and 13
   Response: Selection was made by others and given to BRC as part of scope.

2. Modifications to bases of life extension
   Response: Bases are being changed to indicate a 15 year life for refurbished/repaired items and 30 year life for replaced items

3. Revised SO_2 and NOx emission limits
   Response: Capital costs are unaffected by the new SO_2 and NOx emission limits. Operating data will be adjusted.

4. Co-Firing ratio
   No response required from Burns and Roe.

5. FBC boiler
   - (I) Comparative analysis with conventional design
     Response: Not within present scope
   - (II) Additional budget quote from Polish firm "Rafako"
     Response: Not required in present scope
   - (III) Develop a 62.5 MW option with single boiler
     Response: Not in present scope

6. Import duty in cost estimates
   Response: Import duty costs will be removed from estimates and cash flow data supplied to Parsons Power will be revised accordingly.

The World Bank
INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

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TELEFAX TRANSMITTAL SHEET
Infrastructure Division
(EC4IN)

DATE: Nov. 15, 1995

Number of pages (incl. this): 4

TO: Mr. Howard Feibus
ORGANIZATION: US DoE
FAX NUMBER: 301 903 0243

FROM: Vladislav Vucetic
TEL. NO: (202) 473 3977
FAX NUMBER: (202) 522-0078

SUBJECT: <u>Ukraine: Lugansk Feasibility Study</u>

MESSAGE

Dear Mr. Feibus:

It was pleasure meeting you last week and discussing the results of the study. Enclosed are my comments on the study, most of which were raised during the last week discussions, complementing comments from other memebers of the World Bank team.

Sincerely,

V. Vucetic

Vladislav Vucetic

1.0 Burns and Roe Study

1.1 Rehabilitation of Units 10 and 13

1. The increase in steam production from 400 t/h when using uncleaned coal (options 1b and 2b) to 564 t/h (40% increase; see tables 4.4-3, 4.4-4, pp. 4-79, 4-80), or even to 640 t/h (60% increase; p. 4-45), caused just by switching to the design ("clean") coal (options 1a and 2a), seems as a possible overestimation, particularly given the significant reduction in use of supplemental fuel when using clean coal (from 30% to 15%). It would need to be elaborated and better proven. This is very important, since the increase in steam production capacity allows for a significantly higher power rating of the units and also affects the specific heat rates, which are driving rehabilitation benefits indicators.

2. A major problem with the existing units is their poor load-following capabilities. The study, however, does not assess this capability in relation to the proposed rehabilitation options. It would be very useful to quantify load-following indicators for each of the options proposed.

3. The proposed use of low NOx burners in anthracite-fired boilers is not well-established technology and may not bring the expected benefits. It would be necessary to support the claimed performance by data from a reference plant or tests performed, if any.

4. On p. 4-57 it is claimed that, with low NOx burners, NOx emissions would be reduced from 1000 mg/Nm3 to 800 mg/Nm3 when switching from uncleaned to cleaned coal. This leaves the impression that coal cleaning may reduce NOx emission, which is not correct. To what factor is this reduction due? Reduction in supplemental fuel use?

5. Cost of a new 225-MW generator does not seem to be accounted for in options 4a and 4b (tables in the Appendices A and B); please explain.

6. Dispatch, control and monitoring at the plant level has not been addressed, except for a passing remark in Section 4.1.6. Is it necessary, e.g., to upgrade both equipment and procedures for scheduling plant production among the individual units?

7. It would be very much of interest to examine a case with arch-firing and a new 225-MW turbo-generator set, particularly for unit 13 (combining options 3 and 4).

8. To properly analyze benefits from any of the rehabilitation options, it is necessary to describe performance of the units, over time, in case no rehabilitation is done (expected life-time, availability, operating and maintenance costs, fuel consumption/heat rates, use of supplemental fuel, etc.). Recent data on plant and unit performance should be presented (heat rates, fuel mix - including reasons for the mix, total generation, station use, etc.); it would be useful to cover several years, including 1994 and 1995.

9. It may be that additional measures are needed for rehabilitation, which could not be properly assessed in the course of the feasibility study (e.g., metallurgical tests of high-pressure parts). An assessment of this uncertainty in the form of contingency allowances would be necessary.

10. An additional problem in determining the basis for calculating reductions in emission levels comes from the fact that a reduction in supplemental fuel use is foreseen, which would lead to an <u>increase</u> in emission level relative to the current situation in which use of natural gas is

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higher than in any of the after-reahab cases. Has this fact been properly accounted for in assessing the emission levels after rehabilitation?

11. It would be necessary to specify characteristics of each type of fuel assumed (uncleaned and cleaned coal/schtib, schlam), including sulphur content. Specifically, what is the reduction in sulphur assumed for cleaned coal/schtib?

12. Specification of all parameters (fuel characteristics, environmental performance, thermal efficiencies, supplemental fuel rates, maximum capacity, load following capability, etc.) should be given with sufficient detail to allow potential suppliers to give performance guarantees.

13. Some costs for the proposed environmental measures seem to be too low, particularly for the ESPs and FGD facilities. Are they based on Ukrainian, CIS or Western estimates? (E.g., KEMA's study estimated cost for ESP for a 200-MW boiler at US$10 million.)

14. There are potential problems with the proposed selective non-catalytic reduction, some of which are discussed in section 4.3.2.2 (pp. 4-57,4-58). However, the discussion does not lead to an explicitly stated judgment/opionion on applicability of this technology in the Ukrainian and Lugansk conditions.

15. Important parameters (like heat rates, supplemental fuel rates, etc.) should be given for partial loads also, not just for the full load.

16. Characteristics of the waste and its usability for other purposes (e.g., making construction materials) should be described. Waste disposal constraints, which seem to be severe for the Lugansk plant, need to be addressed.

1.2 AFBC Boiler

17. A possibility of building only one 62.5 MW boiler which would feed a smaller turbine (possibly an existing one, refurbished if needed) should be investigated and presented. It could make the AFBC option more attractive on the cost/benefit basis, and also reduce the technology risk involved.

18. Is it necessary to endorse a particular technology and a producer (p. 5-4)? The reasons listed on p. 5-4 do not seem too convincing for such an endorsement, particularly since the costs of the four producers considered appear quite close to each other (net of import duties). It would be better to keep the discussion and the analysis as much generic as possible, specifying performance requirements, and based on "average" costs.

19. Particularly important is specification of fuel for the AFBC option - its characteristics, availability and price; an elaboration of these issues would be needed to assess viability of this option. Comment 12 above applies for this option as well.

2.0 Parsons Power Study

20. Please do not use reference to the "AGEAS" (it should have been "EGEAS") software, since it is a trademark; rather, use generic name "least-cost model". Also, the page titled "Progress in Luganske Project" (the name should be Lugansk, as in the Burns and Roe Study) suggests more involvement by the World Bank then is warranted (e.g., point 6 on the same page implies that there would be a "World Bank report featuring the selected options"). The World Bank could assist by making one or two runs of the least-cost model with the selected options and providing the capacity factors for the Lugansk plant as output; there will be no formal report.

21. Please do not use prices for the "AFBC", "WASTE" and "Rehab" fuels from the World Bank least-cost model data base which we sent some time ago; those prices were only notional and served the purpose of sensitivity analysis for a generic AFBC option for a generic site. Prices for fuel for the AFBC boiler should be assumed on the basis of information from Ukraine on the availability and characteristics of such a fuel at the Lugansk location.

22. When screening options, it may be useful to separate analysis for units 10 and 13, since least cost option for one unit can be selected largely independently from another. The common plant component can be excluded from the analysis for the purpose of screening the options, and can be added at the end, after selecting best option for each unit, when it would be possible to perform economic analysis for the least-cost plan including both units and the common plant system. (Such analysis, at the end, would be of interest to give cost of electricity for the optimal selection across the capacity factor range.)

    It seems that options dominate each other across the entire range of capacity factors with very few exceptions, and the least-cost option dominates all others. Therefore, the screening curves seem to lead to the selection of the least-cost option without need for a system-wide analysis. The least-cost system analysis would then be needed only to provide capacity factors for the financial analysis.

23. Analysis of the benefits from using or selling the waste material would be useful for differentiating among options that produces waste with different characteristics and usability.

24. Rates of increase in real costs for O&M could be higher then proposed (2%), given relatively low starting O&M costs due to a less-than-needed maintenance program in recent years and low wages. Rates between 5% and 10% could be more reasonable for the next 10 years.

3.0 General

25. It would be very useful to involve experts from Minenergo and the Lugansk plant at the working level, and solicit their comments, opinions and counter-proposals (in case of possible disagreements in proposing engineering measures and estimating costs and benefits). This would allow for a sense of ownership of the study by the Ukrainians, give them chance to debate the issues before presenting reports, enhance understanding of foreign consultants of local problems and, ultimately, lead to better proposals and easier discussion in proceeding with the project.

4. RESPONSES TO COMMENTS ON BURNS AND ROE STUDY, V. VUCETIC, WORLD BANK, 11/15/95

1. Increase in steam production from uncleaned to cleaned coal
Response: Refer to Item 6 in Response to Document No. 1.

2. Load-following capabilities
Response: The existing boilers are very large for this steam rating compared with current Western designs, with high thermal inertia, and therefore they have very slow load-following characteristics. An assessment of their load-following capability, as existing and in each rehabilitation option, is beyond the scope of this study. Even if this assessment were made, there wouldn't be much that we could do to improve it without very major modifications.

3. Capability of low NOx burners
Response: Several boiler/burner manufacturers offer double register low NOx burners for pulverized bituminous coal, for horizontal, opposed wall firing furnaces. These burners, when used in conjunction with bulk furnace air staging (over fire air) can reduce NOx emissions by 55 to 60 percent. Admittedly, their use with low volatile, high mineral matter content anthracite coal is not a well-established technology.

    Deutsche Babcock has developed and is in the process of testing its low NOx Type DS (swirl stage) burner firing low volatile anthracite coal. Foster Wheeler reports that it intends to initiate a similar testing program shortly.

    We included low NOx burners together with SNCR for control of NOx emissions in our report, as we believe that suitable burners will have been developed by the time required for this project.

4. Reduction in NOx emissions: uncleaned to cleaned coal
Response: Estimated **uncontrolled** NOx emissions of the existing configuration, wet bottom furnaces with minimal modifications are 1600 mg/nm^3 with uncleaned shtib and 1300 mg/nm^3 with cleaned shtib. The reason for the lower emission estimate with cleaned shtib firing is improved furnace heat sink efficiency and thus lower combustion zone gas temperatures with lower mineral matter content shtib, less probability of furnace slagging. Less supplemental fuel firing with the cleaned shtib tends to increase NOx emissions because, although formation of thermal NOx is reduced, the addition coal firing increases fuel NOx.

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Estimates of **controlled** NOx emissions, using in-furnace combustion modifications (i.e., low NOx burners), from the existing configuration wet bottom furnace boilers with minimal modifications are 1000 mg/nm^3 and 800 mg/nm^3 for uncleaned and cleaned shtib firing, respectively. These estimates represent NOx emission reductions of approximately 38% in each case. We believe that low NOx burners should be able to provide these relatively modest NOx emission reductions.

We recognize that the 800 mg/nm^3 with cleaned shtib meets the new NOx limitation; however, in view of the controversy over the effectiveness of low NOx burners, we propose to keep the SNCR system in the cost estimate as backup to insure that the NOx limitation will not be exceeded.

5. Cost of new 225 MW generator
Response: This is included in the cost of the turbine

6. Dispatch, control and monitoring at the plant level
Response: New control equipment in the individual units will be suitable for receiving a dispatch signal from external sources. There is no system provided for the overall plant.

7. New option for arch-firing with new 225 MW turbine generator
Response:

	Unit 10		Unit 13	
	Uncleaned Coal	Cleaned Coal	Uncleaned Coal	Cleaned Coal
Capital Cost Estimate, $	96,024,104	95,280,246	96,048,197	95,210,770
Performance data				
Turbine gross output, MW	225	225	225	225
Turbine gross heat rate, kcal/kwh	1889	1889	1889	1889
Unit net output, MW	206.6	208.6	206.6	208.6
Unit net heat rate, kcal/kwh	2286	2263	2286	2263

Detailed breakdowns of the capital cost estimates are included in the attached estimate summary sheets. The increase in cost from Option 4 is due to a reconfiguration of the boiler furnace with a much more steeply sloped bottom section than that included with Option 3, to accommodate the additional steaming capacity. This necessitates a deep sub-level below the existing ground floor at the furnace. Also the air preheaters must be moved slightly and the connecting ductwork modified.

The furnace in Option 3 is also sloped, but to a lesser degree, which avoids excavation. We considered this slope suitable for the lower steam flow. However, the configuration would have been inadequate for the Option 5 steam flow.

8. Develop details of Base Case consisting of "no project"
Response: Details of 1994 costs were obtained from Lugansk GRES and given to Parsons Power for developing the Base Case.

9. Need for contingency allowances in cost estimates
Response: Contingencies have been included for all items in each cost estimate, ranging from 5 percent on construction management and engineering to 20 percent on civil/structural items. These contingencies cover possible variations in the actual cost of each item plus miscellaneous minor items not identified.

10. Effects of supplementary fuel on emission levels
Response: The increase in emission levels resulting from reduction in supplemental fuel use has been taken into account in determining emission reduction requirements.

11. Characteristics of cleaned and uncleaned coal
Response: The following characteristics were provided by PETC:

	Cleaned	Uncleaned
Moisture, %	8	8
Volatile matter, %	3-6	3-6
Fixed carbon, %	68-71	50-53
Ash, %	18	36
Calorific value (LHV), kcal/kg	5720	4400
Sulfur, %	2.6	2.9

12. Specification of all parameters to allow potential suppliers to give performance guarantees
Response: These details should be prepared as part of the tender documents.

13. Cost of proposed ESP's and FGD's
Response: Cost estimates are US supply and Ukrainian installation. The supply costs are based on in-house information including proposals for similar equipment.

14. Potential problems with the proposed selective non-catalytic reduction system
Response: Refer to Item 1 in Response to Document No. 1.

15. Important parameters should be given for partial loads
Response: Heat rate and generation data at partial loads have been provided to Parsons Power for evaluation.

16. Characteristics of the waste and its usability for other purposes
Response: The problem of lack of disposal area for ash was not reported to us until the November 8, 1995 meeting at PETC. All options in our report are based on utilizing the existing wet ash disposal system which conveys the ash to the existing ponds. In this condition it can be used only as a fill material.

17. Investigate the possibility of building one 62.5 MWe unit with CFB boiler
Response: Not in present scope

18. Necessary to endorse particular CFB technology and producer?
Response: Scope required budget cost estimates from two or more US manufacturers and at least one Ukrainian manufacturer. Selection of one technology was required to develop layouts in order to determine installation costs.

19. Elaboration of CFB fuel details (Characteristics, availability, price)
Response: Characteristics of CFB fuel we provided by PETC (the uncleaned fuel listed in Item 11). Investigation of other aspects - not in scope.

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PETC

Dear Messrs. Feibus, Dobozi, Ruether:

On the basis of our meetings held within the period of November 8...9, 1995 in the PETC and the World Bank, we send you a list of questions and remarks which we would like to ask you to take into account during preparation of technical and economic study recommended to the Luganskaya GRES. As preliminary agreed, this study is necessary to consider once again during the meetings planned in Kiev in the middle of December (1995).

1. Upon the reconstruction in accordance with 1B-case, unit capacity, in our opinion, should be accepted as 160 MWe rather than 200 MWe; as to 2B-case - 180 MWe.

