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PREFEASIBILITY STUDY

OIL SHALE UTILIZATION FOR POWER PRODUCTION IN THE HASHEMITE KINGDOM OF JORDAN

VOLUME VI OF VI - APPENDICES 7 THRU 12
BECHTEL/PYROPOWER DESIGN STUDIES

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JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY

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JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY

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PYROPOWER CORPORATION TEST BURN REPORT

INTERIM REPORT

JORDAN OIL SHALE DIRECT COMBUSTION TESTS IN AN 850KW AHLSTROM PYROFLOW® PILOT PLANT

Prepared For
JORDAN ELECTRIC AUTHORITY

Prepared By
PYROPOWER CORPORATION

June 1988

Pyropower Corporation

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JORDAN OIL SHALE TEST REPORT

1.0 EXECUTIVE SUMMARY

A two week Pilot Plant test program was conducted with Jordanian Oil Shale to determine its suitability as a fuel in circulating fluidized bed boiler applications. Approximately 70 tons of oil shale from the Sultani field was shipped to Finland for this test program. The tests were conducted in January 1988, in a 0.85 MWe AHLSTROM PYROFLOW Circulating Fluidized Bed Boiler pilot plant located at the Hans Ahlstrom Laboratory in Karhula, Finland. The test program covered a range of operating conditions which included variations in primary/secondary air ratio, combustor temperature, combustor pressure drop and firing load. Approximately 100 hours of testing was conducted during the two week time period.

The results of the test program were very encouraging. The oil shale burned in a very stable manner throughout the range of test conditions. Combustion efficiencies exceeded 98% for all tests and CO emissions were low throughout the 2 weeks of testing.

Gaseous pollutant emissions were very low throughout the test program. SO_2 emissions were maintained low throughout the test by the reaction of fuel sulfur with the inherent fuel calcium to form solid $CaSO_4$. Because of the high percentage of calcium inherent in the oil shale ash, over 90% of the fuel sulfur was absorbed as $CaSO_4$. NOx emissions were also maintained at an acceptably low level during all test conditions.

In conclusion, the test results indicate that the Sultani Oil Shale, in spite of its high ash and high sulfur content, can be combusted very stably in an AHLSTROM PYROFLOW CFB boiler with acceptably low flue gas pollutant emissions.

2.0 INTRODUCTION

The Kingdom of Jordan has substantial reserves of oil shale which represent an untapped source of indigenous fossil fuel for the country. The Kingdom has been investigating methods of economically utilizing this fuel resource for over a decade. Until recently, most of this effort has been directed towards retorting processes to extract oil from the oil shale. The current program represents the first effort to evaluate the use of Jordanian oil shale in a direct combustion process for steam/electric power generation.

The Jordanian oil shale is considered to have too low a fuel quality to be effectively used in conventional combustion processes. However, in recent years, the AHLSTROM PYROFLOW Circulating Fluidized Bed combustion process has demonstrated at commercial scale the ability to effectively utilize low grade fuels. These commercial successes with other low quality fuels has led to the current interest in evaluating the direct combustion of Jordanian oil shale.

Under the joint sponsorship of the Kingdom of Jordan and the U.S. Agency for International Development, a preliminary study is being conducted to evaluate the technical and economic feasibility of the direct combustion of Jordanian oil shale in an AHLSTROM PYROFLOW Circulating Fluidized Bed Boiler for electric power generation. As part of this study, a two-week burn test with Jordanian oil shale was conducted in a PYROFLOW pilot plant to develop key performance data for the design of full-scale boilers. The results of this burn test program are described in this report.

Jordanian oil shale is a low grade fuel containing about 70% ash and having a higher heat value of 5-6 MJ/kg in dry solids. Furthermore, this oil shale has a fairly high sulfur content, approximately 3%. This would lead to unacceptably high environmental pollution if these emissions were uncontrolled.

Approximately half of the ash in the oil shale is comprised of calcium carbonate ($CaCO_3$). The $CaCO_3$ naturally occurring in the oil shale effectively reacts in the Circulating Fluidized Bed combustion process with fuel-bound sulfur to form solid $CASO_4$. This greatly reduces the SO_2 gaseous emissions typically associated with the combustion of high sulfur fuels.

In order to evaluate the direct combustion of oil shale, a two week test was carried out in a 850 kW AHLSTROM PYROFLOW pilot plant at the Hans Ahlstrom Laboratory in Karhula, Finland.

About 70 tons of oil shale was shipped to Finland for the test program which was conducted in January, 1988. The test program consisted of evaluations of oil shale combustion performance over a range of parametric variations. The key process parameters varied during the test program were:

- primary/secondary air ratio
- combustor temperature
- combustor pressure drop
- firing load

Approximately 100 hours of testing was conducted during the two-week time period.

3.0 TEST PROGRAM DESCRIPTION

3.1 Test Objectives

The objective of the test was to determine the suitability of firing Jordan oil shale in a AHLSTROM PYROFLOW circulating fluidized bed unit and to develop relevant data for the design of CFB boilers using this oil shale.

Major parameters of interest were:

- combustion stability
- combustion efficiency
- optimum primary/secondary air split
- CO, SO_2, and NOx emissions
- optimum reactor temperature
- impact of reduced load operation
- bottom ash/flyash split

3.2 Test Equipment Description

The tests were performed in the 850 kW AHLSTROM PYROFLOW pilot plant located at the Hans Ahlstrom Laboratory in Karhula, Finland. The flow sheet of the pilot plant is given in Figure 3-1.

The inner diameter of the furnace is approximately 600mm and overall height is 8 m. Solids are separated from flue gas in a hot cyclone and recirculated into the bed through the hot cyclone loopseal.

Bayonet cooling tubes are used in the furnace. The length these tubes extending into the furnace is adjusted to meet the heat transfer duty required for the tested fuel at the desired process conditions.

After the hot cyclone, flue gas is cooled down in a water tube boiler. After the boiler, flue gas flows through the pre-cyclone and the baghouse, where fly ash is separated from the flue gas stream.

Oil shale is fed to the furnace by means of the screw feeder.

3.3 Measurements, Instrumentation and Sampling

The process data measurement recording was carried out by an ALCONT automatic process control system. A portion of the measurements were also plotted with pen recorders.

The oil shale feed rate was calculated on the basis of weighed fuel amount and time records.

Outcoming fly ash amounts were weighed in weighing hoppers hanging from strain gauges. Signals from the amplifiers were drawn by the recorder and the mass flows were obtained by determining slopes of the recorder curves.
Bottom ash was collected in barrels that were weighed manually.

The continuous gas analyzing equipment include the following analyzers:

O_2 (in dry gas)	Taylor Servomex OA 570
CO (in dry gas)	Thermo Electron, Model 48
SO_2 (in wet gas)	Monitor Labs, Model 8850
NOx (in wet gas)	Monitor Labs, Model 8840

The analyzers listed above were subjected to a daily calibration during the course of the test program.

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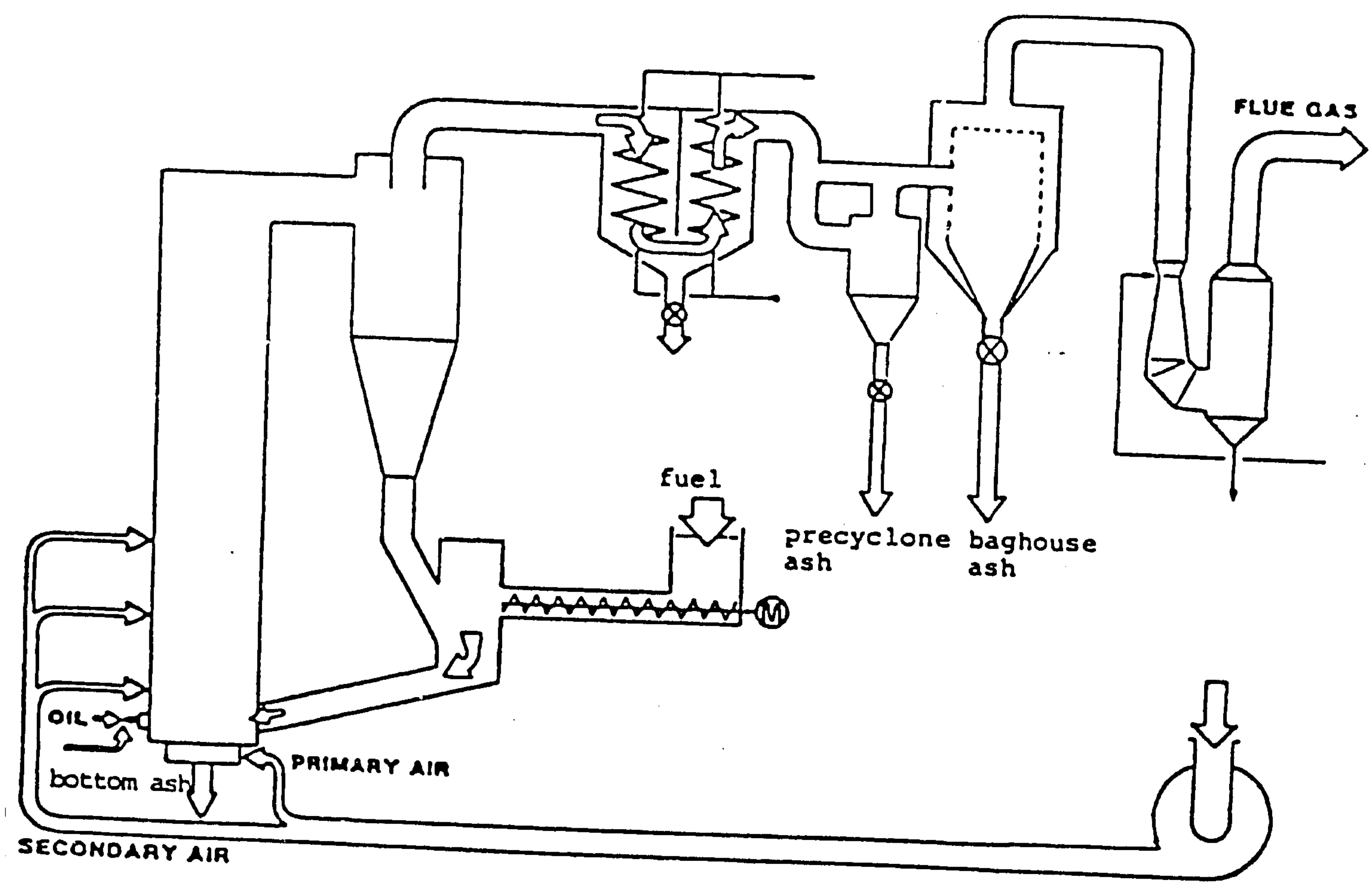
Figure 3-1

AHLSTROM PYROFLOW PILOT PLANT FLOW DIAGRAM



PpC

The sampling point for the O_2 and CO analyzers was located between the hot cyclone and the water tube boiler and for the SO_2 and NOx analyzers after the water tube boiler.

Temperatures and pressures throughout the system were monitored on a continuous basis.

Solids sampling points are indicated in Figure 3-2. The sampling was carried out by collecting a sample directly from each stream. The sampling frequency was once every 2 hours. The samples from each test were composited into one sample for that test period and representative samples of the composite were taken for chemical and physical analysis.

3.4 Test Series Description

Eight different tests were conducted during a two week time period. The first two days of operation were spent in adjusting the test unit for high ash oil shale firing and in calibrating the instrumentation on the test unit. Following the unit adjustment and calibration, the test program was begun. Test 1, 2 and 3 consisted of varying the primary air to secondary air ratio to determine its impact on overall process performance.

Test 4 was a test of the effect of low solids inventory (low furnace P) on process performance.

Test 5 was a high furnace temperature test.

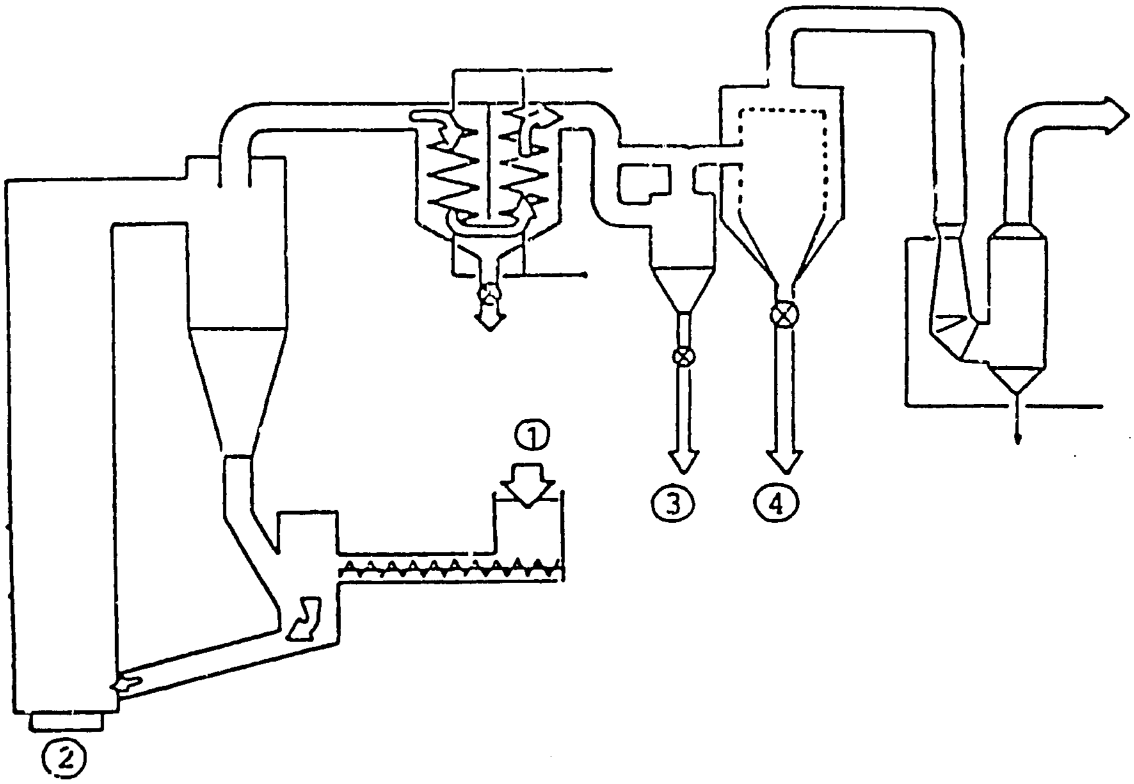
Tests 6 and 7 were reduced firing load tests.

Test 8 was a repeat of the Test 5 high furnace temperature condition.

The test conditions for these tests are summarized in Table 3-1.

Figure 3-2

SOLIDS STREAMS SAMPLING POINTS



1. Oil shale feed
2. Bottom ash
3. Pre-cyclone ash
4. Baghouse ash

PpC

TABLE 3-1

JORDAN OIL SHALE TEST CONDITIONS SUMMARY

Test No.	Hours	% Load	Primary Air/ Secondary Air	Furnace Temp. Degrees C	Furnace ΔP, Mbar	Remarks
1	8	100	50/50	871	70	Air ratio test.
2	10	100	60/40	871	70	Air ratio test.
3	10	100	70/30	871	70	Air ratio test.
4	12	100	50/50	867	40	Low furnace ΔP test.
5	12	100	50/50	901	70.	High furnace temp. test.
6	12	45	66/34	830	70	Reduced load test.
7	8	75	59/41	840	40	Reduced load test.
8	9	100	67/33	900	70	High furnace temp. test.

4.0 TEST RESULTS

4.1 Oil Shale Characteristics

The analyses of an oil shale sample taken before the tests are given in Table 4-1. The heat value of this pre-test sample was slightly better than those of the test run samples.

Table 4-1
FUEL ANALYSES

Proximate Analyses (wt.%)		
- moisture	%	8.5
- ash in dry solids	%	67.1
- volatiles in dry solids	%	32.9
- Fixed carbon in dry solids	%	0.0
Ultimate Analyses (wt. % in dry solids)		
- C	%	18.7
- H	%	1.8
- N	%	0.4
- S	%	3.1
- O (as difference)	%	8.9
Higher heat value in dry solids MJ/kg		6.6
CO_3 in dry solids	%	20.2
Ca in dry solids	%	17.7

During each test series, as-fed fuel samples were periodically collected and composited for the run. A representative sample was taken from this composite and analyzed for moisture, ash, carbon, sulfur, calcium, carbonate and particle size. The results of these analyses are given in Table 4-2. As can be seen from this table, the oil shale analyses varied very little during the two week test program.

Table 4-2
FUEL ANALYSIS BY TEST PERIOD

Test No.	Dry Solids	Ash in d.s.%	Total C* in d.s.%	S in d.s.%	CO_3 in d.s.%	Ca in d.s.%	Higher heat val. in d.s. MJ/kg
1	96.7	67.4	17.7	3.0	18.6	14.6	5.97
2	96.2	68.4	16.2	3.0	23.6	15.3	5.32
3	96.8	68.4	16.8	3.1	17.0	15.3	5.66
4	96.8	67.7	16.9	3.1	21.0	14.7	5.60
5	96.8	68.0	16.6	3.0	18.6	15.0	5.43
6	96.5	67.3	17.0	3.1	25.3	15.1	5.81
7	96.2	66.7	17.5	3.3	20.6	15.1	5.91
8	97.5	66.8	17.4	3.0	23.1	15.4	5.92

* Total carbon is the sum of combustible carbon and carbonate carbon.

4.2 Ash Analyses

Samples of bottom ash and fly ash were periodically collected during each test run. Samples collected during a test run were composited and a representative sample was extracted from the composite for physical and chemical analysis.

4.3 Combustion Efficiency

Since not all of the $CaCO_3$ in the oil shale calcined to CaO, some of the carbon in the ash streams was in the form of $CaCO_3$ which has no fuel value. To determine the amount of unburned combustible carbon in the ash streams, the amount of carbon in the form of carbonate was subtracted from the total carbon value.

The Jordan oil shale combustion efficiency was excellent for all the test conditions; in excess of 98%.

4.4 Flue Gas Pollutant Emissions

Carbon monoxide, sulfur dioxide and nitrogen oxides concentrations in the flue gas were monitored continuously throughout the test program. All of these pollutant emissions were maintained at acceptably low levels through- out the test program. Furthermore, fluctuation in emissions concentrations were very minor during steady state periods.

The average SO_2 concentrations in the flue gas ranged from 10 to 200 ppm. Sulfur reduction exceeded 98% under all test conditions with inherent Ca/S of 3.8 to 4.1.

The percent sulfur absorption was very high under all test conditions. However, sulfur absorption was slightly lower during the high furnace temperature test and the low furnace pressure drop test. Both of these effects would be expected. The calcium-sulfur reaction process becomes less effective at temperature above 900°C and the low furnace pressure tests implies a reduced quantity of calcium bearing material in the hot circulation loop thus giving less effective sulfur removal.

The nitrogen oxide emissions were acceptably low throughout the test program. The average NOx emissions ranged from 70 to 120 ppm. The NOx emissions were fairly insensitive to changes in operating conditions over the ranges tested in this program.

The carbon monoxide emissions were acceptably low throughout the test series and were extremely low during most of the tests, i.e., less than 50 ppm. During the reduced load tests, the CO emissions reached their highest levels, between 90 and 500 ppm.

4.5 Oil Shale Ash Characteristics

The ash in the Sultani Oil Shale is high in calcium carbonate ($CaCO_3$) which when calcined to calcium oxide (CaO) is effective in CFB applications in absorbing sulfur released during combustion. Therefore, although the Sultani oil shale is high in sulfur, the SO_2 emissions were very low due to the high concentration and high reactivity of the calcium inherent in the oil shale ash.

The ash in the oil shale, in addition to providing the sulfur sorbent, also provides the solid particulate material required in the circulating fluidized bed process. Ash is removed from the CFB process as either bottom ash i.e., removed from the bottom of the furnace or ash fly ash, i.e., removed from the flue gas stream. A nominal 45% bottom ash 55% fly ash split was typical for most of the tests. The high furnace temperature tests resulted in higher percentages of flyash generation and the low load tests resulted in higher percentages of bottom ash generation.

The extent of calcination of the $CaCO_3$ in the oil shale ash was fairly insensitive to variations in operating conditions. However, there was a slight increase in calcination with the higher furnace temperature tests. In general, the percent of calcination in the flyash ranged between 92 and 96% and the percent of calcination in the bottom ash ranged between 82 and 90%. During the high furnace temperature test, the percent of calcination in the bottom ash reached 92 to 93%.

The oil shale feed was crushed to a top size of 1/4". This is reflected in the top size of the bottom ash, i.e., approximately 8 mm. Very little of the bottom ash is less than 0.25 mm.

Very little of the fly ash is larger than about 0.1 mm.

5.0 CONCLUSIONS

A two-week burn test program was conducted to evaluate the suitability of using Jordanian Oil Shale as a boiler fuel. Although it was felt that the oil shale is not a suitable boiler fuel for conventional boilers, experience with other low grade fuels suggested that the oil shale would be an acceptable fuel in an AHLSTROM PYROFLOW circulating fluidized bed boiler.

The test program was conducted in an 850 kw AHLSTROM PYROFLOW pilot plant. The combustion performance of the oil shale was evaluated over a range of operating conditions.

The combustion efficiency was excellent over the test program in excess of 98.5%. CO emissions were typically less than 50 ppm. Both SO_2 and NOx emissions were acceptably low throughout the test program. The calcium naturally occurring in the Jordanian Oil Shale was very effective in absorbing sulfur released during combustion of the oil shale. Over 90% of the fuel sulfur was absorbed by the inherent calcium resulting in acceptably low SO_2 emissions.

The NOx emissions showed a slight sensitivity to furnace temperature, being slightly higher at higher furnace temperature. However, under all test conditions, the NOx emissions were very low.

In summary, the test program demonstrated that Jordanian oil shale can be combusted in the AHLSTROM PYROFLOW CFB boiler process very efficiently and stably. Furthermore, the oil shale can be burned very cleanly with very low levels of gaseous pollutant emissions. From a technical feasibility standpoint, Jordanian oil shale is a suitable boiler fuel for AHLSTROM PYROFLOW CFB boiler applications.

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APPENDIX 8

PYROPOWER BOILER DESIGN - 50 MW

INTERIM REPORT

PRELIMINARY DESIGN STUDY FOR A 50 MW AHLSTROM PYROFLOW® CIRCULATING FLUIDIZED BED FIRING JORDAN OIL SHALE

Prepared For
JORDAN ELECTRIC AUTHORITY

Prepared By
PYROPOWER CORPORATION

July 1988

Pyropower Corporation

CONTENTS

EXECUTIVE SUMMARY

Under the joint sponsorship of the Kingdom of Jordan and the U.S. Agency for International Development, a preliminary study is being conducted to evaluate the technical and economic feasibility of the direct combustion of Jordanian oil shale in an AHLSTROM PYROFLOW Circulating Fluidized Bed Boiler for electric power generation. As part of this study, Pyropower conducted a two-week burn test with Jordanian Oil shale in an 850 KW AHLSTROM PYROFLOW pilot plant. The test burn results were used in subsequent design studies for nominal 20 MWe and 50 MWe PYROFLOW CFB boilers. The results of these design studies are contained in this report.

This feasibility study report has been organized for your convenience and ready reference to the technical design, performance and project schedule. Pricing information are contained in a separate document and will be submitted later.

Section 1 contains a discussion of Pyropower and Ahlstrom's operating experience and corporate background. Included is a complete listing of units sold throughout the world with highlights of selected projects.

Section 2 provides a general description of the AHLSTROM PYROFLOW CFB process.

Scope of supply and system terminal points are detailed in Section 3. Please pay particular attention to the items indicated as work by others.

The basis of design, including fuel and limestone analysis is outlined in Section 4. In addition, we have indicated any assumptions about design conditions which might affect final boiler design.

Section 5 contains a more detailed description of the equipment and components which are included in Pyropower's scope of supply.

Predicted performance is listed in Section 6.

Section 7 outlines a typical boiler supply schedule for a unit of this size.

Finally, the boiler general arrangement is presented in drawings following the last section.

1. INTRODUCTION

The Kingdom of Jordan has substantial reserves of oil shale which represent an untapped source of indigenous fossil fuel for the country. The Kingdom has been investigating methods of economically utilizing this fuel resource for over a decade. Until recently, most of this effort has been directed towards retorting processes to extract oil from the oil shale. The current program represents the first effort to evaluate the use of Jordanian oil shale in a direct combustion process for steam/electric power generation.

The Jordanian oil shale is considered to have too low a fuel quality to be effectively used in conventional combustion processes. However, in recent years, the AHLSTROM PYROFLOW Circulating Fluidized Bed combustion process has demonstrated at commercial scale the ability to effectively utilize low grade fuels. These commercial successes with other low quality fuels has led to the current interest in evaluating the direct combustion of Jordanian oil shale.

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1.1. OPERATING EXPERIENCE

There are more than 60 AHLSTROM PYROFLOW units in operation or under construction worldwide with over 100 unit years of operating experience. Five (5) of the operating units are in the United States, with sixteen (16) more under construction in this country. Together, Ahlstrom and Pyropower offer the most comprehensive experience with CFB technology available in the world today.

This extensive operating history is of value to the customer because it saves money in terms of plant efficiency and operating cost. AHLSTROM PYROFLOWs are located in four of Ahlstroms own paper mills. This makes Ahlstrom unique among boiler suppliers - focusing our designs on user sensitivity. As a result of our experience, many improvements have been made to the AHLSTROM PYROFLOW boiler to enhance reliability and to lower maintenance costs. The AHLSTROM PYROFLOW has consistently demonstrated availabilities in excess of 95%, even in the most demanding operating situations such as pulp and paper mills, chemical plants, etc. No Ahlstrom or Pyropower unit has ever failed to delivery 100% of the rated steam conditions including those permitted in accordance with the strictest emission limits. A complete PYROFLOW installation list as well as boiler availability data is presented at the end of this section. A summary of selected key projects is presented in Appendix 3.

2. TECHNICAL DESCRIPTION

2.1. CIRCULATING FLUID BED PRINCIPLES

The AHLSTROM PYROFLOW circulating fluidized bed boiler is based on second generation fluidized bed technology, as distinct from earlier bubbling fluidized bed designs. The AHLSTROM PYROFLOW boiler offers simplicity of design, high reliability, superior performance, and flexible operation backed by extensive experience.

Fluid bed principles are best illustrated by examining the gradual increase of gas velocity through a fixed bed of material. The particles are initially stationary and system pressure drop is a function of velocity. As the minimum fluidizing velocity is reached, the pressure drop reaches a maximum and the particles become fluidized. As gas velocity increases, the bed expands until the entrainment velocity is reached and material starts elutriating from the bed. Higher gas velocities result in greater elutriation and solids recycle is required to maintain the solids inventory. A circulating fluid bed operates in this region.

A circulating fluid bed is characterized by a high-fluidizing velocity, the absence of a defined bed level and extensive solids entrainment. Hot cyclone(s) separate most of the entrained material which is returned to the combustion chamber through nonmechanical seal(s). Internal solids recycling occurs as a result of the high differential ("slip") velocity between the gas and solids. The large solids circulation rate provides for a uniform temperature, high heat transfer coefficients and excellent mixing.

Crushed oil shale contacts primary or fluidizing air in the lower combustion chamber. The oil shale is combusted in an oxygen starved (reducing) environment while the calcium carbonate in the oil shale is calcined to lime. Secondary air is introduced at a higher level to provide the additional air required for complete combustion. The lime reacts with the sulfur dioxide in an oxidizing environment to form calcium sulfate.

Combustion and sulfur retention occur at a temperature of approximately 1550-1650°F thereby providing maximum limestone utilization while minimizing the formation of "thermal" NO_x. The conversion of fuel bound nitrogen to NO_x is inhibited through the use of staged combustion. Combustion efficiency is high due to the long solids residence time and well mixed isothermal environment.

The major advantages of the PYROFLOW circulating fluidized bed combustion system can be summarized as follows:

Fuel flexibility -	PYROFLOW boilers can be designed to fire a wide range of fuels including high ash and high moisture coals, oil shale, coke, and biomass.
Low sulfur emissions -	Downstream flue gas desulfurization is not required to meet environmental regulations. Sulfur is captured by limestone (calcium carbonate) in the combustion chamber.

High combustion efficiency - Excellent vertical and lateral mixing efficiency and a long solids residence time resulting from high gas solids slip velocity ensures optimum carbon burnout.

Low NO_x emissions - Low combustion temperature and staged combustion result in low NO_x emissions which meet most regulatory standards without downstream treating.

Elimination of fouling - Low combustion temperature eliminates slagging slag formation and reduces the volatilization of alkali salts. This reduces boiler corrosion and convective surface fouling.

High turndown - The high velocities in the combustion chamber permit large load reductions without bed slumping.

2.2. GENERAL DESCRIPTION

The major components of the PYROFLOW boiler system are the combustion chamber, the hot cyclone collector(s), loop seal(s), and convective section. Combustion and sulfur retention reactions take place in the combustion chamber, which is fully water-cooled. Fuel is fed to the loop seals and if required to the lower combustion chamber. Limestone is not required for this application due to the inherent calcium carbonate in the oil shale. Fuel feed locations are designed for optimal mixing.

Combustion air is supplied by primary and secondary air fans and by a high pressure centrifugal fan. Primary air, which fluidizes the bed is supplied to the air distribution grid at the bottom of the combustion chamber. Secondary air is introduced at two levels in the lower refractory lined portion of the combustion chamber to ensure complete combustion and to reduce NO_x emissions. Secondary air is also ducted to the start-up burners.

The hot cyclone collector(s) separates entrained bed material and uncombusted fuel from the flue gas stream. The collected particles drop into the cyclone stand-pipe(s) where they are conveyed through a specially designed fluidized nonmechanical seal back to the combustion chamber.

Flue gas leaves the hot cyclone collector(s) and passes through the superheater and economizer sections of the system. Next, the flue gas passes through the airheater, enters a multicyclone dust collector where particulate matter is removed. Then the flue gas enters a baghouse filter where more particulate matter is removed. Clean flue gas is discharged to the stack via the induced-draft fan.

Feedwater is supplied to the economizer, where it is heated before entering the steam drum. From the drum, the water is delivered via downcomers to the combustion chamber where it receives additional heat from the fluidized combustion reaction. The resulting steam/water mixture is returned to the steam drum. Steam is separated in the steam drum and routed through a series of superheaters and then to the main steam header. Desuperheaters are located between superheaters.

3. SCOPE OF SUPPLY

3.1. GENERAL DESCRIPTION

The scope of supply for this preliminary design study is typical of scopes of supply for Pyropower commercial projects. This includes design an furnish of one (1) circulating fluidized bed boiler system.

Numbers which precede equipment identification are Pyropower code of account numbers, used in material tracking.

Equipment description is included in section 5 of the proposal.

3.2. SCOPE OF SUPPLY (PER ONE BOILER)

		Supplied By PpC	Supplied By Others
	DRUMS		
101	Steam Drum	X	
102	Water Drum	NA	
103	Drum Internals	X	
	EVAPORATIVE SURFACES		
111	Combustor (Membrane Walls)	X	
113	Boiler Bank	NA	
114	Evaporative Wing Walls	X	
116	Screen Tubes	NA	
117	Headers (Combustor)	X	
	ECONOMIZER		
121	Bare Tube Economizer	X	
126	Economizer Support Tubes	X	
127	Economizer Headers	X	

No.	Item	Supplied By PpC	Supplied By Others
	SUPERHEATERS		
131	Superheater Tube Bundles	X	
132	Radiant Wing Wall Superheater	X	
133	Radiant Wall Superheaters	NA	
134	Steam Cooled Convection Cage	X	
135	Omega Tube Superheater	NA	
137	Superheater Headers	X	
	DESUPERHEATERS		
141	Spray Desuperheaters	X	
143	Sweet Water Condenser	NA	
	BOILER PROPER AND BOILER EXTERNAL PIPING		
151	Downcomers, Supplies & Risers	X	
152	Feedwater Piping	X	
153	Interconnecting Steam Piping	X	
154	Spray Water Piping	X	
155	Blowdown, Drain and Vent Piping	X	
158	Piping Supports	X	
	NON-BOILER EXTERNAL PIPING		
161	Main Steam Piping		X
162	Feedwater Piping		X
164	Vent Piping		X
165	Safety and Start-Up Exhaust Piping		X
166	Blowdown and Drain Piping		X
167	Sample Piping		X
168	Piping Supports		X
169	Spray Water Piping		X
	BOILER VALVES AND FITTINGS		
171	Vent Valves	X	
171	Drain Valves	X	
171	Sampling Valves	X	
171	Feedwater Stop Valve	X	
171	Main Steam Stop Valve	X	
171	Boiler Trim	X	
172	Main Steam Stop/Check Valve	NA	
172	Feedwater Check Valve	X	
173	Drum Safety Valves	X	

		Supplied By PpC	Supplied By Others
173	Main Steam Safety Valve	X	
173	Start-Up Valve	X	
179	Sample Coolers and Analyzing Equipment		X
	REHEATERS		
181	Reheater Tube Bundles	NA	
182	Wing Wall Reheaters	NA	
183	Radiant Wall Reheaters	NA	
184	Membrane Wall Reheaters	NA	
185	Omega Tube Reheaters	NA	
186	Reheater Hanger Tubes	NA	
187	Reheater Headers	NA	
	BOILER SUPPORT STEEL*		
201	Support Steel for Bottom Supported Boiler	NA	
202	Grid Steel for Top Supported Boiler		
	• Design and Specification	X	
	• Procurement	X	
204	Hanger Rods, Springs and Washers	X	
206	Bottom Supports for Economizer and Airheater	X	
	FABRICATED STEEL COMPONENTS		
211	Hot Cyclone(s)	X	
212	Loop Seal	X	
213	Lower Furnace Steel Plate Structure	NA	
214	Hot Cyclone Inlet and Outlet Gas Ducts	X	
215	Hot Cyclone Gas Duct Expansion Joints	X	
	BOILER CASING WITH SUPPORT STRUCTURE		
221	Buckstays and Tie Bars	X	
222	Support Structure for Insulation (penthouse)	NA	
223	Boiler Guides and Seismic Stops	X	
225	Boiler Casings	X	

* Support steel is not part of the structural steel.