2. In accordance with the data of the World Bank, we suggest to assume the increasing in price of natural gas up to 200...210$ US for 1000 Nm^3 by the year of 2010, and 250$ US by 2020.

3. In accordance with the calculations conducted in DHTEC and described in article "Оценка условий стабильного горения высокозольного АШ в факельных котлоагрегатах с жидким шлакоудалением" (журнал Энергетика и электрификация №1, 1995), and taking into account the experimental results obtained in PETC, we propose to accept the following flow rates of natural gas (on the heat basis) for the reconstruction of boiler units at the Luganskaya GRES:
1A-case: 35%, 1B-case: 20 %, 2A-case: 30 %, 2B-case 15 %, [illegible]

4. We think that it is necessary for economic comparison of different cases of reconstruction of the Luganskaya GRES to accept the installation of one CFB boiler with capacity of 125 MWe rather than two boilers of 50-62.5 MWe.

5. We ask to take into account when making calculation of economic efficiency that upon the reconstruction the TP-100 boiler should work during next 15 years, while CFB boiler - about 30 years.

6. Taking into account that CFB boiler is capable to use anthracite with more lower calorific value, slag and coal cleaning waste, we ask you to consider the coal with calorific value of 3700 kcal/kg for the calculation of CFB case; as to pulverised-coal combustion, the coal with calorific value of 4800 kcal/kg and more is recommended.

7. If American boiler manufacturers have objections concerning the item 3, we would request for grounded assessment taking into account that ash contents in fuel could strongly deviate within short period of time (of approximately one hour).

8. The contents of carbon in fly ash for the calculation of reconstruction of TP-100 boiler units is assumed as 12...16 % and this assumption has not been confirmed by any calculation. We think that in case the origin anthracite culm is used at 100 % boiler load, the carbon contents in fly ash will be at 30% (for 1A-case and 2A-case), 20 % (3A-case), 25 % (4A-case). In case a cleaned anthracite (4B-case) is used, the carbon content in fly ash will be at 15...18 %. While decreasing the load of boiler unit, the carbon contents in fly ash will increase. The last is of great importance if taking into account that the boiler units should operate within the load range of 50...100 %.

9. It is necessary to take into account in calculation the payment of emissions within the penalties which will be introduced on January 1, 1996. It is necessary to assume the values of efficiency for NOx-SOx and dust removal at the level agreed with you during the meetings held in PETC on November 8, 1995.

10. We also ask you to take into account the results of tests conducted at the Babcock&Wilcox and the PETC in October... November, 1995 where the Ukrainian anthracite culm was used while making technical and economic comparison of different reconstruction variants of the Luganskaya GRES.

We hope that our comments and notes would assist in economy calculation for reconstruction of boiler units No. 10 and 13 at Luganskaya GRES, approaching the meetings of 11...13 December, 1995 in Kiev.

Best regards,

Stanislav V. Yatskevich
Head of the Board at Ukrainian Minenergo

Alexander Yu. Maystrenko
Deputy Head of DHTEC

5. RESPONSE TO COMMENTS FROM MINISTRY OF POWER INDUSTRY AND ELECTRIFICATION

1. Suggest rehabilitated capacities for options 1B and 2B different from report
   Response: No comment.

2. Suggest supplementary fuel requirements different from those in report
   Response: No comment

3. Suggest one 125 MWe CFB boiler instead of two 62.5 MWe
   Response: Not in scope.

4. Coal specification
   Response: Refer to Item 11 in Response to Document No. 4.

5. Carbon in fly ash
   Response: Refer to Item 2 in Response to Document No. 1.

MEMORANDUM

Date: November 16, 1995

From: Mort Blinn

To: Don Fitzgerald

cc: John Ruether
Jim Wilbur
S.N. Rao

Subject: Stack Parameters for Lugansk GRES Options

As we have discussed, the World Bank has suggested "norms" for SOx and NOx emissions from rehabilitated Lugansk GRES boilers. These norms are suggested as replacements for Ukraine emission standards for projects such as ours. The acceptability of these norms to Donbas environmental officials will depend upon whether or not they cause ambient air quality limits to be exceeded. Bill Lane of the World Bank will visit Ukraine in a week or so to participate in dispersion calculations to evaluate the effect of the norms upon air quality.

I have undertaken to obtain the needed stack parameters for the ambient air quality calculations in Ukraine. Victor Gorokhov is obtaining Lugansk GRES information on stack dimensions, liners, and other parameters including current emissions, i.e. the emissions for boilers, including units 10 and 13, exhausting through the same stacks as units 10 and 13.

To evaluate the consequences of options 1 -4 studied by BRC, would you please provide me with flue gas and pollutant emissions for the cases having the greatest and least emissions, per the list below. This information will be used to derive parameters used in the Briggs plume rise equation.

- Flue gas emission rate, kg/sec
- Pollutant emission rate, g/sec
  - SOx
  - NOx
  - Particulates
- Exit temperature at base of stack (after the last pollution control device), °C
- Exit temperature at stack exit, °C
- Density of emitted flue gas, kg/m^3

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6. RESPONSE TO REQUEST FOR STACK PARAMETER DATA

	Greatest Emissions	Least Emissions
Flue gas emission rate, kg/sec	312	256
Pollutant emission rate, g/sec		
SO_2	1,029	215
NO_x	257	143
Particulates	30	27
Exit Temperature, °C		
Base of stack	130	130
Exit of Stack	*	*
Density of flue gas, kg/m^3		
Base of stack	0.888	0.888

* Dependent upon mixture of flue gas entering stack.

MEMORANDUM

Date: November 28, 1995

From: Mort Blinn

To: Don Fitzgerald
Peter Kemeny

cc: John Ruether
Jim Wilbur

Subject: TA B-11, Subtask 51.08, USAID/Ukraine Support
Additional Question Concerning Options 1 and 2

PETC/DOE is concerned about being able to answer questions concerning rehabilitated boiler performance that might arise at their meeting in Kiev on December 11-12. Additional questions relate to factors concerning the differences in output between rehabilitated boilers operating on uncleaned and cleaned coal:

1. As you discussed by telephone earlier today with H. Feibus and John Ruether, Dr. Feibus estimated that when a rehabilitated boiler operates on uncleaned coal cofired with natural gas, the total heat input is about the same as when it is operated on cleaned coal plus cofiring with less natural gas. He estimates the total ash input to the boiler is the same for each case. Therefore the question has arisen regarding why the steam and electrical outputs differ.

2. An additional question phoned to me this afternoon approaches the subject in a different manner. In this case DOE/PETC wishes to have a listing of the various factors that contribute to the degradation in performance of a boiler prior to rehabilitation, and the amount (in MWe) contributed by each factor. Examples of such factors include: air ingress, production of BFW by steam usage, turbine cylinder degradation, leakage at air preheater seals, etc.

3. Also, DOE/PETC wishes to have a quantified list of post rehabilitation factors that contribute to the still degraded performance of rehabilitated boilers operating on uncleaned coal.

It is recognized that budgetary and time constraints will cause difficulty in providing answers to these questions. However acceptable answers might be to describe the process used in estimating the electrical outputs given in the Lugansk GRES Rehabilitation report. Information regarding limitations imposed by the coal mills seem to be critical to the explanation.

In view of the fact that BRC is now working on answers to an earlier set of questions that have been promised for delivery to PETC on Friday, December 1, it is recommended that answers to the earlier questions be completed before starting to develop answers to the above new questions.

7. RESPONSE TO "ADDITIONAL QUESTION CONCERNING OPTIONS 1 AND 2", M. BLINN, 11/28/95

1. Dr. Feibus estimated that with "minimal" boiler rehabilitation, the following provide the same heat input and ash input, and therefore questions why steam and electrical outputs differ:

    Uncleaned coal co-fired with natural gas
    Cleaned coal co-fired with less natural gas

    Response: Our estimates for supplementary natural gas fuel are based on amounts needed for flame stability. Using these estimates, the following tabulation indicates that the heat and ash inputs are not the same for the predicted generations:

	Uncleaned Coal	**Cleaned Coal**
Supplemental fuel, %	30	15
Main steam flow, t/hr	400	564
Boiler efficiency, %	79	82
Total heat input to furnace, mkcal/h	370	480
Heat input from coal, mkcal/h	259	408
Coal mineral matter, % by wt	36	18
Coal LHV, kcal/kg	4400	5720
Coal mineral matter, kg/mkcal	81.8	31.5
Coal total mineral matter input, kg/hr	21,186	12,852
Ash split, bottom ash/fly ash, %	15/85	15/85
Fly ash flow rate, kg/hr	18,000	10,924

    Both of the above conditions should have about the same flue gas velocity through the boiler convection pass and, therefore, the reduced particulate loading with cleaned coal firing will result in much less pressure parts erosion.

    If the percentage of supplementary fuel were increased while burning the uncleaned coal, the heat input and generation would increase and the ash loading would decrease.

2. List of various factors that contribute to degradation in performance prior to rehabilitation and MWe contributed by each factor
    Response: The list would include the following factors:

    - Creep life is exhausted in boiler pressure parts operating at high metal temperatures.

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- Boiler/furnace setting deteriorated condition, resulting in large amounts of unmeasured ambient air ingress, boiler efficiency decrease, resulting in increased flue gas volume which is limited by capacity of draft system.

- Rotary regenerative air heaters radial and circumferential seal systems deteriorated condition, resulting in increased flue gas volume which is limited by capacity of draft system.

- Low heating value coal requires increased feed flow, which is limited by capacity of coal milling plant.

- Coal milling plant throughput capacity decrease due to reduced grinding index; i.e., grinding capacity decrease. Highly erosive coal mineral matter, high wear rate of grinding/drying circuit components, false air ingress into circuit, reduced ballmill drying capacities.

- Low quality materials for replacement boiler components, lack of hard currency investment capital for thorough/regular equipment maintenance and purchase of spare parts from OEMs.

- Steam flow to evaporator in each unit to produce its make-up water.

- Leakage in the turbine steam condenser.

Of these factors the only one we are able to quantify is the steam flow to the evaporators, which costs about 3.5 MW. We have no way of determining the loss due to each of the other factors.

3. Quantified list of post rehabilitation factors which contribute to the still degraded performance on uncleaned coal.

Response:

- Boiler/furnace setting false air ingress, this problem will not be corrected radically by the patching up of the setting. The flue gas volume will still be limited by the capacity of the draft system.

- Coal milling plant capacity limitation due to lower heating value coal.

- Coal milling plant grinding capacity decrease, due to reduced grindability index.

- As in Item 2, we have no way of quantifying the loss due to each of these factors.

II OPERATION AND MAINTENANCE DATA

CONTENTS

1. REHABILITATION OF LUGANSK GRES

BASELINE DATA

1. Present Unit Ratings (MW)

	Maximum	Continuous
Unit 10	175	143
Unit 13	175	146

2. Minimum Downtime Rules

At present time there are no rules governing operation of the grid. Because of high operating cost, Lugansk GRES is currently run as an intermediate load-following unit.

3. Unit Power Operating Levels and Heat Rates

- Unit 10

Load Level %	100	75	50*	25*
Turbine Gross Output, MW	139	104.2	--	--
Turbine Gross Heat Rate, kcal/kWh	2042	2148	--	--
Unit Net Output, MW	126.5	93.5	--	--
Net Unit Heat Rate, kcal/kWh	2805	2975	--	--

- Unit 13

Load Level %	100	75	50*	25*
Turbine Gross Output, MW	145.5	109. 1	--	--
Turbine Gross Heat Rate, kcal/kWh	2032	2126	--	--
Unit Net Output, MW	132.6	98.1	--	--
Net Unit Heat Rate, kcal/kWh	2852	3004	--	--

*Operation at these loads is not recommended because the boilers are wet bottom type and slag is likely to solidify

4. Maintenance Schedules

At present there are 3 types of planned maintenance shutdown periods:

1. (Minor) Preventive Maintenance: 13 days/year
2. Intermediate Repairs: 25 days/year
3. (Capital or) Major Overhaul: 100-120 days/once in 4 years

The last major overhaul dates were:

Unit 10: 8/15/91 - 12/31/91

Unit 13: 2/13/93 - 8/02/93

5. Unit Forced Outage Rates

Unit 10: 3.7%

Unit 13: 4.9%

DATA FOR OPTIONS IN REPORT

VARIABLE O & M COSTS

OPTION 1A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	435,696	21,583	0	99,302	101,442	0	0	$52,560	see below
UNIT 13	7,014	7446*	461,555	447,748	27,252	0	34,776	104,248	0	0	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**883,444**	**48,835**	**0**	**134,079**	**205,690**	**0**	**0**	**$105,120**	**$60,880**

* = 85% AVAILABILITY 79% BOILER EFF.

OPTION 1B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	528,870	21,583	0	99,302	65,913	0	0	$52,560	see below
UNIT 13	7,014	7446*	461,555	532,372	27,252	0	34,776	66,350	0	0	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,061,242**	**48,835**	**0**	**134,079**	**132,263**	**0**	**0**	**$105,120**	**$85,841**

* = 85% AVAILABILITY 82% BOILER EFF.

OPTION 2A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	435,678	21,583	0	99,302	101,437	35,376	2,010,420	$52,560	see below
UNIT 13	7,014	7446*	461,555	447,789	27,252	0	34,776	104,257	35,376	2,010,420	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**883,467**	**48,835**	**0**	**134,079**	**205,694**	**70,752**	**4,020,840**	**$105,120**	**$60,880**

* = 85% AVAILABILITY 79% BOILER EFF.

OPTION 2B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	529,022	21,583	0	99,302	65,932	36,074	1,638,120	$52,560	see below
UNIT 13	7,014	7446*	461,555	532,299	27,252	0	34,776	66,341	36,074	1,638,120	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,061,321**	**48,835**	**0**	**134,079**	**132,273**	**72,148**	**3,276,240**	**$105,120**	**$85,841**

* = 85% AVAILABILITY 82% BOILER EFF.

DATA FOR OPTIONS IN REPORT

VARIABLE O & M COSTS

OPTION 3A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	8322*	246,060	782,373	21,583	0	99,302	22,370	69,562	2,080,500	$52,560	see below
UNIT 13	7,014	8322*	461,555	786,643	27,252	0	34,776	22,492	69,562	2,080,500	$52,560	see below
TOTALS	**12,933**	**16,644**	**707,615**	**1,569,016**	**48,835**	**0**	**134,079**	**44,862**	**139,124**	**4,161,000**	**$105,120**	**$85,841**

* = 95% AVAILABILITY 90% BOILER EFF.

OPTION 3B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	8322*	246,060	633,636	21,583	0	99,302	0	44,492	2,330,160	$52,560	see below
UNIT 13	7,014	8322*	461,555	636,860	27,252	0	34,776	0	44,492	2,330,160	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,270,496**	**48,835**	**0**	**134,079**	**0**	**88,984**	**4,660,320**	**$105,120**	**$85,841**

* = 95% AVAILABILITY 90% BOILER EFF.

OPTION 4A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7884*	246,060	719,062	21,583	0	99,302	68,936	62,486	3,074,760	$52,560	see below
UNIT 13	7,014	7884*	461,555	719,062	27,252	0	34,776	68,936	62,486	3,074,760	$52,560	see below
TOTALS	**12,933**	**15,768**	**707,615**	**1,438,124**	**48,835**	**0**	**134,079**	**137,872**	**124,972**	**6,149,520**	**$105,120**	**$94,425**

* = 90% AVAILABILITY 90% BOILER EFF.

OPTION 4B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7884*	246,060	618,458	21,583	0	99,302	22,988	43,010	1,813,320	$52,560	see below
UNIT 13	7,014	7884*	461,555	618,458	27,252	0	34,776	22,988	43,010	1,813,320	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,236,916**	**48,835**	**0**	**134,079**	**45,976**	**86,020**	**3,626,640**	**$105,120**	**$94,425**

* = 90% AVAILABILITY 90% BOILER EFF.