	Item	Supplied By PpC	Supplied By Others
	ASH HOPPERS		
231	Economizer Ash Hopper	NA	
231	Airheater Ash Hopper	NA	
231	Gas Duct Ash Hopper	NA	
	BOILER DOORS AND OPENINGS		
240	Boiler Doors and Openings	X	
	REFRACTORY		
260	Design and Specification	X	
260	Refractory Material	X	
260	Installation		X
932	Refractory Curing		X
932	Fuel for Refractory Curing		X
	INSULATION AND LAGGING		
270	Design and Specification	X	
270	Insulation and Lagging Material	X	
270	Installation		X
	SOLID FUEL FEEDING EQUIPMENT		
302	Solid Fuel Feed Equipment	X	
	FLUIDIZING GRID		
318	Nozzles and Nozzle Pipes	X	
	OIL BURNERS		
341	Start-Up Burner(s)	X	
342	Duct Burner(s)	NA	
343	Bed Lances(s)	NA	
	GAS BURNERS		
351	Gas Fired Start-Up Burner(s)	NA	
352	Gas Fired Duct Burner(s)	NA	
353	Gas Fired Bed Lance(s)	NA	
	MIXED FIRING BURNERS		
364	Combined NG and Oil Startup Burner(s)	NA	
364	Combined NG and Oil Duct Burner(s)	NA	

		Supplied By PpC	Supplied By Others
	BURNER IGNITION AND CONTROL EQUIPMENT		
371	Flame Scanners for Start-Up Burners	X	
371	Local, Common Flame Supervisory Panel	X	
	BURNER VALVE TRAINS		
381	Valve Train for Oil Burner(s)	X	
382	Valve Train for Gas Burner(s)	NA	
388	Pressure Reducing Station for Gas Burner(s)	NA	
	FIRE EXTINGUISHER DEVICES		
390	Fire Extinguisher Devices		X
	SOOTBLOWERS		
401	Steam Rotary Sootblowers	X	
405	Sootblower Control Cabinet	X	
406	Sootblower Valves and Fittings	X	
407	Sootblower Piping	X	
	FLUE GAS AIR PREHEATER		
422	Tubular Airheater	X	
426	Heat Pipe Airheater	NA	
	INDIRECT AIR PREHEATER		
431	STEAM COIL AIR PREHEATER(s)	X	
	FANS AND BLOWERS		
441	Primary Air Fan(s)	X	
441	Secondary Air Fan(s)	X	
441	I.D. Fan(s)	X	
441	Gas Recirculation Fan	NA	
443	High Pressure Fan for Loopseal	X	
	FLUE AND DUCTS		
451	Air Ducts	X	
452	Flue Gas Ducts	X	
453	Circulating Gas Ducts	NA	
454	Windbox(es)	X	
458	Air Flow Measuring Devices	X	

No.	Item	Supplied By PpC	Supplied By Others
470	Stack		X
	CENTRIFUGAL ASH SEPARATORS		
501	Multicyclone Ash Separator	X	
	DUCT COLLECTORS		
511	Electrostatic Precipitator(s)	NA	
515	Pulse Jet Baghouse	X	
	FLY ASH HANDLING EQUIPMENT		
531	Fly Ash Conveyors		X
532	Fly Ash Reinjection System	NA	
537	Fly Ash Silo		X
	BOTTOM ASH HANDLING EQUIPMENT		
541	Bottom Ash Conveyors		X
542	Fluidized Bed Ash Removal System(s)	NA	
543	Center Drain Ash Removal System(s)	X	
547	Bottom Ash Silo(s)		X
	ADDITIVE HANDLING AND FEED EQUIPMENT		
584	Sand Feed Equipment	NA	
585	Limestone Feed Equipment	NA	
586	Ammonia/Urea Equipment	NA	
587	Other Additive Feeding Equipment	NA	
	PUMPS		
611	Water Circulating Pumps	NA	
612	Feedwater Pumps		X
	AUXILIARY PIPING		
621	Atomizing Steam Piping		X
621	Steam Coil Airheater Piping		X
622	Heat Tracing Piping	NA	
623	Cooling Water Piping		X
624	Steam Blow Piping (Temporary)		X
626	Instrument and Plant Air Piping		X
627	Loopseal Air and Seal Air Piping	X	

		Supplied By PpC	Supplied By Others
	FUEL PIPING UPSTREAM OF VALVE GROUP		
631	Oil Piping		X
633	Gas Piping	NA	
634	Ignition Gas Piping		NA
	WATER TANKS		
671	Blow Down Tank		X
672	Continuous Blow Down Tank		X
	AUXILIARY EQUIPMENT FOR PIPEWORK		
691	Silencers for Safety Valves	X	
	ELECTRIC MOTORS		
701	Squirrel Cage Motors	X	
702	Variable Speed Drive Equipment	NA	
	ELECTRICAL		
711	Engineering for Electrical		X
712	Motor Control Centers		X
713	Motor and Control Wiring		X
714	Sootblower Wiring		X
715	Electrostatic Precipitator or Baghouse Wiring		X
717	Field Wiring for Electrical Devices		X
718	Motor Starters		X
	AUXILIARY ELECTRICAL EQUIPMENT		
721	Electric Tracing	NA	
	BOILER INTERLOCKING SYSTEM		
732	Burner Management System (BMS) for Auxiliary Fuel Fired Burners	X	
732	Burner Management System (BMS) for Auxiliary Fuel Fired Burners and Solid Fuel Equipment	NA	
732	Engineering and Design of Boiler Logic Diagrams in Boolean Format	X	

INSTRUMENTATION

No.	Item	Supplied By PpC	Supplied By Others
741	Engineering and Documentation of Instrumentation	X	
742	Primary Field Elements	X	
742	Analyzers	X	
743	Flow, Pressure and Temperature Transmitters for Steam, FW and Combustion Control	X	
744	Feedwater Control Valve	X	
744	Superheater Spray Water Control Valves	X	
744	Reheater Spray Water Control Valve	NA	
744	Steam Supply Control Valve for Steam Coil Airheater		X
744	Electromatic Relief Valve	X	
745	Instrument Piping and Tubing Material		X
746	Installation of Basic Instruments		X
747	Installation of Transmitters, Analyzers, Valves etc.		X
748	Installation of Instrument Piping and Tubing		X
748	Field Wiring for Instrumentation		X

BOILER CONTROL SYSTEMS

No.	Item	Supplied By PpC	Supplied By Others
751	Analog Boiler Control System	NA	
752	Engineering and Design of Functional Control Diagrams in SAMA Format	X	
752	Distributive Control System (DCS) for Control and Monitoring	X	
754	Programming of Control System	X	
755	Installation of Control System		X

BOILER STRUCTURAL STEEL

No.	Item	Supplied By PpC	Supplied By Others
801	Engineering of Structural Steel	X	
802	Supporting Columns and Beams	X	
803	Platforms, Stairs and Handrails	X	
804	Boiler Enclosure Walls and Roof	NA	

HEATING, VENTILATING AND AIR CONDITIONING

No.	Item	Supplied By PpC	Supplied By Others
811	Heating Devices		X
812	Air Conditioning Devices		X
813	Elevators		X
816	Sprinkler System		X

		Supplied By PpC	Supplied By Others
	FOUNDATIONS AND CONCRETE WORK		
821	Engineering of Foundations		X
822	Concrete Foundations with Anchor Bolts		X
	WATER TREATMENT		
831	Feedwater Treatment Equipment		X
	SILOS AND SOLIDS HANDLING EQUIPMENT		
841	Fuel Day Silo		X
842	Limestone Silo	NA	
843	Sand Silo	NA	
846	Dust Control System for Silo Vent		X
847	Storage Silo(s)		X
849	Conveyors and Crusher(s)		X
	QUALITY CONTROL		
870	Quality Control	X	
	SPARE PARTS		
891	Spare Parts Inventory		X
899	Spare Parts for Start-Up	X	
	FREIGHT AND TRANSPORTATION		
910	FREIGHT AND TRANSPORTATION F.O.B. NEAREST PORT TO MANUFACTURE	X	
	ERECTION		
928	Erection Site Management	X	
931	Erection of PpC Supplied Equipment		X
936	Painting at the Site		
	Touch-up Painting		X
	Final Painting		X
	CHEMICAL CLEANING		
961	Acid Cleaning		X
	•Supply and Disposal of Chemicals		X
962	Boilout		X
	•Supply and Disposal of Chemicals		X

COMMISSIONING AND TRAINING (REFER TO SECTION 8)

		Supplied By PpC	Supplied By Others
971	Plant Personnel Onsite Training	X	
972	Advisory Services for Commissioning	X	
973	Auxiliary Labor for Start-up		X
974	O&M Manuals	X	
975	Performance Testing		X
	Advisory Services for Performance Testing	X	
	Emissions Tests and Laboratory Tests		X
	Other		
	Boiler Plant Outside PpC Terminal Points		X
	Consumables for Equipment Operation		X
	Cooling Water, Service and Instrument Air		X
	Applicable ASME Code Stamps	X	
	Protective Coating of Pressure Parts	X	
	Standard Shop Prime Painting of Auxiliaries	X	

3.3. TERMINAL POINTS (Per one boiler)

Fuels and Limestone

a. Oil shale: Inlet flange to oil shale silo isolation valve.

b. No. 2 oil: No. 2 oil inlet to each start-up burner valve group.

Steam/Water

a. Superheater Outlet: Superheater outlet piping terminating at the outlet of the stop valve located at the superheater outlet with a maximum of ten (10) feet of main steam interconnecting piping.

b. Safety Valves: Outlet of vent stack located eight (8) feet above top of the boiler steel.

c. Electromatic Relief Valve: Outlet of the common ERV and start up valve silencer.

d. Start-up Valve: Outlet of the common ERV and start up valve silencer.

e. Vents: Outlet of second valve. Both valves will be close connected to source.

f. Atomizing Steam: Atomizing steam connection on each start-up burner.

g. Steam Coil Airheater: Inlet to steam connection and outlet to the condensate connection on the steam coil airheater.

h. Economizer Inlet: Economizer inlet terminating at the inlet to the feedwater check valve located at the economizer inlet header elevation. Maximum of ten (10) feet of feedwater piping.

i. Desuperheater spray water: Inlet to each desuperheater control valve set.

j. Drains: Outlet of second Boiler Code valve. The first valve will be close connected to the source with the second valve five (5) feet above the ground floor.

k. Blowdown: Outlet of blowdown metering valve located five (5) feet above the boiler ground level.

l. Cooling Water: Inlet and outlet connections at each individual user.

m. Chemical Feed: Inlet to first of two valves close connected to drum.

n. Sampling Connections: Outlet of second valve close connected to sample connection.

<u>Air</u>

a. Connections for instrument air at each individual user.

b. Connection for service air at each individual user.

Ash

a. Outlet flange of each multiclone hopper.

b. Outlet flange of each furnace bottom ash screw cooler.

c. Outlet flange of each baghouse hopper.

Ducts

a. Inlet to silencers mounted on air fans.

b. Outlet flange of I.D. fan.

Electrical

a. Motor terminals.

b. Boiler field instrumentation (where provided) terminals.

c. Local control panel input and output terminals.

d. Boiler metal thermocouple terminals in local terminal boxes. All other thermocouples will terminate at the thermocouple head connection.

4. DESIGN REQUIREMENTS

4.1. SITE SPECIFIC SERVICES

The boiler will be located outdoors in Jordan.

Cooling Water

Adequate cooling water will be made available by Others as required for miscellaneous service requirements:

	Design
Supply Pressure	50 psig
Return Pressure	30 psig
Design Pressure	150 psig
Supply Temperature (max)	90°F
Return Temperature	110°F

The cooling water shall have a water quality which precludes concerns about the fouling and corrosion of heat transfer surfaces as a result of dissolved solids, corrosion products, mud, silt or other debris.

Instrument Air

Others shall supply adequate instrument air at the following conditions:

Supply Pressure	80-100 psig
Dewpoint	-40°F

Plant Air

Others shall supply adequate plant air. Plant air shall be unfiltered, but reasonably free from dirt, moisture, and oil.

Supply Pressure	80-100 psig

Electric Power

The Buyer shall provide appropriate sources of electric power for motors and electrical equipment supplied by Pyropower.

Site Conditions

a. Barometric Pressure Average	27.3 in Hg
b. Site Elevation	2700 feet above mean sea level

c. Reference Conditions

- Reference temperature for efficiency calculations: 100°F
- Reference conditions for lagging face temperature

Temperature Difference (Lagging face to ambient)	80°F
Air Velocity	50 ft/min.

d. Air Temperature

Maximum Temp.	110°F
Minimum Temp.	40°F

e. Moisture, lb/lb Dry air — 0.013

f. Wind

Design Wind Speed	___ per ANSI A58.1-1982

g. Seismic Factor — Zone 2

h. Snow

Design Snow Load	N/A

4.2. DESIGN BASIS

A. DESIGN SPECIFICATIONS

The equipment described in this preliminary design study has been developed jointly with the other project participants.

B. DESIGN CONDITIONS

The boiler design is based on the following conditions, while firing the performance fuel.

	Temp. Control Load (75% MCR)	Maximum Continuous Rating
Superheater, Outlet		
Flow, lb/hr	375,000	500,000
Pressure, psig	1550	1550
Temperature, °F	955	955
Feedwater to Economizer		
Temperature, °F	370	370
Feedwater to Desuperheater		
Temperature, °F	370	370
Ambient Air		
Temperature, °F	80	80
Relative Humidity, %	60	60
Blowdown		
Percent blowdown, %	1	1
Flue Gas Exit Temperature		
Temperature, °F	279	300

4.3. FUELS

General

The boiler has been designed to burn oil shale as listed below:

JORDAN OIL SHALE ANALYSIS
(Percent by Weight)

	Performance	Worst Case	Best Case
Moisture	3.20	3.20	3.20
Ash (less CO_2 in $CaCO_3$)	66.80	67.30	66.25
CO_2 (in $CaCO_3$)	13.87	14.14	13.37
Carbon (Organic)	11.32	10.20	12.50
Hydrogen	1.13	1.02	1.25
Nitrogen	.48	.58	.38
Sulfur	2.55	2.38	2.71
Oxygen (by diff.)	.65	1.18	.34
TOTAL	100.00	100.00	100.00
HHV, BTU/lb	2,250	2,000	2,500
Oil Content, %	8.40	7.50	9.25

Size, 1/4"x0

All fuel fired in the boiler must have an acetic acid soluble sodium (Na) and potassium (k) less than 0.05% (500 ppm) on a dry basis.

No. 2 fuel oil will be used as a start-up fuel.

4.4. LIMESTONE

Due to the inherent calcium carbonate in the oil shale, limestone injection is not required for this application.

4.5. EMISSIONS

The boiler will be designed to reduce boiler emissions to the following levels at MCR when firing the performance shale oil.