DATA FOR OPTIONS IN REPORT

CFB OPTION

UNIT NO.	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR
	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR
CFB	0	7884*	0	531,930	0	0	0	0	91,454	0	$210,240

* = 90% AVAILABILITY 86% BOILER EFF.

THE FIXED O&M COSTS WILL CHANGE AS FOLLOWS:

1. EQUIPMENT REPLACEMENT FUND SHOULD INCREASE BY $185,000
2. ADDITIONAL MAINTENANCE COSTS WILL BE $205,000

DATA FOR OPTIONS IN REPORT, BASED ON REVISED WORLD BANK EMISSION LIMIT CRITERIA

VARIABLE O & M COSTS

OPTION 1A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	435,696	21,583	0	99,302	101,442	0	0	$52,560	see below
UNIT 13	7,014	7446*	461,555	447,748	27,252	0	34,776	104,248	0	0	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**883,444**	**48,835**	**0**	**134,079**	**205,690**	**0**	**0**	**$105,120**	**$60,880**

* = 85% AVAILABILITY 79% BOILER EFF.

OPTION 1B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	528,870	21,583	0	99,302	65,913	0	0	$52,560	see below
UNIT 13	7,014	7446*	461,555	532,372	27,252	0	34,776	66,350	0	0	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,061,242**	**48,835**	**0**	**134,079**	**132,263**	**0**	**0**	**$105,120**	**$85,841**

* = 85% AVAILABILITY 82% BOILER EFF.

OPTION 2A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	435,678	21,583	0	99,302	101,437	33,253	1,608,336	$52,560	see below
UNIT 13	7,014	7446*	461,555	447,789	27,252	0	34,776	104,257	33,253	1,608,336	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**883,467**	**48,835**	**0**	**134,079**	**205,694**	**66,506**	**3,216,672**	**$105,120**	**$60,880**

* = 85% AVAILABILITY 79% BOILER EFF.

OPTION 2B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7446*	246,060	529,022	21,583	0	99,302	65,932	33,693	1,228,590	$52,560	see below
UNIT 13	7,014	7446*	461,555	532,299	27,252	0	34,776	66,341	33,693	1,228,590	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,061,321**	**48,835**	**0**	**134,079**	**132,273**	**67,386**	**2,457,180**	**$105,120**	**$85,841**

* = 85% AVAILABILITY 82% BOILER EFF.

DATA FOR OPTIONS IN REPORT, BASED ON REVISED WORLD BANK EMISSION LIMIT CRITERIA

VARIABLE O & M COSTS

OPTION 3A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	8322*	246,060	782,373	21,583	0	99,302	22,370	66,292	1,664,400	$52,560	see below
UNIT 13	7,014	8322*	461,555	786,643	27,252	0	34,776	22,492	66,292	1,664,400	$52,560	see below
TOTALS	**12,933**	**16,644**	**707,615**	**1,569,016**	**48,835**	**0**	**134,079**	**44,862**	**132,584**	**3,328,800**	**$105,120**	**$85,841**

* = 95% AVAILABILITY 90% BOILER EFF.

OPTION 3B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	8322*	246,060	633,636	21,583	0	99,302	0	41,442	1,747,620	$52,560	see below
UNIT 13	7,014	8322*	461,555	636,860	27,252	0	34,776	0	41,442	1,747,620	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,270,496**	**48,835**	**0**	**134,079**	**0**	**82,884**	**3,495,240**	**$105,120**	**$85,841**

* = 95% AVAILABILITY 90% BOILER EFF.

OPTION 4A

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7884*	246,060	719,062	21,583	0	99,302	68,936	59,236	2,367,565	$52,560	see below
UNIT 13	7,014	7884*	461,555	719,062	27,252	0	34,776	68,936	59,236	2,367,565	$52,560	see below
TOTALS	**12,933**	**15,768**	**707,615**	**1,438,124**	**48,835**	**0**	**134,079**	**137,872**	**118,472**	**4,735,130**	**$105,120**	**$94,425**

* = 90% AVAILABILITY 90% BOILER EFF.

OPTION 4B

UNIT	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
NO.	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 10	5,919	7884*	246,060	618,458	21,583	0	99,302	22,988	39,992	1,269,324	$52,560	see below
UNIT 13	7,014	7884*	461,555	618,458	27,252	0	34,776	22,988	39,992	1,269,324	$52,560	see below
TOTALS	**12,933**	**14,892**	**707,615**	**1,236,916**	**48,835**	**0**	**134,079**	**45,976**	**79,984**	**2,538,648**	**$105,120**	**$94,425**

* = 90% AVAILABILITY 90% BOILER EFF.

DATA FOR OPTIONS IN REPORT, BASED ON REVISED WORLD BANK EMISSION LIMIT CRITERIA

CFB OPTION

UNIT NO.	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR
	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR
CFB	0	7884*	0	531,930	0	0	0	0	87,795	0	$210,240

* = 90% AVAILABILITY 86% BOILER EFF.

THE FIXED O&M COSTS WILL CHANGE AS FOLLOWS:

1. EQUIPMENT REPLACEMENT FUND SHOULD INCREASE BY $185,000
2. ADDITIONAL MAINTENANCE COSTS WILL BE $205,000

III. OPTION 5, UNITS 10 AND 13 - ARCH FIRED BOILER, NEW TURBINE GENERATOR

Option 5A - With existing coal fuel

Option 5B - With beneficiated coal fuel

CONTENTS

Note: Import duties and taxes have been excluded from above costs.

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	1,136,000		47,000			236,600	1,419,600
EXCAVATION & BACKFILL	B & R	97,200		36,000			26,640	159,840
CONCRETE & STRUCTURAL STEEL	B & R	248,800		117,000			73,160	438,960
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,608,160**	**0**	**272,000**	**0**	**1,250,000**	**626,032**	**3,756,192**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	1,278,680		13,490,000			1,772,242	16,540,922
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	34,160		385,000			50,299	469,459
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	75,200		1,492,000			188,064	1,755,264
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	22,400		226,000			29,808	278,208
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	32,400		1,125,000			138,888	1,296,288
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,400,000		171,456	1,600,256
NEW BOTTOM ASH SYSTEM	B & R	25,140			485,000		61,217	571,357
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	39,400		478,000			62,088	579,488
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**2,001,380**	**0**	**23,550,000**	**3,430,000**	**0**	**3,477,766**	**32,459,146**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,582,800**	**1,050,000**	**0**	**1,992,480**	**21,038,880**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,900,000		304,400	3,348,400
SO2 CONTROL EQUIPMENT	US	252,000			7,520,000		777,200	8,549,200
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,650,000**	**0**	**1,210,120**	**13,311,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**5,516,900**	**0**	**44,393,800**	**20,591,820**	**1,250,000**	**8,404,591**	**80,157,111**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,825,000	219,000	2,044,000
SUPPORT LABOR & FIELD OFFICE	B & R					1,556,000	186,720	1,742,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					355,000	42,600	397,600
FREIGHT	B & R							2,599,425
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		0	0	0	0	**3,986,000**	**478,320**	**7,063,745**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					4,007,856	200,393	4,208,248
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		0	0	0	0	**8,307,856**	**495,393**	**8,803,248**
TOTAL ESTIMATED PROJECT COST								**96,024,104**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	1,136,000		47,000			236,600	1,419,600
EXCAVATION & BACKFILL	B & R	97,200		36,000			26,640	159,840
CONCRETE & STRUCTURAL STEEL	B & R	248,800		117,000			73,160	438,960
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,608,160**	**0**	**272,000**	**0**	**1,250,000**	**626,032**	**3,756,192**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	1,278,680		13,490,000			1,772,242	16,540,922
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	34,160		385,000			50,299	469,459
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	75,200		1,492,000			188,064	1,755,264
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	22,400		226,000			29,808	278,208
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REFURBISH EXISTING BALL MILLS	B & R	72,000		545,000			74,040	691,040
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,400,000		171,456	1,600,256
NEW BOTTOM ASH SYSTEM	B & R	25,140			485,000		61,217	571,357
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	39,400		478,000			62,088	579,488
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		2,040,980	0	22,970,000	3,430,000	0	3,412,918	31,853,898

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		14,500			2,170	23,870
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,582,800**	**1,050,000**	**0**	**1,992,480**	**21,038,880**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	252,000			7,750,000		800,200	8,802,200
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**451,200**	**0**	**0**	**11,580,000**	**0**	**1,203,120**	**13,234,320**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,667			57,400	440,066
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,167**	**0**	**0**	**575,545**	**4,412,511**
TOTAL DIRECT COSTS		**5,556,500**	**0**	**43,813,967**	**20,521,820**	**1,250,000**	**8,332,768**	**79,475,054**

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ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 10

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,825,000	219,000	2,044,000
SUPPORT LABOR & FIELD OFFICE	B & R					1,556,000	186,720	1,742,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					355,000	42,600	397,600
FREIGHT	B & R							2,573,431
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,986,000**	**478,320**	**7,037,751**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,973,753	198,688	4,172,440
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**8,273,753**	**493,688**	**8,767,440**
TOTAL ESTIMATED PROJECT COST								**95,280,246**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	1,136,000		47,000			236,600	1,419,600
EXCAVATION & BACKFILL	B & R	97,200		36,000			26,640	159,840
CONCRETE & STRUCTURAL STEEL	B & R	248,800		117,000			73,160	438,960
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,608,160**	**0**	**272,000**	**0**	**1,250,000**	**626,032**	**3,756,192**
BOILER REPAIR WORK								
REFURBISH BOILER INTO DBL ARCH CONFIGURATION	B & R	1,278,680		13,490,000			1,772,242	16,540,922
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	34,160		385,000			50,299	469,459
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	75,200		1,492,000			188,064	1,755,264
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	22,400		226,000			29,808	278,208
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
INSTALL NEW BALL MILLS	B & R	72,000		1,125,000			143,640	1,340,640
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,400,000		171,456	1,600,256
NEW BOTTOM ASH SYSTEM	B & R	25,140			485,000		61,217	571,357
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	39,400		478,000			62,088	579,488
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**2,040,980**	**0**	**23,550,000**	**3,430,000**	**0**	**3,482,518**	**32,503,498**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		20,000			2,720	29,920
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,588,300**	**1,050,000**	**0**	**1,993,030**	**21,044,930**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,900,000		304,400	3,348,400
SO2 CONTROL EQUIPMENT	US	226,800			7,520,000		774,680	8,521,480
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**11,650,000**	**0**	**1,207,600**	**13,283,600**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**5,531,300**	**0**	**44,399,300**	**20,591,820**	**1,250,000**	**8,407,373**	**80,179,793**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5A - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,825,000	219,000	2,044,000
SUPPORT LABOR & FIELD OFFICE	B & R					1,556,000	186,720	1,742,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					355,000	42,600	397,600
FREIGHT	B & R							2,599,645
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,986,000**	**478,320**	**7,063,965**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					4,008,990	200,449	4,209,439
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**8,308,990**	**495,449**	**8,804,439**
TOTAL ESTIMATED PROJECT COST								**96,048,197**

NOTE:

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THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
CIVIL/STRUCTURAL								
DEMOLITION COSTS	B & R	1,136,000		47,000			236,600	1,419,600
EXCAVATION & BACKFILL	B & R	97,200		36,000			26,640	159,840
CONCRETE & STRUCTURAL STEEL	B & R	248,800		117,000			73,160	438,960
BUILDINGS REHABILITATION	B & R	106,160		58,000			32,832	196,992
ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R	0				1,250,000	250,000	1,500,000
TOTAL CIVIL/STRUCTURAL		**1,608,160**	**0**	**272,000**	**0**	**1,250,000**	**626,032**	**3,756,192**
BOILER REPAIR WORK								
REFURBISH BOILER INTO MEMBRANE WALL DESIGN	B & R	1,278,680		13,490,000			1,772,242	16,540,922
REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	34,160		385,000			50,299	469,459
REPLACE FURNACE ROOF SUPERHEATER, ROOF PENETRATIONS, ETC.	B & R	256,400		2,699,000			354,648	3,310,048
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	B & R	6,000		35,000			4,920	45,920
REFURBISH AIR PREHEATERS	B & R	75,200		1,492,000			188,064	1,755,264
REPAIR INDUCED DRAFT FANS	B & R	12,000		410,000			50,640	472,640
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	22,400		226,000			29,808	278,208
REPAIR GRINDING CIRCUITS	B & R	34,000		1,120,000			138,480	1,292,480
REPLACE EXISTING MILL CLASSIFIERS	B & R	41,600			1,400,000		172,992	1,614,592
REPAIR/REPLACE EXISTING BALL MILLS	B & R	32,400		545,000			69,288	646,688
INSTALL MILL COAL LEVEL & BALL CHARGE CONTROL SYSTEM	B & R	12,000			145,000		18,840	175,840
NEW LOW NOx BURNERS	B & R	28,800			1,400,000		171,456	1,600,256
REFURBISH SLAG TAP REFRACTORY	B & R	25,140			485,000		61,217	571,357
REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	39,400		478,000			62,088	579,488
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
TOTAL BOILER WORK		**2,001,380**	**0**	**22,970,000**	**3,430,000**	**0**	**3,408,166**	**31,809,546**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
BOP MECHANICAL WORK								
INSTALL NEW 225 MW TURBINE & AUXILLIARIES	UKR	182,400		13,003,400			1,318,580	14,504,380
REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
REPLACE CONDENSATE PUMPS	UKR	10,600		180,000			19,060	209,660
INSTALL NEW CONDENSER	UKR	51,400		2,660,000			271,140	2,982,540
ADD CONDENSER CLEANING SYSTEM	UKR	12,000			225,000		23,700	260,700
CONDENSATE BOOSTER PUMPS	UKR	8,800		159,900			16,870	185,570
REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		20,000			2,720	29,920
REPLACE H.P. FEEDWATER HEATERS	UKR	11,200		400,000			41,120	452,320
REPLACE L.P. FEEDWATER HEATERS	UKR	14,000		280,000			29,400	323,400
NEW HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
REPAIR/REPLACE PIPING & VALVES	UKR	78,400		800,000			175,680	1,054,080
REPLACE MAIN & REHEAT STEAM RELEIF VALVES	UKR	6,000		25,000			3,100	34,100
TOTAL BOP MECHANICAL WORK		**413,600**	**0**	**17,588,300**	**1,050,000**	**0**	**1,993,030**	**21,044,930**
INSTRUMENTS & CONTROLS								
NEW D.C. S. SYSTEM	US	104,000			720,000		82,400	906,400
INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			745,000		114,630	878,830
BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
TOTAL INSTRUMENTS & CONTROLS		**149,300**	**0**	**0**	**1,815,000**	**0**	**253,445**	**2,217,745**
ENVIRONMENTAL SYSTEMS								
REPLACE EXISTING CYCLONES WITH NEW ELECTROSTATIC PRECIPITATORS	US	144,000			2,600,000		274,400	3,018,400
SO2 CONTROL EQUIPMENT	US	226,800			7,750,000		797,680	8,774,480
INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
TOTAL ENVIRONMENTAL SYSTEMS		**426,000**	**0**	**0**	**11,580,000**	**0**	**1,200,600**	**13,206,600**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
ELECTRICAL WORK								
220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
PROTECTIVE RELAYS	US	2,400			390,000		39,240	431,640
UPS SYSTEM	US	880			80,300		8,118	89,298
TOTAL ELECTRICAL WORK		**45,460**	**0**	**0**	**2,646,820**	**0**	**269,228**	**2,961,508**
MISC ELECTRICAL								
POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
GROUNDING SYSTEM	B & R	4,800		67,500			10,845	83,145
CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
TOTAL DIRECT COSTS		**5,491,700**	**0**	**43,819,300**	**20,521,820**	**1,250,000**	**8,326,021**	**79,408,841**