Pollutant	
NOx	0.6 lb/MMBtu of fuel heat input
Particulate	0.03 lb/MMBtu of fuel heat input

4.6. BOILER FEED WATER AND DESUPERHEATER WATER

Feedwater and desuperheater water shall be supplied to the boiler with a quality better than or equal to that listed below:

Total Dissolved Solids	1	ppm
Silica	0.02	ppm
Total Iron	0.01	ppm
Total Copper	0.01	ppm
Total Organics	0.01	ppm
Oxygen	0.007*	ppm
Chlorides	0.01	ppm
Hydrazine	0.02	ppm
Sodium	0.01	ppm
pH (Copper Free System)	9.2-9.4	
pH (Copper Alloy System)	8.8-9.2	

* Lower levels to be achieved with oxygen scavenger

4.7. BOILER CHEMICAL TREATMENT

In the operating pressure range of 1550 psig, the coordinated phosphate/pH method of boiler water treatment is recommended. This system provides for application of materials in such a way that internal passivation by phosphate occurs and the boiler chemistry is maintained in such a manner that corrosion by caustic attack can not occur.

4.8. CODES AND STANDARDS

This proposal is based on the supply of equipment and services which comply with the United States of America codes, standards and regulations in effect at the time of the proposal. Equipment design and fabrication will be in accordance with the applicable sections of the following industrial codes, standards and publications:

- The design and fabrication of the boiler and its component elements will comply with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and American Boiler Manufacturers Association (ABMA) codes and standards.

- Power piping and related work will conform to the Power Piping Code (ANSI B-31.1).

- Pipe, fittings, flanges and bolting will conform to the product standards of the American National Standards Institute (ANSI).

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- Materials will be furnished in accordance with the American Society for Testing and Materials (ASTM) specification or the American Iron and Steel Institute (AISI).

- Electrical and electronic components and enclosures will conform to the National Electrical Manufacturer's Association (NEMA).

- Instrumentation, controls and related work will conform to the Instrument Society of America (ISA) standards.

- Welding and related work will, as a minimum, conform with the American Welding Society (AWS) standards, and ASME Section IX.

- Other recognized codes and standards will be used where required to serve as guidelines for the design, fabrication, and construction, when not in conflict with the codes and standards listed above.

5. EQUIPMENT DESCRIPTION

All equipment information is preliminary.

5.1. PRESSURE PARTS

General

All material, equipment and accessories supplied will be of high quality and suitable for the conditions expected. All material and equipment offered are new and unused.

The design, materials, manufacturing methods and factory testing will comply with the ASME Boiler Code and will bear the standard ASME power boiler (S) stamp.

All welding will be performed in accordance with qualified welding procedures. Procedure qualifications and welder performance qualifications will be in accordance with either ASME Boiler and Pressure Vessels Code or the ANSI B 31.1 of Code for Pressure Piping.

Pyropower will provide the services of a competent representative to assist the erection subcontractor in ensuring that erection procedures and the assembled pressure parts are in accordance with Pyropower's design standards.

The field assembly of the pressure parts will be performed by a competent erection subcontractor possessing an assembly (A) and a pressure piping (PP) stamp. It will be the responsibility of the erection contractor to provide for inspection in accordance with ASME code requirements, apply the required stamp and execute the "Certificate of Field Assembly" as required by local and state laws.

Steam Drum

The steam drum is made of carbon steel plate, welded construction, with a cylindrical shell and dished heads. Manholes with hinged covers are provided at each end of the drum. All drum nozzles are provided with ends prepared for welding.

Steam drum internals provide for proper feedwater distribution, steam/water separation, collection and transfer of continuous blowdown water and internal chemical treatment distribution. A deflection plate and centrifugal water separators are located in the steam drum to provide optimum separation of the steam water mixture leaving the combustion chamber membrane walls. Separators have bolted connections to facilitate removal prior to boiler chemical cleaning. A demister and a perforated distribution plate are provided in the steam drum to ensure high quality steam leaving the drum.

Combustion Chamber

The combustion chamber is a gas-tight enclosure which is fully water-cooled by membrane walls. The lower combustion chamber is a refractory lined, water-cooled enclosure. Openings are provided in the combustion chamber walls to allow for the following connections:

Solids return and fuel inlet (loopseal).
Front wall fuel feed.
Ash outlets.
Limestone inlets.
Burner inlets.
Temperature and pressure instrument penetrations.
Gas ducts to cyclone.
Access openings.

Seal plates at wall penetrations, headers, and piping are provided. All headers, distribution piping, and feed-pipes are provided. Each lower distribution header is equipped with one or more openings closed by welded caps for internal inspection and cleaning.

The complete combustion chamber assembly is arranged for natural circulation. Saturated water from the drum is delivered via downcomers to the downcomer bottles. From the downcomer bottles, supply pipes feed the combustion chamber lower headers via natural circulation, eliminating the need for circulation pumps and reducing mechanical complexity.

The steam/water mixture from the combustion chamber wall tubes is collected in the upper combustion chamber headers and returned to the steam drum via riser tubes. Steam/water separation takes place in the drum.

The combustion chamber operates at a positive pressure and the membrane walls incorporate buckstays and tie bars arranged and designed to withstand a design pressure of ± 35 inches w.g.

Economizer (Bare tube)

The economizer is a bare tube, in line, horizontal serpentine type. The economizer tubes are supported by straps The tubes of the final economizer bank are bent up and welded to the economizer intermediate headers. Hanger tubes connect the intermediate header to the outlet header.

Convection Cage

The convection cage is constructed of gas tight, membrane walls braced with buckstays and tie bars. It is cooled with dry saturated steam from the steam drum.

Primary Superheater

The primary superheater is arranged in banks with a sootblower cavity between the banks. Each bank is top supported by hangers.

Radiant Superheater (Wing Wall)

A radiant wing wall superheater is located in the upper portion of the combustion chamber. The radiant superheater consists of multiple banks of membrane wing walls perpendicular with the upper front wall of the combustion chamber. Steam from the primary superheater is distributed to the lower radiant superheater headers, up through the wing walls to the outlet headers, and on to the final superheater. The superheater is supported by hanger rods from the boiler steel.

Final Superheater

The final superheater is arranged in one (1) bank. The bank is top supported by hangers.

Desuperheater

Desuperheater stations are located between the primary superheater and the radiant superheater and between the radiant superheater and the final superheater. The desuperheaters are designed to operate so that a portion of the required capacity is supplied from each stage. This offers faster response, better control, and minimizes tube metal temperature excursions.

The desuperheater will be venturi/spray type design. A complete system will be furnished including spray desuperheater, control valve, block valves and piping.

ASME Boiler Code Piping

The following boiler interconnecting piping is furnished:

a) Feedwater piping from the terminal point to the economizer.

b) Feedwater piping from economizer to steam drum.

c) Downcomer pipes with bottles.

d) Supply pipes from the downcomer bottles to the combustion chamber lower headers.

e) Riser pipes from the combustion chamber upper headers to the steam drum.

f) Steam pipes from drum to convection cage.

g) Connecting pipes between superheaters.

h) Main steam pipe from final superheater outlet to terminal point.

i) Blowdown and vent piping as defined by terminal points.

j) Spray water piping from the inlet to each control valve set to each of the desuperheaters.

l) Sootblower steam piping.

Non-Boiler External Piping (within terminal points)

a. Vent piping as defined by terminal points.
b. Drain piping as defined by terminal points.
c. Trim piping.

Boiler Valves and Fittings

Included are drum and main steam safety valves, electromatic relief valve, start-up vent valve, main steam stop valve and feedwater inlet stop and check valves.

For the boiler drum, two bulls-eye, bi-color drum level water gauge glasses are furnished. One glass will be equipped with an illuminator for direct viewing. The other glass will be equipped with a fiber optics viewing system including primary element 500 feet of cable, remote indicator, and hood assembly.

One steam drum full-range pressure gauge is provided in accordance with ASME Boiler and Pressure Vessel Code, Section I, with valves and piping.

5.2. FABRICATED STEEL STRUCTURES

Structural Steel (top supported)

Pyropower will provide all structural steel required for support of the boiler and Pyropower provided auxiliaries. Pyropower will provide hanger rods and lugs. Pyropower will provide platforms, walkways, grating, and handrails including structural steel for their support. The Buyer will provide the structural steel to support the silos and all other equipment supplied by Others.

The following describes the general supporting scheme of the boiler. The steam drum is supported by U-shaped hangers hung from the top grid steel. The combustion chamber is supported off the grid steel using hanger rods attached to the combustion chamber upper walls.

Hanger tubes which form rows are welded to the economizer outlet header. The economizer outlet header and hanger tubes have welded lugs and are supported at intermittent points by hanger rods attached to the structural steel.

Support for the convective superheaters is discussed in section 5.1. The airheater is bottom-supported and expansion joints are provided as required.

The cyclones are supported by welding brackets to the sides and supported on the structural steel. The primary air fan, secondary air fan and induced draft fan are supported on individual foundations at grade.

Hot Cyclone Separator, Expansion Joints, and Loop Seal

The hot cyclone separators and nonmechanical loopseals are fabricated from carbon steel complete with gussets, supports and access openings as required. The separator and loopseal are lined with a two-layer refractory.

The inlet to the cyclone separator is equipped with a high temperature expansion joint. An expansion joint is also provided at the hot gas outlet duct connection to the convective cage and at the cyclone separator down spout to the loop seal.

The expansion joints are high temperature fabric joints which are capable of independent lateral and axial movement without stress. They are designed to withstand combustion chamber temperature and are abrasion resistant.

Casings (uncooled)

The economizer and tubular airheater sections of the boiler have uncooled casings, consisting of an inner steel casing, which is externally stiffened, insulated and aluminum lagged. The steel casings are selected for the temperature environment and consist of flanged panels reinforced and seal-welded at all joints to prevent gas leakage.

5.3. INSULATION AND REFRACTORY

Insulation

On all insulated surfaces, the thickness of insulation shall be designed to prevent the outside lagging face temperature from exceeding 140°F at MCR based on 80°F ambient air temperature and 50 ft/min air velocity. All insulated flat surfaces will be covered with box ribbed aluminum lagging not less than 0.040 in. thick over a moisture barrier. Insulated piping shall be covered with a flat aluminum lagging not less than 0.016 in. thick with moisture barrier.

Locations of insulated surfaces and the insulating materials are shown in Table 5-1.

Thermal insulation and lagging is provided for all equipment provided in this proposal which require if for conservation of heat, maintenance of operating temperature, and personnel protection.

TABLE 5-1

INSULATION AND LAGGING

Item	Insulation Type
Combustion Chamber	Mineral Wool
Convection Cage	Mineral Wool
Horizontal Top Surface of Convection Cage and Combustion Chamber	Mineral Wool with Reinforced Lagging
Steam Drum	Mineral Wool with Reinforced Lagging
Economizer Casing	Mineral Wool
Tubular Airheater Casing	Mineral Wool
Hot Air Ducting	Mineral Wool
Hot Gas Ducting	Mineral Wool
Interconnecting Piping	Calcium Silicate Block

Surfaces which have internal refractory attachednectl not be externally insulated and lagged (with the exception of the bottom of the combustion chamber). Therefore, these surfaces will have skin temperatures which exceed that specified for insulated and lagged surfaces. Personnel protection will be provided for those areas with internal refractory which are normally accessible to plant personnel by providing stand-off guards.

Refractory

Refractory linings are used on the following surfaces of the PYROFLOW boiler:

- High temperature cyclone separator and loop seal.
- Cross duct between combustion chamber and high temperature cyclone separator.
- Cross duct between high temperature cyclone and the convection section.
- Lower combustion chamber.

The hot cyclones, the loopseals, and the ducts which connect the cyclones to the combustion chamber and to the convective cage are lined with two layers of refractory secured by anchors. The inner layer is heat and abrasion resistant. The outer layer next to the cyclone surface insulates the cyclone cold face. Both layers are of castable refractory, and method of application will be by casting and/or gunning. Where gunning is used, care will be taken to ensure that surface finish will not initiate premature erosion or steam spalling during initial heatup. For certain applications refractory brick may be used, instead of castable refractory.

The refractory lining of the lower combustion chamber consists of high temperature abrasive-resistant castable or plastic refractory.

The two layer refractory used in the cyclones, connecting ducts and loop seals is shown in Figure 5-1 and the lower combustion chamber refractory liner is shown in Figure 5-2.

Proof tests will be required from the installer to verify that the inplaced material corresponds to the specification. Samples will be prepared by the installer using methods comparable to those used in installation, i.e. gunned for gunned material, cast of cast material. Test will be conducted on samples per ASTM testing methods appropriate to the following locations:

Combustion chamber lower walls	3 samples
Loop seal	3 samples
Cyclone roof	3 samples

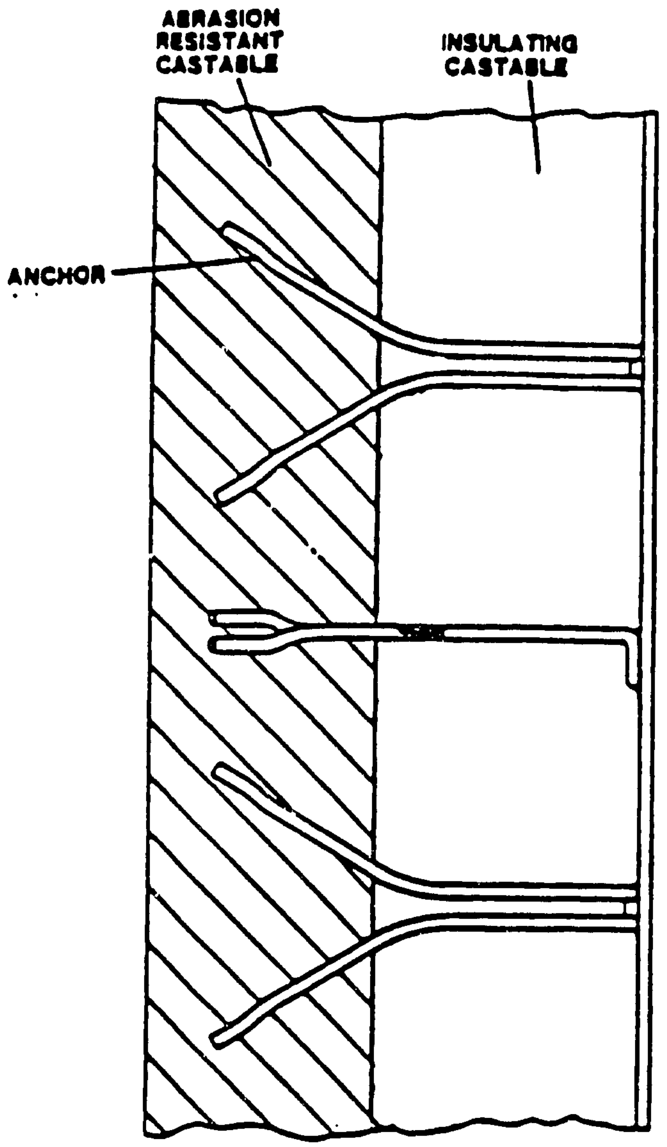
If inplacement extends over more than one day, the three samples will be from different days. Additional samples will be taken if there is a significant hiatus in emplacement or a significant change in conditions.

5.4. FUEL

Fuel Feed System

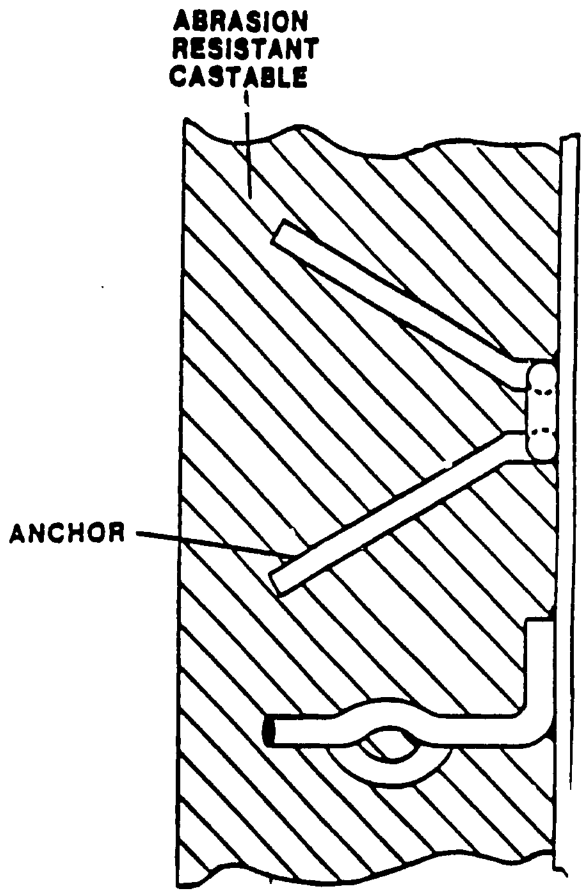
Two types of oil shale feed arrangements are used in this design; 1) combustor front wall feed; and 2) loop-seal(s) feed.

The two feed arrangements are identical up to the feeder discharge. Oil shale flows from the oil shale silo through a manual isolation valve, stand pipe and onto a gravimetric



TWO COMPONENT LINING TYPICAL
FOR LOOPSEAL, AND NON-WATER
COOLED ASH COOLERS

FIGURE 5-1



ONE COMPONENT LINING TYPICAL FOR
WINDBOX WATER COOLED ASH COOLERS

FIGURE 5-2

belt feeder. Oil shale in the standpipe minimizes seal air losses. A seal air fan provides seal air to the feeder to ensure higher pressure in the feed chutes than in the combustion chamber.

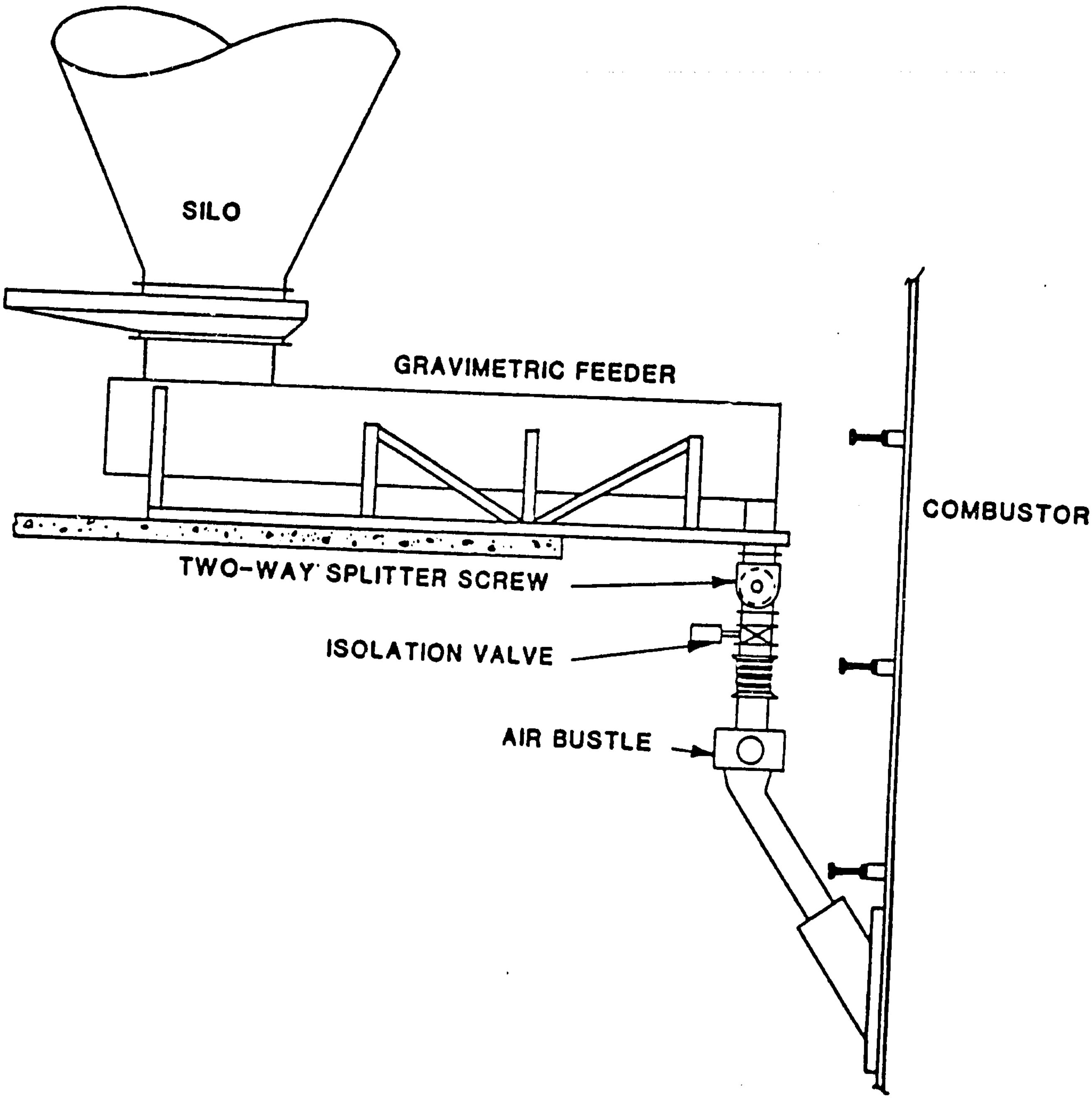
Combustor Front Wall Feed

Oil shale discharges the end of the oil shale feeder into a twin screw conveyor which splits the oil shale feed to two(2) combustor front wall feed points. Fuel travels from the end of the twin screw conveyor, through an isolation valve, feed chute, expansion joint and into the combustor. Secondary air is introduced to the air bustle in the fuel feed chute. Feed chute isolation valves are pneumatically closed in the event of low line pressure or excessive temperature. The combustor front wall feed arrangement is shown in Figure 5.3.

Silo isolation valve(s) (manual)	2
Feeder(s) for front wall feed:	
Quantity	2
Type	Gravimetric belt

Loopseal Feed

Oil shale discharges the end of the oil shale feeder onto an en masse chain conveyor, which carries the fuel along the side of the boiler. A second conveyor picks up the oil shale at the side of the unit and distributes the oil shale to the loopseal(s). Fuel travels from the end of the conveyor, through an isolation valve, feed chute, expansion joint and into the loopseal. Secondary air is introduced to the air bustle in the loopseal feed chute. Loopseal feed chute isolation valves are pneumatically closed in the event of low line pressure or excessive temperature.



FUEL FEED SYSTEM

FIGURE 5-3

Silo isolation valve(s) (manual)	2
Feeders(s) for loop seal feed:	
Quantity	2
Type	gravimetric belt

5.5. BURNERS

Start-up Burners

Start-up burners are to be used during start-up of the boiler using auxiliary fuel as indicated in this proposal. The purpose of the burners is to raise bed temperature sufficiently for solid fuel ignition. The start-up burners will continue in operation until steady state continuous fuel firing has been achieved.

The burners will be supplied complete with electric ignition, flame safeguard equipment, valve trains and local flame supervisory panel. The system will be pre-piped and pre-wired to the maximum extent possible to minimize the amount of field installation. The local panel functions as a flame supervisory panel.

The flame detection system for the startup burners only is a ultraviolet flame detector with a self-checking feature. The flame detector monitors the area of the burner where the root of the flame should be located. The flame intensity is converted to an electrical signal which is used to indicate flame status and initiate the appropriate response. A mechanical shutter is used for the self-checking feature.

The burners will be installed in the lower combustion chamber.

5.6. SOOTBLOWER SYSTEM (Rotary)

A steam operated rotary sootblowing system is used to maintain clean surfaces throughout the boiler.

Each blower will be furnished with an electric motor, motor starter, and local push button starter.

The control logic will be microprocessor based. It will interface with the main digital control system.

5.7. TUBULAR AIRHEATER

An air-in-tube airheater has been proposed for this application. A two-pass design is used for both primary and secondary air. The secondary air section is nested inside the primary section. Tube bank height is optimized to ensure positive cleaning of tube surface by sootblowers. The tubes are arranged horizontally and are split into sections. Each section has the tubes expanded into both tube sheets.

Also included is a gas-tight, stiffened casing and turn around ducts. The inlet and outlet gas and air connections will be attached with bolted flanges to the appropriate ducts.

5.8. STEAM COIL AIRHEATER

A steam coil airheater is included for the primary air stream. The steam coil airheater is used during boiler low load operation to avoid any condensation on the lower tubular air heater tubes. Steam supply to the airheater will be 150 psig saturated steam provided by the Buyer.

5.9. FANS

Two centrifugal fans and one high pressure centrifugal fan are required to supply fluidizing and combustion air to the PYROFLOW combustor.

The primary air fan provides the fluidizing air flow to the bottom of the combustion chamber. Fan capacity is controlled by inlet guide vanes.

The secondary air fan provides the remaining portion of the combustion air required. The secondary air is injected into the furnace at two (2) elevations. Fan capacity is controlled by inlet guide vanes.

The high pressure fan supplies fluidizing air to the nonmechanical solids recirculation loop seals.

An induced draft fan is provided to extract hot flue gas from the combustion chamber outlet through the hot cyclone, boiler convection section, ducts and baghouse and to discharge the gas into the stack breeching. Fan operation is controlled by inlet guide vanes.

Each fan is complete with flexible couplings, coupling guards, inlet vanes or dampers with actuators, gaskets, sole plates, silencers (where applicable) and motors. Motors, are sized for continuous operation of the fans at their test block rating.

All fan housings are split to facilitate removal of the fan housing without disturbing the inlet and outlet duct connections. Inspection doors and drain connections are furnished on each fan housing.

Fans are furnished with horizontally-split, positively-lubricated, self-aligning sleeve bearings supported by heavy pedestals resting on suitable soleplates. Cooling water piping is at least 1/2-inch Schedule 40 galvanized pipe.

The fans are sized for combustion of the range of fuel listed in Section 4 at MCR load and then the test block margins are applied to obtain the proper fan selection basis.

The high pressure loop seal air fan is furnished complete with inlet filter/silencer, motor and baseplate.

<u>MCR Conditions</u> (Performance Fuel)

	Primary Air	Secondary Air	Induced Draft
Flow, lb/hr	428,300	217,450	750,455
Temp., °F	80	80	300
BHP	1,418	415	1245

<u>High Pressure Loopseal Fan</u>

MCR Conditions

Flow, lb/hr	13,200
Temp., °F	80
BHP	262

5.10. AIR AND GAS DUCTING

The following air and gas ducting is provided:

1. Combustion Air

Primary air inlet ducting from the silencer inlet to primary air fan.
Primary air fan discharge to combustion chamber inlet windbox.
Secondary air inlet ducting from the silencer inlet to secondary air fan.
Secondary air fan discharge to secondary air nozzles.
Secondary air to burner system and fuel feed system.

2. Boiler Flue Gas

Airheater ash hopper outlet to baghouse.
Baghouse to induced draft fan.

All main air and flue gas ducting is made of carbon steel. All ducts are properly externally stiffened and reinforced to prevent vibration and to withstand the operating pressures. The ducts are of all welded construction, except at connections to dampers, fans, boiler, etc. Joints are bolted, flanged connections with bolts and gasketing designed for the intended service. The ducting is complete with access doors, dampers, bellows joints and instrument connections.

Clean-out and access doors are provided. The doors are of fabricated steel construction and gas tight.

A hopper is provided below the economizer and at the baghouse inlet. The hoppers terminate with flanged connections which join to the customer's ash removal system.

5.11. MECHANICAL DUST COLLECTOR

A high efficiency multicyclone dust collector will be provided. The multicyclone collector will be installed at the outlet of the tubular airheater. Hoppers are provided below the multicyclone. The hoppers terminate with flanged connections which join the Buyer's ash removal system.

5.12. BOTTOM ASH REMOVAL (Center Drain)

Bottom ash will be removed on a continuous basis from the combustion chamber. At each location bottom ash is discharged through a special bed drain system into a water-cooled screw conveyor.

The cooled bottom ash is discharged from each screw conveyor into the Buyer's ash handling system. The rate of ash removal from the combustion chamber is regulated by the variable speed drive on the screw cooler in order to maintain a constant solids inventory in the combustion chamber.

5.13. BAGHOUSE (Pulse Jet)

General

A pulse jet fabric filter dust collection system is proposed to reduce the flue gas content to meet the required particulate emissions. The dust collection system is designed for either on line or offline cleaning and the cleaning cycle can be initiated by demand or by baghouse pressure drop.

Pulse-Jet Off-Line Cleaning

A high efficiency pulse-jet cleaning system is provided utilizing off-line cleaning as the mode of operation with the alternate mode of on-line cleaning.

Bag Access

Bag access will be provided with the manufacturer's standard lift off door design. Each module will be covered by a gas tight door which will be lifted by a two ton electrically operated chain hoist. Complete bag access is available to a particular module once the door is lifted.

A penthouse is provided above the module access walkways and lift off doors for weather protection. The penthouse roof and siding will be constructed of 26 gauge galvanized steel. One roll-up maintenance door and one personnel door are provided. A ventilating fan, intake louvers and other accessory items will be provided to ventilate the penthouse enclosure.

Bypass

Flue gas can be bypassed from the inlet to the outlet manifold through a pneumatically operated, double-seated poppet valve. The bypass damper is automatically opened if the inlet temperature or baghouse differential pressure exceeds preset limits.

Expansion Joints

Expansion joints have been provided at the inlet and outlet connections to the baghouse and on the inlet and outlet duct connections to each module.

Baghouse Support Structure

The baghouse will include all structural steel for supporting the baghouse. All structural steel will be prime coated and will conform to ASTM Standard A-36. Bolting materials for structural steel connections will be high strength bolts. Bolting materials for miscellaneous structural steel such as stairs, ladders, handrailings, walkways and platforms will conform to applicable code standards.

Controls

The baghouse control system will be microprocessor based and will interface with the digital control system.

Hoppers

One (1) hopper fabricated of mild steel plate with 55° minimum valley angles (from horizontal) will be provided for each module. Each hopper will be provided with one (1) quick-opening hinged access door and will include a outlet flange to accommodate ash handling valves supplied by others.

Inlet and Outlet Manifolds

One (1) inlet and one (1) outlet manifold will be provided per compartment, including transition pieces and appropriate expansion joints. Manifolds will be all welded gas tight construction. Access to the inlet manifold will be through a access door. Manifolds will be tapered to maintain uniform gas velocity and sized to minimize premature settling of dust. Inlet manifold transition pieces to each module will be located at or near the bottom of the manifold to assist in sweeping any settled dust into the module.

Isolation Dampers and Lockout System

Each module will be provided with pneumatically actuated inlet and outlet dampers supplied with limit switches to give positive indication of damper open and closed positions. Dampers shall fail in a fail safe position upon loss of plant air.

Inlet dampers will be butterfly dampers and outlet dampers will be the poppet damper type.

Bags, Cages and Accessories

Bags will be supplied with attachments that permit easy and dust tight installation. Bag cages shall be of one (1) section for ease of installation and constructed. There will be no rough spots on cages to cause bag abrasion or failure.

Design Parameters

MCR gas flow, acfm	268,885
Inlet gas temperature (°F)	300
Inlet loading, gr/ACF	18
Outlet loading, gr/ACF	0.01
Air-to-cloth ratio: gross	3.71
Air-to-cloth ratio: Net (with one compartment out of service)	4.00

5.14. CONTROL & INSTRUMENTATION

General Description

The control system for the CFB boiler will be designed to provide start-up, automatic control and monitoring of the following systems:

- Combustion
- Furnace draft
- Drum level and feedwater flow
- Main steam temperature
- Furnace inventory
- Auxiliary fuel start-up burner
- Safety system

The following control schemes are developed to meet the design requirements for control of the systems listed above.

- Main steam (or boiler) demand
- Fuel feed control
- Air flow control
- Steam drum level/feedwater flow control
- Furnace draft control
- Desuperheater spray flow control
- Bed temperature control
- Bottom ash cooling and removal
- Process monitoring
- Interlocks and permissives
- Secondary air pressure

Control Philosophies

The following descriptions provide the control philosophies used in developing the control schemes discussed above.

Steam (or Boiler) Demand

The boiler master demand controls steam pressure at a selected set point by varying fuel and air flow rates to respond to changes in total steam flow, fuel heating value, etc. This is accomplished by an analog control loop balancing the output of the main steam pressure controller with steam flow. The control loop is characterized for boiler performance to insure that load changes occur at a rate compatible with the dynamics of the boiler. This control loop provides the demand signal for fuel feed and air flow control.

Fuel Feed Control

The combustion control utilizes a lead-lag system to prevent a fuel-rich mixture occurring in the furnace. Air flow is always increased before fuel flow increases and fuel flow is always decreased before air flow decreases.