ESTIMATE SUMMARY
LUGANSK GRES
OPTION 5B - UNIT 13

ARCH FIRED BOILER & TURBINE REPLACEMENT / IMPROVED EMISSION CONTROLS

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
SITE INDIRECTS								
CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,825,000	219,000	2,044,000
SUPPORT LABOR & FIELD OFFICE	B & R					1,556,000	186,720	1,742,720
CONSTRUCTION FACILITY & OTHER INDIRECTS	B & R					355,000	42,600	397,600
FREIGHT	B & R							2,573,645
VENDOR REPS/TRAINING/MANUALS	B & R					250,000	30,000	280,000
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**3,986,000**	**478,320**	**7,037,965**
CONSTRUCTION MGMT & ENGINEERING SERVICES								
A/E DESIGN SERVICES	B & R					3,500,000	175,000	3,675,000
CONSTRUCTION MANAGEMENT	B & R					3,970,442	198,522	4,168,964
START-UP, TESTING & TRAINING	B & R					800,000	120,000	920,000
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**8,270,442**	**493,522**	**8,763,964**
TOTAL ESTIMATED PROJECT COST								**95,210,770**

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

TABLE 2.2-2A RECOMMENDED REHABILITATION OF UNIT 13

TASK MATRIX

RECOMMENDED REFURBISHMENTS	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL	UNCLEANED COAL	CLEANED COAL
	OPTION 1A UNIT 13	OPTION 1B UNIT 13	OPTION 2A UNIT 13	OPTION 2B UNIT 13	OPTION 3A UNIT 13	OPTION 3B UNIT 13	OPTION 4A UNIT 13	OPTION 4B UNIT 13	OPTION 5A UNIT 13	OPTION 5B UNIT 13
BOILER										
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	X	X	X	X						
REFURBISH BOILER INTO DOUBLE ARCH CONFIGURATION					X	X			X	X
REFURBISH BOILER WITH MEMBRANE WALLS					X	X	X	X	X	X
REPAIR BACK-PASS CASING, INSULATION, ETC.	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHIELDS	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE ATTEMPERATOR PIPING, VALVING, ETC.	X	X	X	X	X	X	X	X	X	X
REFURBISH AIR PREHEATERS	X	X	X	X	X	X	X	X	X	X
REPAIR INDUCED DRAFT FANS	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	X	X	X	X	X	X	X	X	X	X
REPAIR GRINDING CIRCUITS	X	X	X	X	X	X	X	X	X	X
REPLACE EXISTING MILL CLASSIFIERS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW BALL MILLS					X		X		X	
REPAIR/REFURBISH EXISTING BALL MILLS	X	X	X	X		X		X		X
INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	X	X	X	X	X	X	X	X	X	X
INSTALL LOW NOx BURNERS			X	X	X	X	X	X	X	X
REFURBISH EXISTING BURNERS	X	X								
INSTALL NEW BOTTOM ASH REMOVAL SYSTEM					X	X			X	X
REFURBISH SLAG TAP REFRACTORY	X	X	X	X			X	X		
REFURBISH EXISTING SOOTCLEANING SYSTEMS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW DUCT BURNER FOR BALL MILL INLET	X	X	X	X	X	X	X	X	X	X
REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	X	X	X	X			X	X		
TURBINE										
INSTALL NEW 225 MW TURBINE & AUXILIARIES							X	X	X	X
REPLACE H.P. & I.P TURBINE CYLINDERS & CROSSOVER LINES										
REPLACE L.P. TURBINE LAST STAGE BLADING	X	X	X	X	X	X				
REPLACE TURBINE GOVERNOR & INTERCEPT VALVES	X	X	X	X	X	X				
UPGRADE GLAND SEAL EXHAUSTER SYSTEM	X	X	X	X	X	X				
UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	X	X	X	X	X	X				
REPLACE GOVERNING SYSTEM	X	X	X	X	X	X				
REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	X	X	X	X	X	X				
REPLACE OIL COOLER	X	X	X	X	X	X				
INSTALL L.P. HEATER NO. 1 BY-PASS	X	X	X	X	X	X				
IMPROVE H2 SEALING SYSTEM	X	X	X	X	X	X				
CREEP MONITORING EQUIPMENT	X	X	X	X	X	X				
BALANCE OF PLANT										
REPLACE FEEDWATER PUMPS	X	X	X	X	X	X	X	X	X	X
REPLACE CONDENSATE PUMPS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW CONDENSER							X	X	X	X
ADD CONDENSER CLEANING SYSTEM	X	X	X	X	X	X	X	X	X	X
REPLACE FEEDWATER CONTROL VALVES	X	X	X	X	X	X	X	X	X	X
REPLACE H.P. FEEDWATER HEATERS	X	X	X	X	X	X	X	X	X	X
REPLACE L.P. FEEDWATER HEATERS	X	X	X	X	X	X	X	X	X	X
INSTALL NEW HEATER DRAIN PUMPS							X	X	X	X
INSTALL NEW STEAM SAMPLING SYSTEM	X	X	X	X	X	X	X	X	X	X
REPACK/REPLACE LEAKING CONDENSER VALVES & EXPANSION JOINT	X	X	X	X	X	X	X	X	X	X
REPAIR/REPLACE PIPING & VALVES	X	X	X	X	X	X	X	X	X	X
REPLACE MAIN & REHEAT STEAM RELIEF VALVES	X	X	X	X	X	X	X	X	X	X

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TABLE 2.2-2B RECOMMENDED REHABILITATION OF UNIT 13

TASK MATRIX

RECOMMENDED REFURBISHMENTS	UNCLEANED COAL OPTION 1A UNIT 13	CLEANED COAL OPTION 1B UNIT 13	UNCLEANED COAL OPTION 2A UNIT 13	CLEANED COAL OPTION 2B UNIT 13	UNCLEANED COAL OPTION 3A UNIT 13	CLEANED COAL OPTION 3B UNIT 13	UNCLEANED COAL OPTION 4A UNIT 13	CLEANED COAL OPTION 4B UNIT 13	UNCLEANED COAL OPTION 5A UNIT 13	CLEANED COAL OPTION 5B UNIT 13
INSTRUMENTS & CONTROLS										
NEW D.C. S. SYSTEM	X	X	X	X	X	X	X	X	X	X
INSTALL NEW INSTRUMENTS & CONTROL VALVES	X	X	X	X	X	X	X	X	X	X
BURNER MANAGEMENT SYSTEM UPGRADE	X	X	X	X	X	X	X	X	X	X
ENVIRONMENTAL										
REPLACE EXISTING PRECIPITATORS W/ NEW ELECTROSTATIC PRECIPITATOR	X	X	X	X	X	X	X	X	X	X
INSTALL SO2 CONTROL EQUIPMENT			X	X	X	X	X	X	X	X
INSTALL SNCR EQUIPMENT			X	X	X	X	X	X	X	X
NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	X	X	X	X	X	X	X	X	X	X
ELECTRICAL EQUIPMENT										
220KV SWITCHYARD EQUIPMENT	X	X	X	X	X	X	X	X	X	X
6 KV SWITCHGEAR & BUS	X	X	X	X	X	X	X	X	X	X
400 VOLT SWITCHGEAR & TRANSFORMER	X	X	X	X	X	X	X	X	X	X
INSTALL NEW 225 MW GENERATOR							X	X	X	X
INSTALL NEW GENERATOR EXCITATION SYSTEM							X	X	X	X
MOTOR CONTROL CENTERS	X	X	X	X	X	X	X	X	X	X
BATTERIES & CHARGERS	X	X	X	X	X	X	X	X	X	X
PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	X	X	X	X	X	X	X	X	X	X
UPS SYSTEM	X	X	X	X	X	X	X	X	X	X
POWER/CONTROL/INSTRUMENT WIRING	X	X	X	X	X	X	X	X	X	X
BUILDING LIGHTING/PANELS/RECEPT	X	X	X	X	X	X	X	X	X	X
CONDUIT & CABLE TRAY	X	X	X	X	X	X	X	X	X	X
GROUNDING	X	X	X	X	X	X	X	X	X	X
CATHODIC PROTECTION	X	X	X	X	X	X	X	X	X	X
PLANT COMMUNICATIONS/FIRE PROTECTION	X	X	X	X	X	X	X	X	X	X

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TABLE 2.2-2C PERFORMANCE SUMMARY - UNIT 13

DESCRIPTION	CURRENT CONDITION	UNCLEANED COAL OPTION 1A UNIT 13	CLEANED COAL OPTION 1B UNIT 13	UNCLEANED COAL OPTION 2A UNIT 13	CLEANED COAL OPTION 2B UNIT 13	UNCLEANED COAL OPTION 3A UNIT 13	CLEANED COAL OPTION 3B UNIT 13	UNCLEANED COAL OPTION 4A UNIT 13	CLEANED COAL OPTION 4B UNIT 13
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	1972	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 @ 40% EXCESS AIR, mg/Nm3(D)	6660	6660	5206	1200	1200	1200	1200	1200	1200
NOx EMISSIONS @ 40% EXCESS AIR, mg/Nm3(D)	1600	1600	1300	800	800	800	800	800	800
PARTICULATE EMISSIONS @ 40% EXCESS AIR, mg/Nm3(D)	1300	150	150	150	150	150	150	150	150

TABLE 2.2-2D PERFORMANCE SUMMARY - UNIT 13

DESCRIPTION	UNCLEANED COAL OPTION 1A UNIT 13	CLEANED COAL OPTION 1B UNIT 13	UNCLEANED COAL OPTION 2A UNIT 13	CLEANED COAL OPTION 2B UNIT 13	UNCLEANED COAL OPTION 3A UNIT 13	CLEANED COAL OPTION 3B UNIT 13	UNCLEANED COAL OPTION 4A UNIT 13	CLEANED COAL OPTION 4B UNIT 13
CIVIL/STRUCTURAL/DEMOLITION WORK	$2,662,128	$2,662,128	$2,662,128	$2,662,128	$3,192,000	$3,192,000	$3,238,272	$3,238,272
BOILER & FUEL FEED EQUIPMENT REPAIR/REFURBISHMENT	$13,239,072	$13,239,072	$14,652,736	$14,652,736	$26,435,584	$25,785,984	$23,444,512	$22,750,559
TURBINE AND BALANCE OF PLANT EQUIPMENT UPGRADES/REPAIR	$7,090,862	$7,090,862	$7,090,862	$7,090,862	$7,090,862	$6,988,562	$21,044,930	$21,044,930
INSTRUMENTS AND CONTROLS	$2,217,745	$2,217,745	$2,217,745	$2,217,745	$2,217,745	$2,217,745	$2,217,745	$2,217,745
ENVIRONMENTAL EQUIPMENT UPGRADES	$3,323,320	$3,323,320	$11,703,120	$13,674,320	$12,291,620	$12,508,100	$12,717,100	$12,964,600
ELECTRICAL EQUIPMENT REPAIR/REPLACEMENT	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828	$7,373,828
SITE INDIRECTS	$4,410,693	$4,410,693	$4,755,693	$4,825,093	$6,029,493	$6,009,773	$6,442,245	$6,428,045
ENGINEERING & CONSTRUCTION MANAGEMENT	$5,372,615	$5,372,615	$5,886,772	$5,989,394	$7,671,586	$7,643,476	$8,271,910	$8,248,472
TOTAL COST ESTIMATE (U.S. DOLLARS)	$45,690,263	$45,690,263	$56,342,884	$58,486,106	$72,302,718	$71,719,468	$84,750,542	$84,266,451
COST/NET KW (U.S. DOLLARS)	$339	$245	$420	$316	$396	$388	$410	$403
$ VALUE OF UKRAINIAN LABOR, EQUIPMENT & MATERIAL	$22,561,730	$22,561,730	$22,043,282	$22,075,282	$34,350,593	$33,717,411	$46,111,810	$45,381,398
PERCENTAGE OF TOTAL PROJECT ESTIMATE	49%	49%	39%	38%	48%	47%	54%	54%

IV. PROJECT CASH FLOW DATA

CONTENTS

LUGANSK, UKRAINE
REHABILIT[illegible]ON / REPOWERING PROJECT
SUMMA[illegible]OF PROJECT CASH FLOW
(Dollars in $1,000s)

	Year	Year 1											
	Month	1	2	3	4	5	6	7	8	9	10	11	12
	Budget												
Option 1A													
Unit - 10	$53,747	$5,375	$1,075	$1,612	$1,612	$2,687	$3,762	$2,687	$5,375	$2,687	$2,687	$2,687	$2,687
Unit - 13	$48,402	$4,840	$968	$1,452	$1,452	$2,420	$3,388	$2,420	$4,840	$2,420	$2,420	$2,420	$2,420
Option 1B													
Unit - 10	$53,747	$5,375	$1,075	$1,612	$1,612	$2,687	$3,762	$2,687	$5,375	$2,687	$2,687	$2,687	$2,687
Unit - 13	$48,402	$4,840	$968	$1,452	$1,452	$2,420	$3,388	$2,420	$4,840	$2,420	$2,420	$2,420	$2,420
Option 2A													
Unit - 10	$65,514	$6,551	$1,310	$1,965	$1,965	$3,276	$4,586	$3,276	$6,551	$3,276	$3,276	$3,276	$3,276
Unit - 13	$60,911	$6,091	$1,218	$1,827	$1,827	$3,046	$4,264	$3,046	$6,091	$3,046	$3,046	$3,046	$3,046
Option 2B													
Unit - 10	$68,008	$6,801	$1,360	$2,040	$2,040	$3,400	$4,761	$3,400	$6,801	$3,400	$3,400	$3,400	$3,400
Unit - 13	$63,385	$6,339	$1,268	$1,902	$1,902	$3,169	$4,437	$3,169	$6,339	$3,169	$3,169	$3,169	$3,169
Option 3A													
Unit - 10	$82,588	$8,259	$1,652	$2,478	$2,478	$4,129	$5,781	$4,129	$8,259	$4,129	$4,129	$4,129	$4,129
Unit - 13	$76,377	$7,638	$1,528	$2,291	$2,291	$3,819	$5,346	$3,819	$7,638	$3,819	$3,819	$3,819	$3,819
Option 3B													
Unit - 10	$82,114	$8,211	$1,642	$2,463	$2,463	$4,106	$5,748	$4,106	$8,211	$4,106	$4,106	$4,106	$4,106
Unit - 13	$75,805	$7,581	$1,516	$2,274	$2,274	$3,790	$5,306	$3,790	$7,581	$3,790	$3,790	$3,790	$3,790
Option 4A													
Unit - 10	$87,741	$8,774	$1,755	$2,632	$2,632	$4,387	$6,142	$4,387	$8,774	$4,387	$4,387	$4,387	$4,387
Unit - 13	$88,769	$8,877	$1,775	$2,663	$2,663	$4,438	$6,214	$4,438	$8,877	$4,438	$4,438	$4,438	$4,438
Option 4B													
Unit - 10	$87,396	$8,740	$1,748	$2,622	$2,622	$4,370	$6,118	$4,370	$8,740	$4,370	$4,370	$4,370	$4,370
Unit - 13	$88,330	$8,833	$1,767	$2,650	$2,650	$4,417	$6,183	$4,417	$8,833	$4,417	$4,417	$4,417	$4,417
CFB	$108,840	$10,884	$2,177	$3,265	$3,265	$5,442	$7,619	$5,442	$10,884	$5,442	$5,442	$5,442	$5,442