The fuel feed control loop maintains fuel flow to the bed in balance with boiler demand and combustion air flow. This is accomplished by comparing boiler demands, air flow and fuel flow with the resulting signal used to modulate the fuel feed rate.

Air Flow Control

Total air flow demand is determined as a function of boiler demand and fuel feed rates. This total air flow requirement is satisfied through the primary and secondary air flow rates. Primary air provides the air required for fluidization of the delivered fuel. Secondary air optimizes fuel and air mixing and provides staged combustion to minimize NO_x production.

The primary air flow rates to the grid nozzles are calculated as a function of the demand signal then compared with actual air flow. The resulting outputs are biased by the output of the bed temperature control loop and are used to modulate the air control dampers.

The secondary air flow rates to the air nozzles are calculated as a function of the demand signal then compared with the actual air flow. The resulting outputs biased by the output of the oxygen and bed temperature control loops and are used to modulate the air control dampers.

Primary and secondary air duct pressures are input to pressure control loops which control the primary and secondary air fan to insure that the required air is being provided.

Steam Drum Level/Feedwater Flow Control

A three element drum level control loop is used to control feedwater flow at a rate equal to the steam flow output. The drum level is compared to the setpoint. The resulting output is adjusted by the steam flow measurement which provides feed forward adjustment for rapid changes in process steam usage. This signal is then compared to the feedwater flow with the output used to modulate the feedwater control valve.

Furnace Draft Control

The pressure in the combustion chamber is maintained by imputing an upper furnace draft pressure signal to a pressure controller which controls the induced-draft (ID) fan. A measurement of the combustion air flow from the primary and secondary air fans provides a dynamically compensated feed forward signal for this loop.

Desuperheater Spray Flow Control

Steam temperature is controlled by using a conventional desuperheating spray water system. The steam temperature is regulated by the use of a control valve that controls water flow into the spray nozzle of the desuperheater. The outlet temperature of the superheater is the process variable which is compared to an operator established setpoint. The output of this control loop is the setpoint for the desuperheater outlet steam temperature controller. The final output signal modulates the spray control valve. This type of configuration is a cascade control system which will correct desuperheater outlet temperature before it affects the superheater outlet temperature. Therefore, responds faster to varying desuperheater spray conditions.

<u>Bed Temperature Control</u>

The purpose of this loop is to assist in maintaining bed temperature at its prescribed value due to changes in fuel heating value. Thermocouples are located in the lower combustion chamber to monitor the temperature. The temperatures are averaged to provide a single input signal to the bed temperature controller. Output signals from the bed temperature controllers are input into the primary and secondary air control loops, which modulates both air flows to provide bed temperature control.

<u>Bottom Ash Removal</u>

The purpose of this loop is to maintain the proper bed inventory. The amount of bed material in the furnace is measured by the pressure present in the lower combustion chamber. The rate of ash removal is set by the operator and must be adjusted periodically by the operator based on bed pressure indication.

<u>Process Monitoring</u>

These loops provide the operator with indication of the process parameters necessary for operating the boiler efficiently. These loops consist of pressure, temperature and flow measurements for steam, flue gas, combustion air, fuels and ash.

Interlocks and Permissives

The interlocks and permissives are system designed to provide proper sequencing for start-up and shut down as well as safety and emergency shut down for the following:

- Induced draft fan
- Primary air fan
- Secondary air fan
- Start-up burners
- Fuel feeders
- High pressure blowers
- Bottom ash removal equipment
- Other equipment associated with the PYROFLOW boiler

The interlocks and permissives are designed to comply with the applicable requirements of NFPA, IRI and ASME.

Secondary Air Pressure

The objective of secondary air pressure control is to insure duct pressure for controlling the secondary air flowrates. If secondary air flow is too low or too high, inefficient combustion will occur. This optimal pressure is maintained by feeding a duct pressure signal to the secondary air pressure controller and modulating the secondary air fan damper.

Equipment and Information Description

The Pyropower scope of supply will include instruments as outlined in section 3 of this proposal. As indicated in the start up burner description, a local flame supervisory panel will be provided with the start up burners.

All permissive, interlock, combustion control, and process control and logic will be done by the Distributive Control System (DCS).

5.15. DISTRIBUTED CONTROL SYSTEM (DCS)

Scope of Supply

Control processors.
Field bus modules.
Application processor with 80 MB Winchester disk drive and floppy disk drive.
Work station processors.
Work station color CRT monitors & alphanumeric keyboards.

Equipment Description

The Distributed Control System (DCS) is a microprocessor based Cathode Ray Tube (CRT) system, capable of performing all digital, analog control, data acquisition functions, paging historical storage and retrieval, report generation and alarming.

All control monitoring, computation and data storage elements are completely redundant, as well as all communication paths. All operator displays are independent; no single failure any where in the system can cause loss of control. Operator interaction with the system is totally consistent from any console in the plant. Basic interaction method is pulldown menu approach. System is of the modular component type which facilitates installation and maintenance. Modular design and diagnostic makes the system easy to maintain. If a module failure occurs, the operator is notified at the console. A redundant module takes over the operation. The failed module can then be replaced.

Configuration of applications can be accomplished at a single console for the whole system. Configuration can be through a CRT console or a personal computer.

Control system will be capable of performing the following functions.

- I/O: Analog Input, Contact Input, Analog Output, Contact Output, DIO Multi-point Processing, Flow Calc., Voting.
- Control: PID with options, EXACT, Ratio, Bias, Differential Gap, Pulse Duration.
- Selection: High, Low, Switch Position, Vote.
- Miscellaneous: Universal Ramp, Timer, Trip Recorder, Status.
- Dynamic Compensation: Impulse, Lead-Lag, Dead-Time.
- Computation: Add/Subtract, Multiply/Divide, Square Root, Exponential.
- Compensation and Conversion: Characterize, Pulse Counter, Accumulator, High/Low Clamp, Rate of Charge Clamp, Packed Boolean, Historian.
- Boolean: AND, OR, NAND, NOR, XOR, NXOR.

- Logic: Logic Switch, Compare, Bi-Directional Delay, On-off with Feedback, Motorized Valve.

- Alarm and Analysis: Real Type Alarm, Boolean Type Alarm, Truth Table Alarm, Alarm Priority Change, Sequence of Events.

- PLC: No Contact, NC Contact, Energized Coil, Latch Coil, Unlatch Coil, Retentive Timer On-Delay, Retentive Timer Reset, Up-Counter, Down-Counter, Counter Reset, Compare, Program Flow Control, Immediate Input, Immediate Output.

- Sequential Control: User Written via High Level Batch Language (HLBL).

These control blocks can be combined to form a compound type. The compound types are generic control strategies which can be re-used. Application of a user process data base to a block, or a compound type, makes a compound which is then executed in the Control Processor. Blocks and compound types can be nested to form a compound. A compound has a unique system wide name, and this uniqueness is enforced by the Control Processor station. The parameters in a compound can be linked internally to another compound or externally to compounds running in other Control Processor stations.

Alarms and status messages are generated by specific alarm blocks within a compound, not built into other blocks. Each alarm block can be assigned a GROUP and a PRIORITY number independent of the compound in which the alarm resides. Alarm messages destination devices are globally assigned on a GROUP basis (e.g., annunciator pushbuttons, printers, alarm history station, etc.).

Alarms have five levels of priorities to aid the operator in quickly focusing on the most important plant alarm conditions. These are summarized in a single alarm summary parameter for each compound (contains the highest current alarm in that compound). Additionally up to 8 logical destinations can be configured for distributing alarm status information in the network.

To reduce nuisance alarms, alarms may be inhibited on a per alarm basis. Or all alarms can be inhibited on a per block or per priority level.

Computing and application functions are also provided. The following are the basic functions:

- Compute Resources
- Historizing and Data Base Management
- Load Server for configuration programs and configuration files.

The DCS system consists of control processors, field Bus modules, communication processor, dot matrix printer, application processor with 80-MB winchester disk drive and floppy disk drive for trending and data base storage, work station processors, work station CRT color monitors and APPHA numeric key board.

Pyropower is responsible for supplying any documentation to the DCS vendor for configuration and implementation of Pyropower supplied system, i.e., Boiler, feeders etc. Supplies of balance of plant equipment will be responsible for providing all documentation in the appropriate format to the DCS supplier for configuration and implementation.

5.16. DOCUMENTATION

Pyropower will supply contract documentation in the form of drawings and equipment lists. Detailed shop drawings will not be issued to the Engineer or Customer. Drawings will be in sufficient detail for erection of the equipment.

A typical list of contract drawings is shown in Table 5.16. Pyropower will transmit eight (8) blueprints and one (1) sepia for each issue of a particular drawing.

Pyropower will provide equipment lists which outline equipment information as follows:

- Motor list.
- Valve list.
- Instrument list.
- ISA data sheets.
- Major boiler equipment

TABLE 5.16.

TYPICAL CONTRACT DRAWINGS

		SIZE
1.0	Arrangement drawings	E
	• General arrangement	E
	• Duct layout	E
	• Platform arrangement	E
	• Sectional arrangement	E
2.0	P & ID	
	• Steam/water	E
	• Air/flue gas	E
	• Fuel/limestone/ash	E
	• Startup burner	E
3.0	Control and Instrumentation	
	• Digital Logic Diagrams (Boolean Format)	11" x 17"
	• Analog Control Diagrams (SAMA Format)	11" x 17"
	• Instrument Location Drawings	E
	• Instrument Installation Details (IID)	11" x 17"
4.0	Vendor Drawings	
	PpC purchased equipment	Vendor Standard
5.0	Detail Drawings	
	• Pressure part details	E
	• Structural details	E
	• Auxiliary fuel system	E
	• Main fuel system	E
	• Refractory and insulation	E

6. PREDICTED PERFORMANCE

6.1. PERFORMANCE DATA

LOAD CONDITION % MCR	100%	75%
TYPE OF FUEL	Jordanian Oil Shale	Jordanian Oil Shale
STEAM LEAVING SH, MLB/hr	500.0	375.0
EXCESS AIR, %	20%	20%
CALCIUM TO SULFUR MOLAR RATIO	N/A	N/A
FUEL HEAT INPUT, MMBTU/hr	734.6	562.56
QUANTITY, MLB/hr		
Fuel	303.6	232.5
Air	658.9	504.6
Flue gas	740.5	567.0
Ash (Total)	220.0	170.0
Fly ash, % of total ash	55.0	30.0
PRESSURE, PSIG		
Econ. inlet	1750	1674
Drum	1715	1643
Superheater outlet	1550	1550
STEAM/WATER TEMPERATURES, °F		
Entering economizer	370	370
Leaving economizer	534	527
Leaving Drum	615	609
Superheater outlet	955	955
AIR TEMPERATURES		
Entering fans	80	80
Leaving fans (weighted aver.)	100	100
FLUE GAS TEMPERATURES, °F		
Leaving furnace	1600	1510
Entering economizer	952	892
Leaving economizer	516	488
Entering airheater	516	488
Leaving airheater	300	278

LOAD CONDITION % MCR	100%	75%
Net efficiency	76.15	74.59

PREDICTED PERFORMANCE IS BASED ON COMBUSTION AIR LEAVING FANS AT A WEIGHTED AVERAGE TEMPERATURE OF 100°F WITH 0.013 LB MOISTURE/LB DRY AIR AND 13.40 PSIA BAROMETRIC PRESSURE.

7. PROJECT SCHEDULE

A schedule depicting the engineering, manufacturing, construction and start-up/testing activities is included in this section. This schedule is predicated on two (2) key milestones:

1. Foundations in place ready for erection by 10-1/2 months after contract award.

2. Turbine roll and synchronization by 27 months after contract award.

Pyropower's project involvement is currently allotted 27 months from the contract award to turbine synchronization. Note that a second unit on the same site would lag this schedule by approximately two months.

Milestone dates associated with Pyropower's scope of work are:

<u>Months after Contract Award</u>

0	-	Notice to proceed.
2	-	Preliminary boiler design completed. Place the major boiler pressure parts order.
3	-	Prepare equipment specifications. Begin material and equipment procurement.

10-1/2	-	Foundations in place ready for erection. Erection contractor mobilized. Begin boiler erection.
20	-	Final major equipment delivered to project site.
21	-	Boiler hydrostatic testing completed.
23-1/2	-	Begin equipment checkout.
25-1/2	-	Ready for steam blows.
27	-	Initial turbine roll and synchronization.

Activities comprising the detailed boiler design portion of the schedule include completion of process and design calculations; preparation of purchased equipment specifications; and completion of general arrangement and layout drawings, piping and instrumentation diagrams, fuel and air flow diagrams, boiler and equipment load diagrams, electrical schematics, control and instrumentation schematics, structural drawings, and all associated detail and routing drawings. Engineering support will continue throughout the procurement, construction, and start-up phases.

Only major component purchases are listed in the equipment procurement phase of the schedule. However, orders for virtually all equipment and materials comprising Pyropower's scope of supply will be placed during this period to assure delivery as required by the construction schedule.

The construction phase is projected to span 14 months. Construction must be closely integrated into both the engineering and procurement phases to assure unimpeded erection and subsequent equipment start-up and successful operation. Receiving and temporary storage of materials and equipment is included in this phase, as well as protection and maintenance of equipment throughout the duration of construction activities. All equipment is erected, leveled, coupled, connected and made ready to operate.

As a top-supported unit, erection will progress from the top downward. Construction of the unit will be essentially completed before start up and checkout activities begin 23-1/2 months after contract award. (Boiler hydro is scheduled after erection of the pressure parts and prior to refractory installation).

Start-up and testing involves equipment and systems checkout and initial operation. Temporary burners are installed at several locations in the boiler to dry refractory in the cyclones, the wind box and lower combustion chamber, and the crossover ducts. After the refractory is cured the initial boiler firing (on secondary fuel) occurs. Boilout, chemical cleaning, and steam blows are completed and steam is made available for initial turbine roll and synchronization. Any operational problems which occur with the equipment are corrected during start-up.

In general, the critical schedule path involves the design, specification, ordering, manufacturing, delivery and erection of the pressure parts. These activities must be carefully controlled and expedited.

APPENDIX 9

BECHTEL POWER BLOCK DESIGN - 50 MW

APPENDIX 9

POWER BLOCK DESIGN
50 MW UNIT

A. DESIGN BASES AND ASSUMPTIONS

1.0 CIVIL AND ARCHITECTURAL

1.1 Site Conditions

Location Topography - The plant is to be located in the Sultani oil shale mine development area of Jordan. The plant site is about 100 KM (160 miles) northeast of Aqaba which is a port city location on the Gulf of Aqaba. The site elevation is 823 meters (2700 ft) above mean sea level. The topography of the area is generally flat rolling desert with very little vegetation.

All major imported equipment for the plant would be unloaded at Aqaba and transported by road to the site. There is a major highway from Aqaba to Amman which passes about a mile away from the plant site. A new road from this highway to the plant is required.

Meteorology - The meteorological site conditions assumed in this study are presented in Table 1. All weather data shown in the table are preliminary and are based on available data for Qutraneh Station.

Table 1

METEOROLOGICAL CONDITIONS

Elevation, meters (MSL) (feet)	823 (2700)	
Atmospheric pressure, mm HgA (psia)	690 (13.4)	
Temperatures, °C (°F)	Dry Bulb	Wet Bulb
Maximum	43 (110)	-
Minimum	5 (41)	-
Average	16 (61)	-
Design	24 (75)	-
Wind Velocity		
Maximum	Not Available	
Average	8-15 Kts.	
Design (assumed for this study)	Not Available	
Prevailing direction	S-W'ly (Winter)	
	W-N'ly (Summer)	
Precipitation	mm (inches)	
Average, yearly	111 (4.37)	
Maximum, yearly	Not Available	
Maximum, monthly	Not Available	

<u>Seismic Area</u> - The seismic activity in the region is not known. For design purposes, Uniform Building Code (UBC) Zone 2 is assumed.

<u>Soil Conditions</u> - The soil conditions are not known. From photos and site visits the surface material appears to be dry gravel and dirt with no outcropping consolidate rock.

1.2 Foundations

Reinforced concrete mat foundations are assumed for the generator unit. Foundations for other structures are assumed to be strip or spread footings founded in the overburden, bedrock or compacted overfill.

1.3 Buildings

An administration facility and a maintenance warehouse facility is required for the power generating plant. Employee service facilities such as locker rooms, water closets, etc., also are required.

In general, all the plant process equipment for the power generating facility except for the boiler and its auxiliaries are located in unheated, covered buildings. Air conditioning to be provided only in the control room and administration office.