BASIS: OPTIONS IN REPORT

LUGANSK, UKRAINE
REHABILIT[illegible]N / REPOWERING PROJECT
SUMMA[illegible]F PROJECT CASH FLOW
(Dollars in $1,000s)

	Year	Year 2											
	Month	13	14	15	16	17	18	19	20	21	22	23	24
	Budget												
Option 1A													
Unit - 10	$53,747	$188	$188	$376	$376	$376	$752	$752	$941	$941	$941	$941	$941
Unit - 13	$48,402	$169	$169	$339	$339	$339	$678	$678	$847	$847	$847	$847	$847
Option 1B													
Unit - 10	$53,747	$188	$188	$376	$376	$376	$752	$752	$941	$941	$941	$941	$941
Unit - 13	$48,402	$169	$169	$339	$339	$339	$678	$678	$847	$847	$847	$847	$847
Option 2A													
Unit - 10	$65,514	$229	$229	$459	$459	$459	$917	$917	$1,146	$1,146	$1,146	$1,146	$1,146
Unit - 13	$60,911	$213	$213	$426	$426	$426	$853	$853	$1,066	$1,066	$1,066	$1,066	$1,066
Option 2B													
Unit - 10	$68,008	$238	$238	$476	$476	$476	$952	$952	$1,190	$1,190	$1,190	$1,190	$1,190
Unit - 13	$63,385	$222	$222	$444	$444	$444	$887	$887	$1,109	$1,109	$1,109	$1,109	$1,109
Option 3A													
Unit - 10	$82,588	$289	$289	$289	$578	$578	$578	$1,156	$1,156	$1,156	$1,445	$1,445	$1,445
Unit - 13	$76,377	$267	$267	$267	$535	$535	$535	$1,069	$1,069	$1,069	$1,337	$1,337	$1,337
Option 3B													
Unit - 10	$82,114	$287	$287	$287	$575	$575	$575	$1,150	$1,150	$1,150	$1,437	$1,437	$1,437
Unit - 13	$75,805	$265	$265	$265	$531	$531	$531	$1,061	$1,061	$1,061	$1,327	$1,327	$1,327
Option 4A													
Unit - 10	$87,741	$307	$307	$307	$307	$614	$1,228	$1,228	$1,228	$1,228	$1,535	$1,535	$1,535
Unit - 13	$88,769	$311	$311	$311	$311	$621	$1,243	$1,243	$1,243	$1,243	$1,553	$1,553	$1,553
Option 4B													
Unit - 10	$87,396	$306	$306	$306	$306	$612	$1,224	$1,224	$1,224	$1,224	$1,529	$1,529	$1,529
Unit - 13	$88,330	$309	$309	$309	$309	$618	$1,237	$1,237	$1,237	$1,237	$1,546	$1,546	$1,546
CFB	$108,840	$381	$381	$762	$762	$762	$1,524	$1,524	$1,905	$1,905	$1,905	$1,905	$1,905

LUGANSK, UKRAINE
REHABILIT[illegible]ON / REPOWERING PROJECT
SUMMA[illegible]OF PROJECT CASH FLOW
(Dollars in $1,000s)

Year		Year 3											
Month		25	26	27	28	29	30	31	32	33	34	35	36
	Budget												
Option 1A													
Unit - 10	$53,747	$1,505	$1,505	$1,881	$1,881	$1,505	$1,129	$752	$752	$188	-	-	-
Unit - 13	$48,402	$1,355	$1,355	$1,694	$1,694	$1,355	$1,016	$678	$678	$169	-	-	-
Option 1B													
Unit - 10	$53,747	$1,505	$1,505	$1,881	$1,881	$1,505	$1,129	$752	$752	$188	-	-	-
Unit - 13	$48,402	$1,355	$1,355	$1,694	$1,694	$1,355	$1,016	$678	$678	$169	-	-	-
Option 2A													
Unit - 10	$65,514	$1,376	$1,376	$1,834	$2,293	$2,293	$1,376	$917	$917	$459	$229	$229	$229
Unit - 13	$60,911	$1,279	$1,279	$1,706	$2,132	$2,132	$1,279	$853	$853	$426	$213	$213	$213
Option 2B													
Unit - 10	$68,008	$1,428	$1,428	$1,904	$2,380	$2,380	$1,428	$952	$952	$476	$238	$238	$238
Unit - 13	$63,385	$1,331	$1,331	$1,775	$2,218	$2,218	$1,331	$887	$887	$444	$222	$222	$222
Option 3A													
Unit - 10	$82,588	$1,734	$1,734	$2,312	$2,602	$2,602	$1,734	$1,156	$1,156	$578	$578	$578	$578
Unit - 13	$76,377	$1,604	$1,604	$2,139	$2,406	$2,406	$1,604	$1,069	$1,069	$535	$535	$535	$535
Option 3B													
Unit - 10	$82,114	$1,724	$1,724	$2,299	$2,587	$2,587	$1,724	$1,150	$1,150	$575	$575	$575	$575
Unit - 13	$75,805	$1,592	$1,592	$2,123	$2,388	$2,388	$1,592	$1,061	$1,061	$531	$531	$531	$531
Option 4A													
Unit - 10	$87,741	$1,843	$1,843	$2,457	$2,457	$2,457	$1,843	$1,228	$1,228	$614	$614	$614	$614
Unit - 13	$88,769	$1,864	$1,864	$2,486	$2,486	$2,486	$1,864	$1,243	$1,243	$621	$621	$621	$621
Option 4B													
Unit - 10	$87,396	$1,835	$1,835	$2,447	$2,447	$2,447	$1,835	$1,224	$1,224	$612	$612	$612	$612
Unit - 13	$88,330	$1,855	$1,855	$2,473	$2,473	$2,473	$1,855	$1,237	$1,237	$618	$618	$618	$618
CFB	$108,840	$3,048	$3,048	$3,809	$3,809	$3,048	$2,286	$1,524	$1,524	$381	-	-	-

LUGANSK, UKRAINE
REHABILITATION [illegible]POWERING PROJECT
SUMMARY OF [illegible]OJECT CASH FLOW
(Dollars in $1,000s)

	Year	Year 4												
	Month	37	38	39	40	41	42	43	44	45	46	47	48	
	Budget													Total
Option 1A														
Unit - 10	$53,747	-	-	-	-	-	-	-	-	-	-	-	-	$53,747
Unit - 13	$48,402	-	-	-	-	-	-	-	-	-	-	-	-	$48,402
Option 1B														
Unit - 10	$53,747	-	-	-	-	-	-	-	-	-	-	-	-	$53,747
Unit - 13	$48,402	-	-	-	-	-	-	-	-	-	-	-	-	$48,402
Option 2A														
Unit - 10	$65,514	-	-	-	-	-	-	-	-	-	-	-	-	$65,514
Unit - 13	$60,911	-	-	-	-	-	-	-	-	-	-	-	-	$60,911
Option 2B														
Unit - 10	$68,008	-	-	-	-	-	-	-	-	-	-	-	-	$68,008
Unit - 13	$63,385	-	-	-	-	-	-	-	-	-	-	-	-	$63,385
Option 3A														
Unit - 10	$82,588	$578	$289	$289	-	-	-	-	-	-	-	-	-	$82,588
Unit - 13	$76,377	$535	$267	$267	-	-	-	-	-	-	-	-	-	$76,377
Option 3B														
Unit - 10	$82,114	$575	$287	$287	-	-	-	-	-	-	-	-	-	$82,114
Unit - 13	$75,805	$531	$265	$265	-	-	-	-	-	-	-	-	-	$75,805
Option 4A														
Unit - 10	$87,741	$307	$307	$307	$307	$307	-	-	-	-	-	-	-	$87,741
Unit - 13	$88,769	$311	$311	$311	$311	$311	-	-	-	-	-	-	-	$88,769
Option 4B														
Unit - 10	$87,396	$306	$306	$306	$306	$306	-	-	-	-	-	-	-	$87,396
Unit - 13	$88,330	$309	$309	$309	$309	$309	-	-	-	-	-	-	-	$88,330
CFB	$108,840	-	-	-	-	-	-	-	-	-	-	-	-	$108,840

[illegible]ANSK, UKRAINE
REHABILITA[illegible]N / REPOWERING PROJECT
SUMMARY OF PROJECT CASH FLOW
(Dollars in $1,000s)

	Year	Year 1											
	Month	1	2	3	4	5	6	7	8	9	10	11	12
	Budget												
Option 1A													
Unit - 10	$51,644	$5,164	$1,033	$1,549	$1,549	$2,582	$3,615	$2,582	$5,164	$2,582	$2,582	$2,582	$2,582
Unit - 13	$45,690	$4,569	$914	$1,371	$1,371	$2,285	$3,198	$2,285	$4,569	$2,285	$2,285	$2,285	$2,285
Option 1B													
Unit - 10	$51,644	$5,164	$1,033	$1,549	$1,549	$2,582	$3,615	$2,582	$5,164	$2,582	$2,582	$2,582	$2,582
Unit - 13	$45,690	$4,569	$914	$1,371	$1,371	$2,285	$3,198	$2,285	$4,569	$2,285	$2,285	$2,285	$2,285
Option 2A													
Unit - 10	$61,695	$6,170	$1,234	$1,851	$1,851	$3,085	$4,319	$3,085	$6,170	$3,085	$3,085	$3,085	$3,085
Unit - 13	$56,343	$5,634	$1,127	$1,690	$1,690	$2,817	$3,944	$2,817	$5,634	$2,817	$2,817	$2,817	$2,817
Option 2B													
Unit - 10	$63,840	$6,384	$1,277	$1,915	$1,915	$3,192	$4,469	$3,192	$6,384	$3,192	$3,192	$3,192	$3,192
Unit - 13	$58,470	$5,847	$1,169	$1,754	$1,754	$2,923	$4,093	$2,923	$5,847	$2,923	$2,923	$2,923	$2,923
Option 3A													
Unit - 10	$78,513	$7,851	$1,570	$2,355	$2,355	$3,926	$5,496	$3,926	$7,851	$3,926	$3,926	$3,926	$3,926
Unit - 13	$72,303	$7,230	$1,446	$2,169	$2,169	$3,615	$5,061	$3,615	$7,230	$3,615	$3,615	$3,615	$3,615
Option 3B													
Unit - 10	$78,006	$7,801	$1,560	$2,340	$2,340	$3,900	$5,460	$3,900	$7,801	$3,900	$3,900	$3,900	$3,900
Unit - 13	$71,719	$7,172	$1,434	$2,152	$2,152	$3,586	$5,020	$3,586	$7,172	$3,586	$3,586	$3,586	$3,586
Option 4A													
Unit - 10	$83,863	$8,386	$1,677	$2,516	$2,516	$4,193	$5,870	$4,193	$8,386	$4,193	$4,193	$4,193	$4,193
Unit - 13	$84,751	$8,475	$1,695	$2,543	$2,543	$4,238	$5,933	$4,238	$8,475	$4,238	$4,238	$4,238	$4,238
Option 4B													
Unit - 10	$83,472	$8,347	$1,669	$2,504	$2,504	$4,174	$5,843	$4,174	$8,347	$4,174	$4,174	$4,174	$4,174
Unit - 13	$84,266	$8,427	$1,685	$2,528	$2,528	$4,213	$5,899	$4,213	$8,427	$4,213	$4,213	$4,213	$4,213
Option 5A													
Unit - 10	$96,024	$9,602	$1,920	$2,881	$2,881	$4,801	$6,722	$4,801	$9,602	$4,801	$4,801	$4,801	$4,801
Unit - 13	$96,048	$9,605	$1,921	$2,881	$2,881	$4,802	$6,723	$4,802	$9,605	$4,802	$4,802	$4,802	$4,802
Option 5B													
Unit - 10	$95,280	$9,528	$1,906	$2,858	$2,858	$4,764	$6,670	$4,764	$9,528	$4,764	$4,764	$4,764	$4,764
Unit - 13	$95,211	$9,521	$1,904	$2,856	$2,856	$4,761	$6,665	$4,761	$9,521	$4,761	$4,761	$4,761	$4,761
CFB	$105,376	$10,538	$2,108	$3,161	$3,161	$5,269	$7,376	$5,269	$10,538	$5,269	$5,269	$5,269	$5,269

BASIS: OPTIONS IN REPORT, PLUS OPTION 5
(IMPORT DUTIES AND TAXES DELETED)

[illegible]ANSK, UKRAINE
REHABILIT[illegible]N / REPOWERING PROJECT
SUMMARY OF PROJECT CASH FLOW
(Dollars in $1,000s)

Year		Year 2											
Month		13	14	15	16	17	18	19	20	21	22	23	24
	Budget												
Option 1A													
Unit - 10	$51,644	$181	$181	$362	$362	$362	$723	$723	$904	$904	$904	$904	$904
Unit - 13	$45,690	$160	$160	$320	$320	$320	$640	$640	$800	$800	$800	$800	$800
Option 1B													
Unit - 10	$51,644	$181	$181	$362	$362	$362	$723	$723	$904	$904	$904	$904	$904
Unit - 13	$45,690	$160	$160	$320	$320	$320	$640	$640	$800	$800	$800	$800	$800
Option 2A													
Unit - 10	$61,695	$216	$216	$432	$432	$432	$864	$864	$1,080	$1,080	$1,080	$1,080	$1,080
Unit - 13	$56,343	$197	$197	$394	$394	$394	$789	$789	$986	$986	$986	$986	$986
Option 2B													
Unit - 10	$63,840	$223	$223	$447	$447	$447	$894	$894	$1,117	$1,117	$1,117	$1,117	$1,117
Unit - 13	$58,470	$205	$205	$409	$409	$409	$819	$819	$1,023	$1,023	$1,023	$1,023	$1,023
Option 3A													
Unit - 10	$78,513	$275	$275	$275	$550	$550	$550	$1,099	$1,099	$1,099	$1,374	$1,374	$1,374
Unit - 13	$72,303	$253	$253	$253	$506	$506	$506	$1,012	$1,012	$1,012	$1,265	$1,265	$1,265
Option 3B													
Unit - 10	$78,006	$273	$273	$273	$546	$546	$546	$1,092	$1,092	$1,092	$1,365	$1,365	$1,365
Unit - 13	$71,719	$251	$251	$251	$502	$502	$502	$1,004	$1,004	$1,004	$1,255	$1,255	$1,255
Option 4A													
Unit - 10	$83,863	$294	$294	$294	$294	$587	$1,174	$1,174	$1,174	$1,174	$1,468	$1,468	$1,468
Unit - 13	$84,751	$297	$297	$297	$297	$593	$1,187	$1,187	$1,187	$1,187	$1,483	$1,483	$1,483
Option 4B													
Unit - 10	$83,472	$292	$292	$292	$292	$584	$1,169	$1,169	$1,169	$1,169	$1,461	$1,461	$1,461
Unit - 13	$84,266	$295	$295	$295	$295	$590	$1,180	$1,180	$1,180	$1,180	$1,475	$1,475	$1,475
Option 5A													
Unit - 10	$96,024	$336	$336	$336	$336	$672	$1,344	$1,344	$1,344	$1,344	$1,680	$1,680	$1,680
Unit - 13	$96,048	$336	$336	$336	$336	$672	$1,345	$1,345	$1,345	$1,345	$1,681	$1,681	$1,681
Option 5B													
Unit - 10	$95,280	$333	$333	$333	$333	$667	$1,334	$1,334	$1,334	$1,334	$1,667	$1,667	$1,667
Unit - 13	$95,211	$333	$333	$333	$333	$666	$1,333	$1,333	$1,333	$1,333	$1,666	$1,666	$1,666
CFB	$105,376	$369	$369	$738	$738	$738	$1,475	$1,475	$1,844	$1,844	$1,844	$1,844	$1,844