2.0 MECHANICAL PLANT DESIGN

2.1 General

The power generating facility consists of one condensing turbine-generator unit. The unit is rated at 59.3 MW gross output at the generator terminals with 103 kg/sq cm Abs (1463.5 psia), 510°C (950°F) turbine throttle steam conditions, 188°C (370°F) final feedwater temperature, and 139.7 mm (5.5 inches) of HgA condenser pressure. Four stages of feedwater heating are used. An air cooled dry condenser is used to minimize plant water consumption.

2.2 Codes and Standards

It is assumed that the conceptual plant design is required to meet U.S. standards for safety of personnel and not required to meet other U.S. standards such as U.S. environmental emission standards.

No environmental protection regulations are yet enforced in the country. Environmental protection requirements as currently adopted by the World Bank are used for the study.

2.3 Design Basis Fuels

The design fuel used in the study is Sultani oil shale. Fuel analysis presented in Table 2. The startup fuel is No. 2 fuel oil.

Table 2

SULTAMI OIL SHALE

	Low Calorific Value Fuel	Performance Fuel	High Calorific Value Fuel
F. A. Oil Content, WT% (Median)	7.5	8.4	9.25
Range, "	6.7-8.3	7.5-9.0	8.4-9.9
HHV, Kcal/Kg (Btu/lb)	1111(2000)	1250(2250)	1389(2500)

Ultimate Analysis

Composition, WT%			
Moisture	3.20	3.20	3.20
Carbon (Organic)	10.20	11.32	12.50
Carbon Dioxide	14.14	13.87	13.37
Hydrogen	1.02	1.13	1.25
Nitrogen	0.58	0.48	0.38
Sulfur	2.38	2.55	2.71
Oxygen (by diff.)	1.18	0.65	0.34
Ash	67.30	66.80	66.25
	100.0	100.0	100.0

Ash analysis is being developed by ORNL.

2.4 Design Fuel Flow Rates

It is assumed that the oil shale mine and materials handling system will do the necessary blending, crushing and sizing of the fuel to make it suitable for firing in the Pyropower boiler.

The design fuel flow rate for the plant is about 148 metric tons/hr (163 tons/hr), or about [illegible]2,400 metric tons/year (1,072,000 tons/year). The above values are based on an annual plant capacity factor of 0.75.

2.5 Process Makeup Water

Process makeup water for the power plant is assumed to come from two 100% capacity deep well pumps. Well water will be used for cooling tower makeup, pump seals and other uses without treatment. Makeup water for the steam cycle will be provided from this source through a set of demineralizers and domestic water will be treated as required. Cooling tower blowdown will be used for ash handling dust suppression. Estimated annual water consumption for the 50 MW power plant at 75% capacity factor is about 0.31 million cu. meters (81.6 million gallons), exclusive of mining and domestic requirements. Well water analysis is shown in Table 3 below:

Table 3

JORDAN SULTANI GROUND WATER ANALYSES

	ppm
Electrical Conductivity	1230
T.D.S	757
Elemental Analysis	
Ca	83
Mg	45
Na	47
K	4.3
Cl	170
SO_3	101
HCO_3	320
NO_3	2.3
TH	392
pH	7.36

2.6 Environmental Design Bases

2.6.1 Flue Gas Emissions

The estimated emissions from the power generating facility are presented in Table 4. These emissions are compared with those from a typical U.S. industrial power plant. The stack height is assumed to be 92 meters (300 ft.).

Table 4

FLUE GAS EMISSIONS

	Kg/10^6 Kcal Heat Input (Lb/10^6BTU)		
	SO_2	NO_X	Particulate
50 MW Oil Shale-Fired Plant	4.29 (2.38)	1.11 (0.6)	0.05 (0.03)
Typical U.S. Coal-Fired Industrial Plant	2.16 (1.2)	1.26 (0.7)	0.18 (0.1)

2.6.2 Solid Waste Disposal

The production flow rate for combined bottom ash and fly ash streams from the boiler plant is 100 metric tons/hr or about 657,000 metric tons/year. To suppress dust emissions the ash discharge is wetted in a pug mill to about 15 to 20 wt% water content.

Wetted fly ash and bottom ash collected in the power generation facility will be hauled away by trucks for disposal. It is assumed that the solid wastes generated in the power generating facility are classified as nonhazardous material and, therefore, can be disposed of safely in the mine.

2.7 Utility and Process Tie-Ins for Cost Estimating

The utility and process stream tie-in data that are assumed for this study are presented in Table 5.

Table 5

UTILITY AND PROCESS TIE-INS

1.	Electrical Power	See Electrical Single Line Diagram E101
2.	Makeup Water	Raw water pump discharge
3.	Fire Protection Water	Well water storage tank at site
4.	Domestic Water	Raw water pump discharge
5.	Compressed Air	A separate compressed air system
6.	Oil Shale	Live storage silo outlet
7.	Sulfuric Acid, Caustic and Ammonia	Truck delivery to site
8.	Hydrazine, Morpholine, Phosphate, etc.	Chemicals delivered in sacks or 55-gallon drums
9.	Carbon Dioxide Gas	Truck delivery to site
10.	Clean Lube Oil	Truck delivery to site
11.	Fly Ash/Bottom Ash	Truck removal from power plant to mine
12.	Wastewater	Holding tank at site for disposal with ash
13.	Dirty Lube Oil	Truck away from plant site

3.0 CONTROL SYSTEMS/ELECTRICAL

3.1 Instruments and Controls

The conceptual design assumes the following control concepts:

- A central control room for plant operation and monitoring.

- Local instruments and controls panels for boiler to enable local startup of boiler and auxiliaries. After start-up, control can be transferred to the central control room

- Single Phase uninterruptible source of power supply at 115 V ac for electronic instruments.

- Critical circuits hard-wired to dedicated control panels.

- Instrument air supply at 6.7 to 8.8 kg/sq cm (80 to 110 psig).

3.2 Electrical

The electrical generation is at 22 kV, 3 phase, 50 Hz. An auxiliary transformer steps down the voltage from 22 kV to 6.6 kV to supply electric power to the various auxiliary equipment in the power plant. Auxiliary power demand is assumed to be about 15.6% of the gross generation at the generator terminals. The generation voltage is stepped up tp 400 kV with a main transformer. The Single Line Diagram E101 shows the scope for electrical work included in this study.

Power requirements at the mine and crushing plant are assumed to be purchased from the national grid.

50 MW UNIT

B. LIST OF MAJOR EQUIPMENT

A. TURBINE AND AUXILIARIES

QUANTITY	ITEM	DESCRIPTION
1	Turbine/Generator	Condensing w/4 uncontrolled extractions Throttle conditions 226.700 kg/hr (500,000 lb/hr) 103 kg/sq cm Abs (1463.5 psia) 510°C (950°F) Extraction conditions 0.4 kg/sq cn Abs (5.7 psia) 1.9 kg/sq cm Abs (27 psia) 5.2 kg/sq cm Abs (74 psia) 12.8 kg/sq cm Abs (182.5 psia) Exhaust conditions 139.7 mm HgA (5.5 in HgA) Output 59.3 MW Generator 70 MVA, 0.9 PF, 22 KV 3 Phase, 50 Hz Including Static exciter Voltage regulator Stop and control valves Lube oil system Electro-hydraulic governor system Gland steam system Turning gear, 15 HP motor Supervisory instrumentation Air cooled generator, exciter, lube oil system
1	Air Cooled Condenser	139.7 mm HgA (5.5 in Hga) 88.3 mm Kcal/hr (350.9 MM Btu/hr)

QUANTITY	ITEM	DESCRIPTION
2	Vacuum Pump	Liquid ring type, 2 stage Motor driven, 200 HP
2	Condensate Pump	Horizontal centrifugal type Motor driven 100 HP 207,700 kg/hr (916 GPM), 88.9 m (290 ft) TDH
1	L.P. Feedwater Heater No. 1	Closed - shell and tube 0.4 kg/sq cm Abs (5.7 psia) extraction pressure 5,600 kg/hr (12,253 lb/hr) extraction flow
	(L.P Feedwater Heater No. 1)	199,700 kg/hr (440,300 lb/hr) feedwater flow 2.8^{o}C (5^{o}F) TTD, 5.6^{o}C (10^{o}F) DC approach
1	L.P Feedwater Heater No. 2	Closed - shell and tube 1.9 kg/sq cm Abs (27 psia) extraction pressure 15,300 kg/hr (33,800 lb/hr) extraction flow 199,700 kg/hr (440,300 lb/hr) feedwater flow 2.8^{o}C (5^{o}F) TTD, 5.6^{o}C (10^{o}F) DC approach
1	Deaerating Heater	Open - deaerating spray type 5.2 kg/sq cm Abs (74 psia) extraction pressure 14,700 kg/hr (32,400 lb/hr) extraction flow 229,500 kg/hr (506,000 lb/hr) outlet flow

QUANTITY	ITEM	DESCRIPTION
2	Feedwater Pumps	Horizontally split case - multistage Motor Drive, 1500 HP 238,700 kg/hr (1150 GPM), 1325 m (4350 ft) TDH
1	H.P Feedwater Heater No. 1	Closed - shell and tube type 12.8 kg/sq cm ABS (182.5 psia) extraction pressure 15,300 kg/hr (33,800 lb/hr) extraction flow 229,500 kg/hr (506,000 lb/hr) feedwater flow 0^oC (0^oF) TTD, 5.6^oC (10^oF) DC approach
1	Bridge Crane	45 ton with auxiliary hook

B. BOILER AND AUXILIARIES

QUANTITY	ITEM	DESCRIPTION
1	Steam Generator	Circulating fluidized bed, drum type, subcritical, natural circulation boiler with the following superheater outlet conditions: 109.9 kg/sq cm (1563.5 psia) 512.8^oC (955^oF) 226,800 kg/hr (500,000 lbs/hr) Economizer inlet 188^oC (370F) Main fuel: Oil Shale 1250 Kcal/kg (2250 Btu/lb) Auxiliary fuel No. 2 fuel oil
1	Air Preheater	Tubular air heater 66,125 sq.ft
1	Primary Air (PA) Fan	Centrifugal, motor driven, 2250 HP 237,500 kg/hr (523,710 lb/hr) 2172 mm (85.5 in) Wg

QUANTITY	ITEM	DESCRIPTION
1	Secondary Air (SA) Fan	Centrifugal, motor driven, 700 HP 120,600 kg/hr (265,885 lb/hr) 1308 mm (51.5 in) Wg
1	High Pressure Blower	Multistage blower, motor driven 350 HP 7350 kg/hr (16,200 lb/hr) 6096 mm (240 in) Wg
1	Induced Draft (ID) Fan	Centrifugal, motor driven, 2,000 HP 416,000 kg/hr (917,400 lbs/hr) 787.4 mm (31 in) Wg
1	Steam Coil Air Heater	U-tube model, 70/30 cu ni Aluminum fins
1	Mechanical Dust Collector	High efficiency, multicyclone type
1	Bag House	Particulate removal equipment, pulse jet type with emergency bypass, inlet flue gas flow 8,255 a m^3/min (291,495 acfm)/149°C (300°F)
1	Stack	Self-supporting concrete with steel liner, 91 meters (300 feet) high
1	Blowoff Tank	1.2 meters (4 feet) diameter x 2.7 meters (9 feet) high, vertical, carbon steel

C. FUEL HANDLING

QUANTITY	ITEM	DESCRIPTION
3	Live Storage Silo	Concrete 12 meters (39 feet) diameter 3000 mton (3300 ton) oil shale capacity

QUANTITY	ITEM	DESCRIPTION
3	Vibratory Feeder	100 mtph (110 tph)
2	Fuel Conveyor From Live Storage To Implant Silo	250 mtph (275 tph)
2	Implant Fuel Silo	8 hour storage, 550 mtons (600 tons)
4	Fuel Feeder	Gravimetric type, motor driven 79 mtph (87 tph)
1	Fuel Oil Storage Tank	(100,000 gal)
2	Fuel Oil Handling Pumps	(30 gpm)

D. Ash Handling

1	Fly Ash Storage Silo	24 hr. storage, 1320 mtons, (1452 tons)
1	Bottom Ash Storage Silo	24 hr. storage, 1080 mtons (1188 tons)
2	Fly Ash Vacuum Blowers	2x100% capacity, 250 HP
2	Bottom Ash Vacuum Blowers	2x100% capacity, 200 HP
2	Fluidizing Blowers	2x100% capacity, 75 HP
2	Fly Ash Pug Mills	85 mtons/hr
2	Bottom Ash Pug Mills	75 mtons/hr

E. PLANT WATER SYSTEMS

2	Service Water Pumps	Vertical, centrifugal Motor driven, 150 HP 1,020,400 kg/hr (4,500 gpm) 24.5 m (80 ft)TDH

QUANTITY	ITEM	DESCRIPTION
1	Cooling Tower	Mechanical draft, 75°F wet bulb temperature, 6.7°C (12°F) approach 11.1°C (20°F) range, 7.2 mm Kcal/hr (28.4 MM Btu/hr) duty
1	Chemical Feed System	Consisting of three systems, one each for hydrazine, morpholine and sodium phosphate. Each system is made up of one batch tank and two full capacity feed pumps.
1	Make-up Water Treating System	2-trains of 6800 kg/hr (30 gpm) each and consisting of a feed pump, a carbon filter, a cation unit, an anion unit, and a mixed bed unit.
1	Caustic Storage Tank	7.6 cu meters (2,000 gal) - Horizontal cylinder, carbon steel, heat traced
1	Acid Storage Tank	7.6 cu meters (2,000 gal) - Horizontal cylinder, carbon steel
1	Neutralization Sump	37.9 cu meters (10,000 gal) - concrete, epoxy lined w/2 full capacity motor driven pumps 5,700 kg/hr (25 gpm)/ 24.5 m (80 ft) TDH, 2 HP
2	Sump Pumps	Vertical centrifugal Motor driven, 1 HP 4500 kg/hr (20 gpm)/6.1 m (20 ft) TDH
1	Demineralized Water Storage Tanks	76 cu meters (20,000 gal), epoxy lined carbon steel
2	Demineralized Water Pumps	Horizontal centrifugal Motor driven 2 HP 6800 kg/hr (30 gpm)/30.5 m (100 ft) TDH

QUANTITY	ITEM	DESCRIPTION
2	Well Water pumps	Vertical centrifugal Motor driven, 50 HP 90,700 kg/hr (400 gpm) 91.4 m (300 ft) TDH
2	Raw Water pumps	Horizontal centrifugal Motor driven, 15 HP 68,000 kg/hr (300 gpm) 31 m (100 ft) TDH
1	Well Water Storage Tank	380 cu. meters (100,000 gal) Epoxy lined carbon steel
1	Fire Pump	Horizontal centrifugal Motor driven, 200 HP 385,500 kg/hr (1,700 gpm) 88 m (290 ft) TDH
1	Fire Pump	Horizontal centrifugal Diesel driven 385,500 kg/hr (1700 gpm) 88 m (290 ft)
1	Jockey Fire Pump	Horizontal centrifugal Motor driven, 5 HP 8000 kg/hr (35 gpm) 88 m (290 ft) TDH

F. MISC. SYSTEMS

3	Air Compressors	Reciprocating type, motor driven 600 scfm, 125 psig, 200 HP
2	Air Dryers	300 scfm
3	Air Receivers	--
1	Lube Oil Storage Tank	41.6 cu meter (11,000 gal) complete with transfer pumps

QUANTITY	ITEM	DESCRIPTION
1	Lube Oil Centrifuge	1590 kg/hr (7 gpm)

E. ELECTRICAL

QUANTITY	ITEM	DESCRIPTION
1	Generator Step-Up Transformer	60/80 MVA, OA/FA Rating 22-400 KV, 3 Phase, 50 HERTZ 2 ± 2-1/2% Taps
1	High Voltage Circuit Breaker	SF_6 Power Circuit Breaker 400 KV, 3 Phase, 50 HERTZ 1200 A Rating
2	High Voltage Disconnect Switch	Voltage Rating 400 KV Current Rating 600 A
1	Auxiliary Transformer	10/12.5 MVA, OA/FA Rating 22-6.6 KV, 3 Phase, 50 HERTZ Z = 5.5% 2 ± 2-1/2% Taps
1	Service Transformer	1000/1333 KVA, AA/FA Rating 11 KV - 380 V, 3 Phase, 50 HERTZ Z = 5.75% 2 ± 2-1/2% Taps
1	Medium Voltage Switch Gear	Indoor Metal-Clad Switchgear Voltage 6.6 KV 3 Phase MVA 250 MVA Main Bus 1,200 A
1	Medium Voltage Supply Circuit Breaker for MV Switchgear	Vacuum Circuit Breaker Rated Voltage 6.6 KV 3 Phase MVA 250 MVA Rated Current 1,200 A Opening Time 5 Cycles