ANSK, UKRAINE
REHABILITA N / REPOWERING PROJECT
SUMMARY OF PROJECT CASH FLOW
(Dollars in $1,000s)

Year		Year 3											
Month		25	26	27	28	29	30	31	32	33	34	35	36
	Budget												
Option 1A													
Unit - 10	$51,644	$1,446	$1,446	$1,808	$1,808	$1,446	$1,085	$723	$723	$181	-	-	-
Unit - 13	$45,690	$1,279	$1,279	$1,599	$1,599	$1,279	$959	$640	$640	$160	-	-	-
Option 1B													
Unit - 10	$51,644	$1,446	$1,446	$1,808	$1,808	$1,446	$1,085	$723	$723	$181	-	-	-
Unit - 13	$45,690	$1,279	$1,279	$1,599	$1,599	$1,279	$959	$640	$640	$160	-	-	-
Option 2A													
Unit - 10	$61,695	$1,296	$1,296	$1,727	$2,159	$2,159	$1,296	$864	$864	$432	$216	$216	$216
Unit - 13	$56,343	$1,183	$1,183	$1,578	$1,972	$1,972	$1,183	$789	$789	$394	$197	$197	$197
Option 2B													
Unit - 10	$63,840	$1,341	$1,341	$1,788	$2,234	$2,234	$1,341	$894	$894	$447	$223	$223	$223
Unit - 13	$58,470	$1,228	$1,228	$1,637	$2,046	$2,046	$1,228	$819	$819	$409	$205	$205	$205
Option 3A													
Unit - 10	$78,513	$1,649	$1,649	$2,198	$2,473	$2,473	$1,649	$1,099	$1,099	$550	$550	$550	$550
Unit - 13	$72,303	$1,518	$1,518	$2,024	$2,278	$2,278	$1,518	$1,012	$1,012	$506	$506	$506	$506
Option 3B													
Unit - 10	$78,006	$1,638	$1,638	$2,184	$2,457	$2,457	$1,638	$1,092	$1,092	$546	$546	$546	$546
Unit - 13	$71,719	$1,506	$1,506	$2,008	$2,259	$2,259	$1,506	$1,004	$1,004	$502	$502	$502	$502
Option 4A													
Unit - 10	$83,863	$1,761	$1,761	$2,348	$2,348	$2,348	$1,761	$1,174	$1,174	$587	$587	$587	$587
Unit - 13	$84,751	$1,780	$1,780	$2,373	$2,373	$2,373	$1,780	$1,187	$1,187	$593	$593	$593	$593
Option 4B													
Unit - 10	$83,472	$1,753	$1,753	$2,337	$2,337	$2,337	$1,753	$1,169	$1,169	$584	$584	$584	$584
Unit - 13	$84,266	$1,770	$1,770	$2,359	$2,359	$2,359	$1,770	$1,180	$1,180	$590	$590	$590	$590
Option 5A													
Unit - 10	$96,024	$2,017	$2,017	$2,689	$2,689	$2,689	$2,017	$1,344	$1,344	$672	$672	$672	$672
Unit - 13	$96,048	$2,017	$2,017	$2,689	$2,689	$2,689	$2,017	$1,345	$1,345	$672	$672	$672	$672
Option 5B													
Unit - 10	$95,280	$2,001	$2,001	$2,668	$2,668	$2,668	$2,001	$1,334	$1,334	$667	$667	$667	$667
Unit - 13	$95,211	$1,999	$1,999	$2,666	$2,666	$2,666	$1,999	$1,333	$1,333	$666	$666	$666	$666
CFB	$105,376	$2,951	$2,951	$3,688	$3,688	$2,951	$2,213	$1,475	$1,475	$369	-	-	-

LUGA[illegible]K, UKRAINE
REHABILITATIO[illegible]EPOWERING PROJECT
SUMMARY OF PROJECT CASH FLOW
(Dollars in $1,000s)

Year		Year 4												
Month		37	38	39	40	41	42	43	44	45	46	47	48	
	Budget													Total
Option 1A														
Unit - 10	$51,644	-	-	-	-	-	-	-	-	-	-	-	-	$51,644
Unit - 13	$45,690	-	-	-	-	-	-	-	-	-	-	-	-	$45,690
Option 1B														
Unit - 10	$51,644	-	-	-	-	-	-	-	-	-	-	-	-	$51,644
Unit - 13	$45,690	-	-	-	-	-	-	-	-	-	-	-	-	$45,690
Option 2A														
Unit - 10	$61,695	-	-	-	-	-	-	-	-	-	-	-	-	$61,695
Unit - 13	$56,343	-	-	-	-	-	-	-	-	-	-	-	-	$56,343
Option 2B														
Unit - 10	$63,840	-	-	-	-	-	-	-	-	-	-	-	-	$63,840
Unit - 13	$58,470	-	-	-	-	-	-	-	-	-	-	-	-	$58,470
Option 3A														
Unit - 10	$78,513	$550	$275	$275	-	-	-	-	-	-	-	-	-	$78,513
Unit - 13	$72,303	$506	$253	$253	-	-	-	-	-	-	-	-	-	$72,303
Option 3B														
Unit - 10	$78,006	$546	$273	$273	-	-	-	-	-	-	-	-	-	$78,006
Unit - 13	$71,719	$502	$251	$251	-	-	-	-	-	-	-	-	-	$71,719
Option 4A														
Unit - 10	$83,863	$294	$294	$294	$294	$294	-	-	-	-	-	-	-	$83,863
Unit - 13	$84,751	$297	$297	$297	$297	$297	-	-	-	-	-	-	-	$84,751
Option 4B														
Unit - 10	$83,472	$292	$292	$292	$292	$292	-	-	-	-	-	-	-	$83,472
Unit - 13	$84,266	$295	$295	$295	$295	$295	-	-	-	-	-	-	-	$84,266
Option 5A														
Unit - 10	$96,024	$336	$336	$336	$336	$336	-	-	-	-	-	-	-	$96,024
Unit - 13	$96,048	$336	$336	$336	$336	$336	-	-	-	-	-	-	-	$96,048
Option 5B														
Unit - 10	$95,280	$333	$333	$333	$333	$333	-	-	-	-	-	-	-	$95,280
Unit - 13	$95,211	$333	$333	$333	$333	$333	-	-	-	-	-	-	-	$95,211
CFB	$105,376	-	-	-	-	-	-	-	-	-	-	-	-	$105,376

V. ESTIMATED COSTS FOR UNITS 10 AND 13 IN SECOND 15 YEAR PERIOD

CONTENTS

ESTIMATED COSTS FOR UNITS 10 AND 13
OVER SECOND 15 YEAR PERIOD

OPTION 1A (UNIT 10)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH EXISTING FUEL INJECTORS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,813,434
PROJECT INDIRECTS	2,670,033
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	27,983,467

OPTION 1A (UNIT 13)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH EXISTING FUEL INJECTORS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,935,456
PROJECT INDIRECTS	3,032,825
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	28,468,281

OPTION 1B (UNIT 10)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH EXISTING FUEL INJECTORS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,813,434
PROJECT INDIRECTS	2,670,033
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	27,983,467

OPTION 1B (UNIT 13)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH EXISTING FUEL INJECTORS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,935,456
PROJECT INDIRECTS	3,032,825
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	28,468,281

ESTIMATED COSTS FOR UNITS 10 AND 13
OVER SECOND 15 YEAR PERIOD

OPTION 2A (UNIT 10)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,297,952
PROJECT INDIRECTS	2,215,938
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	27,013,890

OPTION 2A (UNIT 13)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	9,548,448
PROJECT INDIRECTS	2,234,918
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	26,283,366

OPTION 2B (UNIT 10)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	10,297,952
PROJECT INDIRECTS	2,138,104
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	26,936,056

OPTION 2B (UNIT 13)	
REPAIR/REFURBISH BOILER REFRACTORY, INSULATION, LAGGING & CASING	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REPAIR/REFURBISH EXISTING BALL MILLS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	9,548,448
PROJECT INDIRECTS	2,162,897
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	26,211,345

ESTIMATED COSTS FOR UNITS 10 AND 13
OVER SECOND 15 YEAR PERIOD

OPTION 3A (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,871,488
PROJECT INDIRECTS	1,278,610
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	21,650,098

OPTION 3A (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,871,488
PROJECT INDIRECTS	1,370,108
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	21,741,596

OPTION 3B (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,871,488
PROJECT INDIRECTS	1,274,914
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	21,646,402

OPTION 3B (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,871,488
PROJECT INDIRECTS	1,365,325
NEW TURBINE GENERATOR	14,500,000
TOTAL 15 YEAR REPLACEMENT ITEMS	21,736,813

ESTIMATED COSTS FOR UNITS 10 AND 13
OVER SECOND 15 YEAR PERIOD

OPTION 4A (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,929,504
PROJECT INDIRECTS	1,244,661
TOTAL 15 YEAR REPLACEMENT ITEMS	7,174,165

OPTION 4A (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,929,504
PROJECT INDIRECTS	1,250,703
TOTAL 15 YEAR REPLACEMENT ITEMS	7,180,207

OPTION 4B (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,929,504
PROJECT INDIRECTS	1,241,859
TOTAL 15 YEAR REPLACEMENT ITEMS	7,171,363

OPTION 4B (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH SLAG TAP REFRACTORY	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	5,929,504
PROJECT INDIRECTS	1,247,504
TOTAL 15 YEAR REPLACEMENT ITEMS	7,177,008

ESTIMATED COSTS FOR UNITS 10 AND 13
OVER SECOND 15 YEAR PERIOD

OPTION 5A (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	6,563,379
PROJECT INDIRECTS	1,269,363
TOTAL 15 YEAR REPLACEMENT ITEMS	7,832,742

OPTION 5A (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	6,563,379
PROJECT INDIRECTS	1,269,472
TOTAL 15 YEAR REPLACEMENT ITEMS	7,832,851

OPTION 5B (UNIT 10)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	7,254,419
PROJECT INDIRECTS	1,422,467
TOTAL 15 YEAR REPLACEMENT ITEMS	8,676,886

OPTION 5B (UNIT 13)	
REPAIR BACK-PASS CASING, INSULATION, ETC.	
REPAIR/REPLACE SH, RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	
REFURBISH AIR PREHEATERS	
REPAIR INDUCED DRAFT FANS	
REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	
REPAIR GRINDING CIRCUITS	
REFURBISH EXISTING SOOTCLEANING SYSTEMS	
DIRECT COST OF WORK LISTED ABOVE	7,254,419
PROJECT INDIRECTS	1,422,174
TOTAL 15 YEAR REPLACEMENT ITEMS	8,676,593

LUGANSK, UKRAINE
REHABILITATION/REPOWERING PROJECT
VALUE OF SECOND 15 YEAR PERIOD UPGRADES
SUMMARY OF PROJECT CASH FLOW
(Dollars in $1,000s)

				MONTH									
			Value	1	2	3	4	5	6	7	8	9	
Option 1A*													
	Unit -	10	$27,983	$2,798	$2,798	$5,597	$2,798	$2,798	$2,798	$2,798	$2,798	$2,798	
	Unit -	13	$28,468	$2,847	$2,847	$5,694	$2,847	$2,847	$2,847	$2,847	$2,847	$2,847	
Option 1B*													
	Unit -	10	$27,983	$2,798	$2,798	$5,597	$2,798	$2,798	$2,798	$2,798	$2,798	$2,798	
	Unit -	13	$28,468	$2,847	$2,847	$5,694	$2,847	$2,847	$2,847	$2,847	$2,847	$2,847	
Option 2A*													
	Unit -	10	$27,014	$2,701	$2,701	$5,403	$2,701	$2,701	$2,701	$2,701	$2,701	$2,701	
	Unit -	13	$26,283	$2,628	$2,628	$5,257	$2,628	$2,628	$2,628	$2,628	$2,628	$2,628	
Option 2B*													
	Unit -	10	$26,936	$2,694	$2,694	$5,387	$2,694	$2,694	$2,694	$2,694	$2,694	$2,694	
	Unit -	13	$26,211	$2,621	$2,621	$5,242	$2,621	$2,621	$2,621	$2,621	$2,621	$2,621	
Option 3A*													
	Unit -	10	$21,650	$2,165	$2,165	$4,330	$2,165	$2,165	$2,165	$2,165	$2,165	$2,165	
	Unit -	13	$21,742	$2,174	$2,174	$4,348	$2,174	$2,174	$2,174	$2,174	$2,174	$2,174	
Option 3B*													
	Unit -	10	$21,646	$2,165	$2,165	$4,329	$2,165	$2,165	$2,165	$2,165	$2,165	$2,165	
	Unit -	13	$21,747	$2,175	$2,175	$4,349	$2,175	$2,175	$2,175	$2,175	$2,175	$2,175	
Option 4A													
	Unit -	10	$7,174	$717	$717	$1,435	$717	$717	$717	$717	$717	$717	
	Unit -	13	$7,180	$718	$718	$1,436	$718	$718	$718	$718	$718	$718	
Option 4B													
	Unit -	10	$7,171	$717	$717	$1,434	$717	$717	$717	$717	$717	$717	
	Unit -	13	$7,177	$718	$718	$1,435	$718	$718	$718	$718	$718	$718	
Option 5A													
	Unit -	10	$7,833	$783	$783	$1,567	$783	$783	$783	$783	$783	$783	
	Unit -	13	$7,833	$783	$783	$1,567	$783	$783	$783	$783	$783	$783	
Option 5B													
	Unit -	10	$8,677	$868	$868	$1,735	$868	$868	$868	$868	$868	$868	
	Unit -	13	$8,677	$868	$868	$1,735	$868	$868	$868	$868	$868	$868	

*** Denotes that the cost of a new turbine generator at $14,500,000 has been included for both Units 10 & 13**

VI. REVISED ESTIMATE SUMMARIES, INCORPORATING REVISED SCOPE ITEMS IN UKRAINE "PLAN FOR RECONSTRUCTION OF LUGANSK GRES" (1200 MG/NM^3 SO_2 EMISSION LIMIT)

OPTION 2A, UNIT 13
CFB UNIT
COMMON FACILITIES

OPTION 2A WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(1200 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/2/96

	ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
			UKR	OTHER	UKR	OTHER	$	$	$
	CIVIL/STRUCTURAL								
1	DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
2	EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
3	CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
4	BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
5	ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
6	ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
	TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
	BOILER REPAIR WORK								
1	RETROFIT INNER & OUTER CASING, REFRACTORY, INSULATION, & LAGGING	B & R	97,500		743,000			100,860	941,360
2	REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
3	REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
4	REPLACE HORIZONTAL RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
5	REPLACE SUPERHEATER & REHEATER PENDANT TUBE BANKS	B & R	171,200		1,935,000			252,744	2,358,944
6	REPAIR/REPLACE ATTEMPERATOR PIPING & VALVING	B & R	7,200		95,000			12,264	114,464
7	REPLACE STEAM, WATER GAS, OIL & AIR VALVES (except boiler drains)	B & R	34,000		245,000			33,480	312,480
8	REPLACE AIR PREHEATERS	B & R	143,200		1,895,000			244,584	2,282,784
9	REPAIR INDUCED DRAFT FANS, ADD ABRASION RESISTANT MATERIAL	B & R	12,000		410,000			50,640	472,640
10	REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
11	REPAIR GRINDING CIRCUITS WITH ABRASION RESISTANT MATERIALS	B & R	34,000		420,000			54,480	508,480
12	REPLACE MILL CLASSIFIERS & RELINE CYCLONES	B & R	41,600			1,842,000		226,032	2,109,632
13	REPLACE EXISTING BALL MILLS W/ NEW 60 TPH UNITS	B & R	130,000		3,745,000			465,000	4,340,000
14	INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	32,000			245,000		33,240	310,240
15	INSTALL NEW LOW NOx BURNERS USING TRI-ANGULAR ARRANGEMENT	B & R	37,600			1,900,000		232,512	2,170,112
16	REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
17	REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
18	INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
19	MODIFY COAL BUNKER OUTLET & PIPING TO SUIT NEW BURNER ARGMT	B & R	71,200		985,000			126,744	1,182,944
20	REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
	TOTAL BOILER WORK		**1,167,700**	**0**	**15,679,000**	**3,987,000**	**0**	**2,500,044**	**23,333,744**
	BOP MECHANICAL WORK								
1	REFURBISH HP & IP CYLINDERS, CROSSOVER PPG &PRV/ ATTEMP STATIONS	UKR	113,600		1,450,000			156,360	1,719,960
2	REPLACE L.P. ROTOR & MODIFY EXHAUST	UKR	96,000		3,085,000			318,100	3,499,100
3	INSTALL NEW VIBRATION MONITORING EQUIPMENT	US	3,800			50,000		5,380	59,180
4	REPLACE TURBINE STOP, GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
5	UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
6	UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
7	REPLACE GOVERNING SYSTEM	US	2,000			700,000		70,200	772,200
8	REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140

OPTION 2A WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(1200 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/2/96

	ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
9	REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
10	INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
11	REPLACE HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
12	IMPROVE H2 SEALING EQUIPMENT	UKR	1,200		20,000			2,120	23,320
13	CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
14	REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
15	REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
16	ADD CONDENSATE POLISHING UNIT	US	33,600			1,400,000		143,360	1,576,960
17	ADD CONDENSER CLEANING SYSTEM	US	19,200			400,000		41,920	461,120
18	REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		94,500			10,170	111,870
19	REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
20	NEW L.P. FEEDWATER HEATERS WITH STAINLESS STEEL TUBES	UKR	14,000		280,000			29,400	323,400
21	INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
22	REPLACE CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
23	THERMAL HEAT TREATMENT FOR STEAM PIPES	UKR	15,200			1,100,000		111,520	1,226,720
24	REPAIR/REPLACE PIPING & VALVES	UKR	78,400		750,000			165,680	994,080
25	REPLACE MAIN & REHEAT STEAM RELIEF VALVES	UKR	6,000		25,000			3,100	34,100
	TOTAL BOP MECHANICAL WORK		**469,120**	**0**	**8,227,500**	**4,645,000**	**0**	**1,417,002**	**14,758,622**
	INSTRUMENTS & CONTROLS								
1	NEW D.C. S. SYSTEM including add'l capacity for future I/O	US	336,000			900,000		123,600	1,359,600
2	INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			1,500,000		227,880	1,747,080
3	BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
	TOTAL INSTRUMENTS & CONTROLS		**381,300**	**0**	**0**	**2,750,000**	**0**	**407,895**	**3,539,195**
	ENVIRONMENTAL SYSTEMS								
1	REPLACE EXISTING ELECTROSTATIC PRECIPITATORS	US	144,000			4,500,000		464,400	5,108,400
2	INSTALL SO2 CONTROL EQUIPMENT	US	210,000			6,400,000		661,000	7,271,000
3	INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
4	NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
	TOTAL ENVIRONMENTAL SYSTEMS		**409,200**	**0**	**0**	**12,130,000**	**0**	**1,253,920**	**13,793,120**
	ELECTRICAL WORK								
1	220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
2	6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
3	400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
4	MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
5	BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
6	PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
7	UPS SYSTEM	US	880			80,300		8,118	89,298
8	REPLACE ALL EXISTING ELECTRIC MOTORS	US	14,800			450,000		46,480	511,280
	TOTAL ELECTRICAL WORK		**60,260**	**0**	**0**	**3,096,820**	**0**	**315,708**	**3,472,788**

OPTION 2A WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(1200 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/2/96

	ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
			UKR	OTHER	UKR	OTHER			
	MISC ELECTRICAL								
1	POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
2	BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
3	CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
4	GROUNDING	B & R	4,800		67,500			10,845	83,145
5	CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
6	PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
	TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
	TOTAL DIRECT COSTS		**4,169,820**	**0**	**27,029,500**	**26,608,820**	**1,250,000**	**6,913,777**	**65,971,917**
	SITE INDIRECTS								
1	CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
2	SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
3	CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
4	FREIGHT	B & R							2,145,533
5	VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
	TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**5,443,933**
	CONSTRUCTION MGMT & ENGINEERING SERVICES								
1	A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
2	CONSTRUCTION MANAGEMENT	B & R					3,298,596	164,930	3,463,526
3	START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
	TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**6,548,596**	**402,430**	**6,951,026**
	TOTAL ESTIMATED PROJECT COSTS								78,366,875

NOTE:

THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

4/2/96

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and TURBINE NO. 6
2- CFB BOILERS WITH 125 MW TURBINE

	ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
			UKR	OTHER	UKR	OTHER	$	$	$
	CIVIL/STRUCTURAL								
1	DEMOLITION COSTS	B & R	352,400		68,000			84,080	504,480
2	EXCAVATION & BACKFILL	B & R	106,000		43,000			29,800	178,800
3	CONCRETE & STRUCTURAL STEEL	B & R	490,000		1,495,000			397,000	2,382,000
4	BUILDINGS REHABILITATION	B & R	172,000		450,000			124,400	746,400
5	ROADWAYS / PARKING / FENCING	B & R	60,000		57,000			23,400	140,400
6	NEW STACK LINER & DUCTWORK	US	272,000		421,000			138,600	831,600
7	ASBESTOS & TRANSFORMER OIL REMOVAL SPECIAL LABOR COSTS	B & R					1,350,500	270,100	1,620,600
8	REPAIR CIRCULATING WATER PUMPHOUSE	UKR	157,000		295,000			90,400	542,400
	TOTAL CIVIL/STRUCTURAL		**1,609,400**	**0**	**2,829,000**	**0**	**1,350,500**	**1,157,780**	**6,946,680**
	CFB BOILER & MECH EQUIP								
1	CFB BOILER SYSTEM INCLUDING STRUCTURAL SUPPORTS	UKR	914,800		27,500,000			2,841,480	31,256,280
2	INDUCED DRAFT FANS & F.D. BLOWERS	UKR	26,000		1,160,000			118,600	1,304,600
3	ASH CONVEYOR AND SILO	UKR	26,800		420,000			44,680	491,480
4	COAL FEEDING EQUIPMENT	US	32,000		1,200,000			123,200	1,355,200
5	NEW COAL CONVEYORS	B & R	20,800			549,000		56,980	626,780
6	NEW COAL CRUSHER SYSTEM	US	18,800			214,300		23,310	256,410
7	NEW COAL BUNKERS	B & R	30,000		305,000			33,500	368,500
8	LIME PREPERATION AND STORAGE SYSTEM	US	41,800			1,650,000		169,180	1,860,980
9	BOILER FEED PUMPS	UKR	8,000		600,000			60,800	668,800
10	125 MW TURBINE GENERATOR	UKR	54,000		10,457,800			1,051,180	11,562,980
11	SURFACE CONDENSER	UKR	31,600		1,600,000			163,160	1,794,760
12	ADD NEW CONDENSATE POLISHER	US	25,200			1,000,000		102,520	1,127,720
13	CONDENSER CLEANING SYSTEM	US	12,800			300,000		31,280	344,080
14	NEW CIRCULATING WATER PUMPS & PIPING	UKR	90,220		545,000			63,522	698,742
15	NEW INSTRUMENT & SERVICE AIR COMPRESSORS	B & R	9,600			140,000		14,960	164,560
16	L.P. FEEDWATER HEATERS	UKR	21,200		210,000			23,120	254,320
17	H.P. FEEDWATER HEATERS	UKR	22,000		300,000			32,200	354,200
18	CONDENSATE PUMPS	UKR	8,800		150,000			15,880	174,680
19	CONDENSATE BOOSTER PUMPS	UKR	6,000		180,000			18,600	204,600
20	PIPING & VALVES	UKR	67,200		750,000			163,440	980,640
21	HEATER DRAIN PUMPS	UKR	2,000		30,000			3,200	35,200
22	DEAERATOR & BLOWDOWN EQUIPMENT	B & R	5,200			155,000		16,020	176,220
23	CHEMICAL FEED SYSTEM	B & R	16,800			60,000		7,680	84,480
	TOTAL CFB BOILER & MECH EQUIPMENT		**1,491,620**	**0**	**45,407,800**	**4,068,300**	**0**	**5,178,492**	**56,146,212**

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4/2/96

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and TURBINE NO. 6
2- CFB BOILERS WITH 125 MW TURBINE

	ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
	INSTRUMENTS & CONTROLS								
1	DCS SYSTEM	US	75,600			760,000		83,560	919,160
2	INSTUMENTS & CONTROLS	B & R	37,000			418,000		68,250	523,250
	TOTAL INSTRUMENTS & CONTROLS		**112,600**	**0**	**0**	**1,178,000**	**0**	**151,810**	**1,442,410**
	ENVIRONMENTAL SYSTEMS								
1	BAGHOUSE SYSTEM	US	50,000			3,800,000		385,000	4,235,000
2	CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
	TOTAL ENVIRONMENTAL SYSTEMS		**77,200**	**0**	**0**	**4,050,000**	**0**	**412,720**	**4,539,920**
	ELECTRICAL WORK								
1	220 KV SWITCHYARD EQUIPMENT	US	43,200			831,020		87,422	961,642
2	MAIN & AUXILIARY TRANSFORMERS & ASSOCIATED EQUIPMENT	US	16,000			2,291,888		230,789	2,538,677
3	SWITCHGEAR & BUS	US	4,000			1,452,000		145,600	1,601,600
4	GENERATOR CIRCUIT BREAKER	US	4,800			540,000		54,480	599,280
5	GENERATOR TO TRANSFORMER NON-SEG. BUS	US	2,000			599,000		60,100	661,100
6	MOTOR CONTROL CENTERS	US	10,000			275,000		28,500	313,500
7	BATTERIES & CHARGERS	US	4,800			71,500		7,630	83,930
8	PROTECTIVE RELAYS	US	3,000			165,000		16,800	184,800
9	UPS SYSTEM	US	1,200			44,000		4,520	49,720
10	MAIN & AUXILIARY PANELS	US	2,400			375,000		37,740	415,140
	TOTAL ELECTRICAL WORK		**91,400**	**0**	**0**	**6,644,408**	**0**	**673,581**	**7,409,389**
	MISC ELECTRICAL								
1	DUCT BANK	B & R	24,000		251,000			41,250	316,250
2	EQUIPMENT INSTALLATION	B & R	64,000		0			9,600	73,600
3	POWER/CONTROL/INSTRUMENT WIRING	B & R	122,000		762,000			132,600	1,016,600
4	BUILDING LIGHTING/PANELS/RECEPT	B & R	40,000		356,000			59,400	455,400
5	CONDUIT & CABLE TRAY	B & R	128,000		678,900			121,035	927,935
6	GROUNDING SYSTEM	B & R	16,000		209,500			33,825	259,325
7	CATHODIC PROTECTION	B & R	7,200		22,500			4,455	34,155
8	PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	14,400		95,600			16,500	126,500
	TOTAL MISC ELECTRICAL		**415,600**	**0**	**2,375,500**	**0**	**0**	**418,665**	**3,209,765**
	TOTAL DIRECT COSTS		**3,797,820**	**0**	**50,612,300**	**15,940,708**	**1,350,500**	**7,993,048**	**79,694,376**

4/2/96

ESTIMATE SUMMARY
LUGANSK GRES
REPOWERING BOILERS NO. 13 & 14 and TURBINE NO. 6
2- CFB BOILERS WITH 125 MW TURBINE

	ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
			UKR	OTHER	UKR	OTHER			
	SITE INDIRECTS								
1	CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					2,845,000	341,400	3,186,400
2	SUPPORT LABOR & FIELD OFFICE COSTS	B & R					2,795,000	335,400	3,130,400
3	CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					500,000	60,000	560,000
4	FREIGHT	B & R							3,993,180
5	VENDOR REPS/TRAINING/MANUALS	B & R					625,000	75,000	700,000
	TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**6,765,000**	**811,800**	**11,569,980**
	CONSTRUCTION MGMT & ENGINEERING SERVICES								
1	A/E DESIGN SERVICES	B & R					9,000,000	450,000	9,450,000
2	CONSTRUCTION MANAGEMENT	B & R					3,984,719	199,236	4,183,955
3	START-UP, TESTING & TRAINING	B & R					1,500,000	225,000	1,725,000
	TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**14,484,719**	**874,236**	**15,358,955**
	TOTAL ESTIMATED PROJECT COSTS								**106,623,311**

NOTE: THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

4/2/96

ESTIMATE SUMMARY
LUGANSK GRES
COMMON FACILITIES
WATER TREATMENT & FUEL HANDLING

ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
	SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
WATER TREATMENT EQUIPMENT 250 T/Hr								
CIVIL/SITE WORK	B & R	352,400		68,000			84,080	504,480
ELECTRICAL WORK	B & R	24,000		251,000			41,250	316,250
PROCESS EQUIPMENT, PUMPS & STORAGE TANKS	US	213,000			7,500,000		385,650	8,098,650
TOTAL WATER TREATMENT SYSTEM		**589,400**	**0**	**319,000**	**7,500,000**	**0**	**510,980**	**8,919,380**
FUEL FEED EQUIPMENT								
STACKER/RECLAIMER & CONVEYORS	UKR	304,000		4,200,000			675,600	5,179,600
TOTAL FUEL FEED		**304,000**	**0**	**4,200,000**	**0**	**0**	**675,600**	**5,179,600**
TOTAL DIRECT COSTS		**893,400**	**0**	**4,519,000**	**7,500,000**	**0**	**1,186,580**	**14,098,980**
SITE INDIRECTS								
FREIGHT/UNLOADING/STORAGE	B & R					1,409,898	169,188	1,579,086
TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**1,409,898**	**169,188**	**1,579,086**
PROJECT SERVICES								
A/E DESIGN SERVICES	B & R					350,000	17,500	367,500
CONSTRUCTION MANAGEMENT	B & R					704,949	35,247	740,196
TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**1,054,949**	**52,747**	**1,107,696**
TOTAL ESTIMATED PROJECT COSTS								**16,785,762**

BURNS AND ROE COMMENTS ON "PLAN" ITEMS

OPTION 2A

1. Instead of Estimate Items 1 and 3 under Boiler Repair Work which involve replacement-in-kind of furnace tubing/casing/refractory/insulation/lagging, we recommend replacement with membrane wall tubing design, as in Option 4A. Although the replacement-in-kind would have resulted in significant performance improvement initially, the cycling mode of operation would soon cause deterioration and air in-leakage, returning the performance to its present state. The membrane wall will maintain tightness.

2. We believe that replacement of the existing 50 TPH ball mills with 60 TPH mills (Item 13) is not warranted. Refurbished 50 TPH mills will produce enough steam to generate nearly 200 MW.

The above two changes would result in a net increase in cost to the estimate of $845,900, including indirect costs.

If there is a need to reduce cost, we suggest investigating the background to the requested replacement of the LP turbine rotor (Estimate Item 2 under BOP Mechanical Work). Burns and Roe examined the maintenance and repair records during the June 1995 inspection visit. It was concluded that only the last stage blading on that rotor needed replacement. (Refer to Paragraphs 4.1.3.4 and 4.4.1.3 of our report.) Replacing the whole LP rotor is costing an additional $2,591,000 and may not be necessary to achieve the life extension goal.

Another questionable item is recorded as Item 23 under BOP Mechanical Work: "Thermal Heat Treatment for Pipes." We are not familiar with in-place heat treatment. We understand that this technology was developed during the Soviet era, but we have found no knowledge of its cost and effectiveness. Our engineers were told about it during their visit to the plant, but were unable to acquire any details. The cost in the estimate for this item is $1,290,000 which is based on the cost listed in the "Plan".

VII. OPTION 2B, UNIT 13, INCORPORATING REVISED SCOPE ITEMS IN UKRAINE "PLAN FOR RECONSTRUCTION OF LUGANSK GRES"

(2000 MG/NM^3 SO_2 EMISSION LIMIT)

OPTION 2B WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(2000 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/4/96

	ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
	CIVIL/STRUCTURAL								
1	DEMOLITION COSTS	B & R	616,400		20,000			127,280	763,680
2	EXCAVATION & BACKFILL	B & R	34,800		15,000			9,960	59,760
3	CONCRETE & STRUCTURAL STEEL	B & R	113,600		65,000			35,720	214,320
4	BUILDINGS REHABILITATION	B & R	49,640		20,000			13,928	83,568
5	ROADWAYS / PARKING / FENCING	B & R	20,000		14,000			6,800	40,800
6	ASBESTOS & TRANSFORMER OIL REMOVAL COSTS	B & R	0				1,250,000	250,000	1,500,000
	TOTAL CIVIL/STRUCTURAL		**834,440**	**0**	**134,000**	**0**	**1,250,000**	**443,688**	**2,662,128**
	BOILER REPAIR WORK								
1	RETROFIT INNER & OUTER CASING, REFRACTORY, INSULATION, & LAGGING	B & R	97,500		743,000			100,860	941,360
2	REPAIR BACK-PASS CASING, INSULATION, ETC.	B & R	24,400		212,000			28,368	264,768
3	REPLACE FURNACE TUBING, ROOF PENETRATIONS, ETC.	B & R	186,000		2,450,000			316,320	2,952,320
4	REPLACE HORIZONTAL RH & ECONO TUBE BANKS, ADD EROSION SHEILDS	B & R	85,600		1,775,000			223,272	2,083,872
5	REPLACE SUPERHEATER & REHEATER PENDANT TUBE BANKS	B & R	171,200		1,935,000			252,744	2,358,944
6	REPAIR/REPLACE ATTEMPERATOR PIPING & VALVING	B & R	7,200		95,000			12,264	114,464
7	REPLACE STEAM, WATER GAS, OIL & AIR VALVES (except boiler drains)	B & R	34,000		245,000			33,480	312,480
8	REPLACE AIR PREHEATERS	B & R	143,200		1,895,000			244,584	2,282,784
9	REPAIR INDUCED DRAFT FANS, ADD ABRASION RESISTANT MATERIAL	B & R	12,000		410,000			50,640	472,640
10	REPAIR/REPLACE FLUE GAS DUCTWORK AND EXPANSION JOINTS	B & R	14,400		157,000			20,568	191,968
11	REPAIR GRINDING CIRCUITS WITH ABRASION RESISTANT MATERIALS	B & R	34,000		420,000			54,480	508,480
12	REPLACE MILL CLASSIFIERS & RELINE CYCLONES	B & R	41,600			1,842,000		226,032	2,109,632
13	REPLACE EXISTING BALL MILLS W/ NEW 60 TPH UNITS	B & R	130,000		3,745,000			465,000	4,340,000
14	INSTALL MILL COAL LEVEL & BALL MILL CHARGE CONTROL SYSTEM	B & R	32,000			245,000		33,240	310,240
15	INSTALL NEW LOW NOx BURNERS USING TRI-ANGULAR ARRANGEMENT	B & R	37,600			1,900,000		232,512	2,170,112
16	REFURBISH SLAG TAP REFRACTORY	B & R	4,800		47,000			6,216	58,016
17	REFURBISH EXISTING SOOTCLEANING SYSTEMS	B & R	12,800		135,000			17,736	165,536
18	INSTALL NEW DUCT BURNER FOR BALL MILL INLET	B & R	4,800		180,000			22,176	206,976
19	MODIFY COAL BUNKER OUTLET & PIPING TO SUIT NEW BURNER ARGMT	B & R	71,200		985,000			126,744	1,182,944
20	REFURBISH BOILER SUPPORTS, PLATFORMS & STAIRS	B & R	23,400		250,000			32,808	306,208
	TOTAL BOILER WORK		**1,167,700**	**0**	**15,679,000**	**3,987,000**	**0**	**2,500,044**	**23,333,744**
	BOP MECHANICAL WORK								
1	REFURBISH HP & IP CYLINDERS, CROSSOVER PPG &PRV/ ATTEMP STATIONS	UKR	113,600		1,450,000			156,360	1,719,960
2	REPLACE L.P. ROTOR & MODIFY EXHAUST	UKR	96,000		3,085,000			318,100	3,499,100
3	INSTALL NEW VIBRATION MONITORING EQUIPMENT	US	3,800			50,000		5,380	59,180
4	REPLACE TURBINE STOP, GOVERNOR & INTERCEPT VALVES	UKR	3,600		900,000			90,360	993,960
5	UPGRADE GLAND SEAL EXHAUSTER SYSTEM	UKR	6,000		200,000			20,600	226,600
6	UPGRADE DRAINAGE/ BLOWDOWN EQUIPMENT	UKR	4,000		70,000			7,400	81,400
7	REPLACE GOVERNING SYSTEM	US	2,000			700,000		70,200	772,200
8	REPLACE FRONT STANDARD AND FLANGE HEATING SYSTEM	UKR	7,400		680,000			68,740	756,140

OPTION 2B WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(2000 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/4/96

	ITEM	PRICING	LABOR		MATERIAL		SUBCONTRACT	CONTINGENCY	TOTAL
		SOURCE	UKR	OTHER	UKR	OTHER	$	$	$
9	REPLACE OIL COOLER	UKR	2,720		8,000			1,072	11,792
10	INSTALL L.P. HEATER NO. 1 BY-PASS	UKR	2,000		5,000			700	7,700
11	REPLACE HEATER DRAIN PUMPS	UKR	10,000		50,000			6,000	66,000
12	IMPROVE H2 SEALING EQUIPMENT	UKR	1,200		20,000			2,120	23,320
13	CREEP MONITORING EQUIPMENT	UKR	400			10,000		1,040	11,440
14	REPLACE FEEDWATER PUMPS	UKR	10,000			700,000		71,000	781,000
15	REPLACE CONDENSATE PUMPS	UKR	8,800			160,000		16,880	185,680
16	ADD CONDENSATE POLISHING UNIT	US	33,600			1,400,000		143,360	1,576,960
17	ADD CONDENSER CLEANING SYSTEM	US	19,200			400,000		41,920	461,120
18	REPLACE FEEDWATER CONTROL VALVES	UKR	7,200		94,500			10,170	111,870
19	REPLACE H.P. FEEDWATER HEATERS	UKR	12,400		600,000			61,240	673,640
20	NEW L.P. FEEDWATER HEATERS WITH STAINLESS STEEL TUBES	UKR	14,000		280,000			29,400	323,400
21	INSTALL NEW STEAM SAMPLING SYSTEM	US	8,400			125,000		13,340	146,740
22	REPLACE CONDENSER VALVES & EXPANSION JOINT	UKR	3,200		10,000			1,320	14,520
23	THERMAL HEAT TREATMENT FOR STEAM PIPES	UKR	15,200			1,100,000		111,520	1,226,720
24	REPAIR/REPLACE PIPING & VALVES	UKR	78,400		750,000			165,680	994,080
25	REPLACE MAIN & REHEAT STEAM RELIEF VALVES	UKR	6,000		25,000			3,100	34,100
	TOTAL BOP MECHANICAL WORK		**469,120**	**0**	**8,227,500**	**4,645,000**	**0**	**1,417,002**	**14,758,622**
	INSTRUMENTS & CONTROLS								
1	NEW D.C. S. SYSTEM including add'l capacity for future I/O	US	336,000			900,000		123,600	1,359,600
2	INSTALL NEW INSTRUMENTS & CONTROL VALVES	B & R	19,200			1,500,000		227,880	1,747,080
3	BURNER MANAGEMENT SYSTEM UPGRADE	B & R	26,100			350,000		56,415	432,515
	TOTAL INSTRUMENTS & CONTROLS		**381,300**	**0**	**0**	**2,750,000**	**0**	**407,895**	**3,539,195**
	ENVIRONMENTAL SYSTEMS								
1	REPLACE EXISTING ELECTROSTATIC PRECIPITATORS	US	144,000			4,500,000		464,400	5,108,400
2	INSTALL SO2 CONTROL EQUIPMENT	US	192,000			4,881,000		507,300	5,580,300
3	INSTALL SNCR EQUIPMENT	US	28,000			980,000		100,800	1,108,800
4	NEW CONTINUOUS EMISSIONS MONITORING SYSTEM	B & R	27,200			250,000		27,720	304,920
	TOTAL ENVIRONMENTAL SYSTEMS		**391,200**	**0**	**0**	**10,611,000**	**0**	**1,100,220**	**12,102,420**
	ELECTRICAL WORK								
1	220KV SWITCHYARD EQUIPMENT	US	19,140			831,020		85,016	935,176
2	6 KV SWITCHGEAR & BUS	US	3,200			320,000		32,320	355,520
3	400 VOLT SWITCHGEAR & TRANSFORMER	US	7,000			612,500		61,950	681,450
4	MOTOR CONTROL CENTERS	US	9,000			315,000		32,400	356,400
5	BATTERIES & CHARGERS	US	3,840			98,000		10,184	112,024
6	PROTECTIVE RELAYS, MAIN & AUXILIARY PANELS	US	2,400			390,000		39,240	431,640
7	UPS SYSTEM	US	880			80,300		8,118	89,298
8	REPLACE ALL EXISTING ELECTRIC MOTORS	US	14,800			450,000		46,480	511,280
	TOTAL ELECTRICAL WORK		**60,260**	**0**	**0**	**3,096,820**	**0**	**315,708**	**3,472,788**

OPTION 2B WITH REVISED SCOPE
ITEMS IN UKRAINE "PLAN"
(2000 MG/NM3 SO2 LIMIT)

ESTIMATE SUMMARY
LUGANSK GRES
REHABILITATION OF UNIT 13

4/4/96

	ITEM	PRICING SOURCE	LABOR		MATERIAL		SUBCONTRACT $	CONTINGENCY $	TOTAL $
			UKR	OTHER	UKR	OTHER			
	MISC ELECTRICAL								
1	POWER/CONTROL/INSTRUMENT WIRING	B & R	628,000		1,687,500			347,325	2,662,825
2	BUILDING LIGHTING/PANELS/RECEPT	B & R	16,000		366,500			57,375	439,875
3	CONDUIT & CABLE TRAY	B & R	178,000		630,000			121,200	929,200
4	GROUNDING	B & R	4,800		67,500			10,845	83,145
5	CATHODIC PROTECTION	B & R	10,000		112,500			18,375	140,875
6	PLANT COMMUNICATIONS/FIRE PROTECTION	B & R	11,000		125,000			20,400	156,400
	TOTAL MISC ELECTRICAL		**847,800**	**0**	**2,989,000**	**0**	**0**	**575,520**	**4,412,320**
	TOTAL DIRECT COSTS		**4,151,820**	**0**	**27,029,500**	**25,089,820**	**1,250,000**	**6,760,077**	**64,281,217**
	SITE INDIRECTS								
1	CONSTRUCTION EQUIP/TOOLS/CONSUMABLES	B & R					1,245,000	149,400	1,394,400
2	SUPPORT LABOR & FIELD OFFICE COSTS	B & R					1,275,000	153,000	1,428,000
3	CONSTRUCTION FACILITIES & OTHER INDIRECTS	B & R					225,000	27,000	252,000
4	FREIGHT	B & R							2,084,773
5	VENDOR REPS/TRAINING/MANUALS	B & R					200,000	24,000	224,000
	TOTAL SITE INDIRECTS		**0**	**0**	**0**	**0**	**2,945,000**	**353,400**	**5,383,173**
	CONSTRUCTION MGMT & ENGINEERING SERVICES								
1	A/E DESIGN SERVICES	B & R					2,500,000	125,000	2,625,000
2	CONSTRUCTION MANAGEMENT	B & R					3,214,061	160,703	3,374,764
3	START-UP, TESTING & TRAINING	B & R					750,000	112,500	862,500
	TOTAL CONSTRUCTION MGMT & ENGINEERING		**0**	**0**	**0**	**0**	**6,464,061**	**398,203**	**6,862,264**
	TOTAL ESTIMATED PROJECT COSTS								**76,526,654**

NOTE:
THE UKR DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM UKRAINIAN SOURCES
THE US DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS OBTAINED FROM NON-UKRAINIAN SOURCES
THE B & R DESIGNATION IN THE PRICING SOURCE COLUMN INDICATES MATERIAL OR EQUIPMENT PRICING WAS DEVELOPED FROM BURNS & ROE'S IN-HOUSE SOURCES

O&M COSTS FOR OPTION 2B WITH
2000 MG/NM3 SO2 LIMIT

OPTION 2B UNIT 13

UNIT NO.	HOURS OF OPERATION		COAL USAGE (TPY)		OIL USAGE (TPY)		GAS USAGE (1000 m3)		LIME USE	UREA USE	ADD'L MNPWR	WATER CHEM'L
	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	EXISTING	UPGRADED	tons/yr	USgal/yr	COSTS/YR	COSTS/YR
UNIT 13	7,014	7446	461,555	532,299	27,252	0	34,776	66,341	59,137	1,638,120	$52,560	$42,921

BURNS AND ROE COMMENTS ON "PLAN" ITEMS

OPTION 2B

1. Instead of Estimate Items 1 and 3 under Boiler Repair Work which involve replacement-in-kind of furnace tubing/casing/refractory/insulation/lagging, we recommend replacement with membrane wall tubing design, as in Option 4B. Although the replacement-in-kind would have resulted in significant performance improvement initially, the cycling mode of operation would soon cause deterioration and air in-leakage, returning the performance to its present state. The membrane wall will maintain tightness.

2. We believe that replacement of the existing 50 TPH ball mills with 60 TPH mills (Item 13) is not warranted. Refurbished 50 TPH mills will produce enough steam to generate the 200 MW.

The above two changes would result in a net increase in cost to the estimate of $845,900, including indirect costs.

If there is a need to reduce cost, we suggest investigating the background to the requested replacement of the LP turbine rotor (Estimate Item 2 under BOP Mechanical Work). Burns and Roe examined the maintenance and repair records during the June 1995 inspection visit. It was concluded that only the last stage blading on that rotor needed replacement. (Refer to Paragraphs 4.1.3.4 and 4.4.1.3 of our report.) Replacing the whole LP rotor is costing an additional $2,591,000 and may not be necessary to achieve the life extension goal.

Another questionable item is recorded as Item 23 under BOP Mechanical Work: "Thermal Heat Treatment for Pipes." We are not familiar with in-place heat treatment. We understand that this technology was developed during the Soviet era, but we have found no knowledge of its cost and effectiveness. Our engineers were told about it during their visit to the plant, but were unable to acquire any details. The cost in the estimate for this item is $1,290,000 which is based on the cost listed in the "Plan".