QUANTITY	ITEM	DESCRIPTION
1	Load Center Transformer	Ventilated Dry Type 1000 KVA, AA Rating 6.6 KV-380 V, 3 Phase, 50 HERTZ Z = 5.75% 2 ± 2-1/2% Taps
2	Load Center Transformer	Ventilated Dry Type 1000/1333 KVA, AA/FA 6.6 KV-380 V, 3 Phase, 50 HERTZ Z = 5.75% 2 ± 2-1/2% Taps
1	Load Center Transformer	Ventilated Dry Type 1500 KVA, AA Rating 6.6KV-380 V, 3 Phase, 50 HERTZ Z = 8% 2 ± 2-1/2% Taps
4	Load Center Bus and Switchgear	Metal-Enclosed Switchgear Rated Voltage 380 V Dielectric Withstand 2200 V Bus Bracing 65 KA Rms. Sym. Main Bus Ratings (1) 1600 A (2) 2000 A (1) 3200 A
8	Motor Control Center (MCC)	Rated Voltage 380 V Main Bus 600 A Interrupting Rating 25,000 A
1	Power Distribution Panel	Rated Voltage 380 V Main Bus 600 A Interrupting Rating 25,000 A

QUANTITY	ITEM	DESCRIPTION
1	110 V DC Battery and Distribution System	Lead-Calcium Stationary Cells, 53 Cells, 2.2 Volt Per Cell Solid-State Rectifier/ Battery Charger AC Input 380 V, DC Output 115 V
1	Uninterruptible Power Supply System	Static Inverter Input: Voltage 115 V DC Output: Voltage 115 V AC Frequency 50 HZ Static Switch for Bypass

APPENDIX 10

PYROPOWER BOILER DESIGN - 20 MW

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INTERIM REPORT

PRELIMINARY DESIGN STUDY FOR A 20 MW AHLSTROM PYROFLOW® CIRCULATING FLUIDIZED BED FIRING JORDAN OIL SHALE

Prepared For
JORDAN ELECTRIC AUTHORITY

Prepared By
PYROPOWER CORPORATION

July 1988

Pyropower Corporation

APPENDIX C

CONTENTS

EXECUTIVE SUMMARY

Under the joint sponsorship of the Kingdom of Jordan and the U.S. Agency for International Development, a preliminary study is being conducted to evaluate the technical and economic feasibility of the direct combustion of Jordanian oil shale in an AHLSTROM PYROFLOW Circulating Fluidized Bed Boiler for electric power generation. As part of this study, Pyropower conducted a two-week burn test with Jordanian Oil shale in an 850 KW AHLSTROM PYROFLOW pilot plant. The test burn results were used in subsequent design studies for nominal 20 MWe and 50 MWe PYROFLOW CFB boilers. The results of these design studies are contained in this report.

This feasibility study report has been organized for your convenience and ready reference to the technical design, performance and project schedule. Pricing information are contained in a separate document and will be submitted later.

Section 1 contains a discussion of Pyropower and Ahlstrom's operating experience and corporate background. Included is a complete listing of units sold throughout the world with highlights of selected projects.

Section 2 provides a general description of the AHLSTROM PYROFLOW CFB process.

Scope of supply and system terminal points are detailed in Section 3. Please pay particular attention to the items indicated as work by others.

The basis of design, including fuel and limestone analysis is outlined in Section 4. In addition, we have indicated any assumptions about design conditions which might affect final boiler design.

Section 5 contains a more detailed description of the equipment and components which are included in Pyropower's scope of supply.

Predicted performance is listed in Section 6.

Section 7 outlines a typical boiler supply schedule for a unit of this size.

Finally, the boiler general arrangement is presented in drawings following the last section.

1. INTRODUCTION

The Kingdom of Jordan has substantial reserves of oil shale which represent an untapped source of indigenous fossil fuel for the country. The Kingdom has been investigating methods of economically utilizing this fuel resource for over a decade. Until recently, most of this effort has been directed towards retorting processes to extract oil from the oil shale. The current program represents the first effort to evaluate the use of Jordanian oil shale in a direct combustion process for steam/electric power generation.

The Jordanian oil shale is considered to have too low a fuel quality to be effectively used in conventional combustion processes. However, in recent years, the AHLSTROM PYROFLOW Circulating Fluidized Bed combustion process has demonstrated at commercial scale the ability to effectively utilize low grade fuels. These commercial successes with other low quality fuels has led to the current interest in evaluating the direct combustion of Jordanian oil shale.

Under the joint sponsorship of the Kingdom of Jordan and the U.S. Agency for International Development, a preliminary study is being conducted to evaluate the technical and economic feasibility of the direct combustion of Jordanian oil shale in an AHLSTROM PYROFLOW Circulating Fluidized Bed Boiler for electric power generation. As part of this study, Pyropower conducted a two-week burn test with Jordanian Oil shale in an 850 KW AHLSTROM PYROFLOW pilot plant. The test burn results were used in subsequent design studies for nominal 20 MWe and 50 MWe PYROFLOW CFB boilers. The results of these design studies are contained in this report.

1.1. OPERATING EXPERIENCE

There are more than 60 AHLSTROM PYROFLOW units in operation or under construction worldwide with over 100 unit years of operating experience. Five (5) of the operating units are in the United States, with sixteen (16) more under construction in this country. Together, Ahlstrom and Pyropower offer the most comprehensive experience with CFB technology available in the world today.

This extensive operating history is of value to the customer because it saves money in terms of plant efficiency and operating cost. AHLSTROM PYROFLOWs are located in four of Ahlstroms own paper mills. This makes Ahlstrom unique among boiler suppliers - focusing our designs on user sensitivity. As a result of our experience, many improvements have been made to the AHLSTROM PYROFLOW boiler to enhance reliability and to lower maintenance costs. The AHLSTROM PYROFLOW has consistently demonstrated availabilities in excess of 95%, even in the most demanding operating situations such as pulp and paper mills, chemical plants, etc. No Ahlstrom or Pyropower unit has ever failed to delivery 100% of the rated steam conditions including those permitted in accordance with the strictest emission limits. A complete PYROFLOW installation list as well as boiler availability data is presented at the end of this section. A summary of selected key projects is presented in Appendix 3.

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2. TECHNICAL DESCRIPTION

2.1. CIRCULATING FLUID BED PRINCIPLES

The AHLSTROM PYROFLOW circulating fluidized bed boiler is based on second generation fluidized bed technology, as distinct from earlier bubbling fluidized bed designs. The AHLSTROM PYROFLOW boiler offers simplicity of design, high reliability, superior performance, and flexible operation backed by extensive experience.

Fluid bed principles are best illustrated by examining the gradual increase of gas velocity through a fixed bed of material. The particles are initially stationary and system pressure drop is a function of velocity. As the minimum fluidizing velocity is reached, the pressure drop reaches a maximum and the particles become fluidized. As gas velocity increases, the bed expands until the entrainment velocity is reached and material starts elutriating from the bed. Higher gas velocities result in greater elutriation and solids recycle is required to maintain the solids inventory. A circulating fluid bed operates in this region.

A circulating fluid bed is characterized by a high-fluidizing velocity, the absence of a defined bed level and extensive solids entrainment. Hot cyclone(s) separate most of the entrained material which is returned to the combustion chamber through nonmechanical seal(s). Internal solids recycling occurs as a result of the high differential ("slip") velocity between the gas and solids. The large solids circulation rate provides for a uniform temperature, high heat transfer coefficients and excellent mixing.

Crushed oil shale contacts primary or fluidizing air in the lower combustion chamber. The oil shale is combusted in an oxygen starved (reducing) environment while the calcium carbonate in the oil shale is calcined to lime. Secondary air is introduced at a higher level to provide the additional air required for complete combustion. The lime reacts with the sulfur dioxide in an oxidizing environment to form calcium sulfate.

Combustion and sulfur retention occur at a temperature of approximately 1550-1650°F thereby providing maximum limestone utilization while minimizing the formation of "thermal" NO_x. The conversion of fuel bound nitrogen to NO_x is inhibited through the use of staged combustion. Combustion efficiency is high due to the long solids residence time and well mixed isothermal environment.

The major advantages of the PYROFLOW circulating fluidized bed combustion system can be summarized as follows:

Fuel flexibility - PYROFLOW boilers can be designed to fire a wide range of fuels including high ash and high moisture coals, oil shale, coke, and biomass.

Low sulfur emissions - Downstream flue gas desulfurization is not required to meet environmental regulations. Sulfur is captured by limestone (calcium carbonate) in the combustion chamber.

High combustion efficiency	- Excellent vertical and lateral mixing efficiency and a long solids residence time resulting from high gas solids slip velocity ensures optimum carbon burnout.
Low NO_x emissions	- Low combustion temperature and staged combustion result in low NO_x emissions which meet most regulatory standards without downstream treating.
Elimination of fouling	- Low combustion temperature eliminates slagging slag formation and reduces the volatilization of alkali salts. This reduces boiler corrosion and convective surface fouling.
High turndown	- The high velocities in the combustion chamber permit large load reductions without bed slumping.

2.2. GENERAL DESCRIPTION

The major components of the PYROFLOW boiler system are the combustion chamber, the hot cyclone collector(s), loop seal(s), and convective section. Combustion and sulfur retention reactions take place in the combustion chamber, which is fully water-cooled. Fuel is fed to the loop seals and if required to the lower combustion chamber. Limestone is not required for this application due to the inherent calcium carbonate in the oil shale. Fuel feed locations are designed for optimal mixing.

Combustion air is supplied by primary and secondary air fans and by a high pressure centrifugal fan. Primary air, which fluidizes the bed is supplied to the air distribution grid at the bottom of the combustion chamber. Secondary air is introduced at two levels in the lower refractory lined portion of the combustion chamber to ensure complete combustion and to reduce NO_x emissions. Secondary air is also ducted to the start-up burners.

The hot cyclone collector(s) separates entrained bed material and uncombusted fuel from the flue gas stream. The collected particles drop into the cyclone stand-pipe(s) where they are conveyed through a specially designed fluidized nonmechanical seal back to the combustion chamber.

Flue gas leaves the hot cyclone collector(s) and passes through the superheater and economizer sections of the system. Next, the flue gas passes through the airheater, enters a multicyclone dust collector where particulate matter is removed. Then the flue gas enters a baghouse filter where more particulate matter is removed. Clean flue gas is discharged to the stack via the induced-draft fan.

Feedwater is supplied to the economizer, where it is heated before entering the steam drum. From the drum, the water is delivered via downcomers to the combustion chamber where it receives additional heat from the fluidized combustion reaction. The resulting steam/water mixture is returned to the steam drum. Steam is separated in the steam drum and routed through a series of superheaters and then to the main steam header. Desuperheaters are located between superheaters.

3. SCOPE OF SUPPLY

3.1. GENERAL DESCRIPTION

The scope of supply for this preliminary design study is typical of scopes of supply for Pyropower commercial projects. This includes design and furnish of one (1) circulating fluidized bed boiler system.

Numbers which precede equipment identification are Pyropower code of account numbers, used in material tracking.

Equipment description is included in section 5 of the proposal.

3.2. SCOPE OF SUPPLY (PER ONE BOILER)

No.	Item	Supplied By PpC	Supplied By Others
	DRUMS		
101	Steam Drum	X	
102	Water Drum	NA	
103	Drum Internals	X	
	EVAPORATIVE SURFACES		
111	Combustor (Membrane Walls)	X	
113	Boiler Bank	NA	
114	Evaporative Wing Walls	NA	
116	Screen Tubes	NA	
117	Headers (Combustor)	X	
	ECONOMIZER		
121	Bare Tube Economizer	X	
126	Economizer Support Tubes	X	
127	Economizer Headers	X	

		Supplied By PpC	Supplied By Others
	SUPERHEATERS		
131	Superheater Tube Bundles	X	
132	Radiant Wing Wall Superheater	X	
133	Radiant Wall Superheaters	NA	
134	Steam Cooled Convection Cage	X	
135	Omega Tube Superheater	NA	
137	Superheater Headers	X	
	DESUPERHEATERS		
141	Spray Desuperheaters	X	
143	Sweet Water Condenser	NA	
	BOILER PROPER AND BOILER EXTERNAL PIPING		
151	Downcomers, Supplies & Risers	X	
152	Feedwater Piping	X	
153	Interconnecting Steam Piping	X	
154	Spray Water Piping	X	
155	Blowdown, Drain and Vent Piping	X	
158	Piping Supports	X	
	NON-BOILER EXTERNAL PIPING		
161	Main Steam Piping		X
162	Feedwater Piping		X
164	Vent Piping		X
165	Safety and Start-Up Exhaust Piping		X
166	Blowdown and Drain Piping		X
167	Sample Piping		X
168	Piping Supports		X
169	Spray Water Piping		X
	BOILER VALVES AND FITTINGS		
171	Vent Valves	X	
171	Drain Valves	X	
171	Sampling Valves	X	
171	Feedwater Stop Valve	X	
171	Main Steam Stop Valve	X	
171	Boiler Trim	X	
172	Main Steam Stop/Check Valve	NA	
172	Feedwater Check Valve	X	
173	Drum Safety Valves	X	

		Supplied By PpC	Supplied By Others
173	Main Steam Safety Valve	X	
173	Start-Up Valve	X	
179	Sample Coolers and Analyzing Equipment		X
	REHEATERS		
181	Reheater Tube Bundles	NA	
182	Wing Wall Reheaters	NA	
183	Radiant Wall Reheaters	NA	
184	Membrane Wall Reheaters	NA	
185	Omega Tube Reheaters	NA	
186	Reheater Hanger Tubes	NA	
187	Reheater Headers	NA	
	BOILER SUPPORT STEEL*		
201	Support Steel for Bottom Supported Boiler	NA	
202	Grid Steel for Top Supported Boiler		
	° Design and Specification	X	
	° Procurement	X	
204	Hanger Rods, Springs and Washers	X	
206	Bottom Supports for Economizer and Airheater	X	
	FABRICATED STEEL COMPONENTS		
211	Hot Cyclone(s)	X	
212	Loop Seal	X	
213	Lower Furnace Steel Plate Structure	NA	
214	Hot Cyclone Inlet and Outlet Gas Ducts	X	
215	Hot Cyclone Gas Duct Expansion Joints	X	
	BOILER CASING WITH SUPPORT STRUCTURE		
221	Buckstays and Tie Bars	X	
222	Support Structure for Insulation (penthouse)	NA	
223	Boiler Guides and Seismic Stops	X	
225	Boiler Casings	X	

* Support steel is not part of the structural steel.

		Supplied By PpC	Supplied By Others
	ASH HOPPERS		
231	Economizer Ash Hopper	NA	
231	Airheater Ash Hopper	X	
231	Gas Duct Ash Hopper	NA	
	BOILER DOORS AND OPENINGS		
240	Boiler Doors and Openings	X	
	REFRACTORY		
260	Design and Specification	X	
260	Refractory Material	X	
260	Installation		X
932	Refractory Curing		X
932	Fuel for Refractory Curing		X
	INSULATION AND LAGGING		
270	Design and Specification	X	
270	Insulation and Lagging Material	X	
270	Installation		X
	SOLID FUEL FEEDING EQUIPMENT		
302	Solid Fuel Feed Equipment	X	
	FLUIDIZING GRID		
318	Nozzles and Nozzle Pipes	X	
	OIL BURNERS		
341	Start-Up Burner(s)	X	
342	Duct Burner(s)	NA	
343	Bed Lances(s)	NA	
	GAS BURNERS		
351	Gas Fired Start-Up Burner(s)	NA	
352	Gas Fired Duct Burner(s)	NA	
353	Gas Fired Bed Lance(s)	NA	
	MIXED FIRING BURNERS		
364	Combined NG and Oil Startup Burner(s)	NA	
364	Combined NG and Oil Duct Burner(s)	NA	

	Supplied By PpC	Supplied By Others
BURNER IGNITION AND CONTROL EQUIPMENT		
371 Flame Scanners for Start-Up Burners	X	
371 Local, Common Flame Supervisory Panel	X	
BURNER VALVE TRAINS		
381 Valve Train for Oil Burner(s)	X	
382 Valve Train for Gas Burner(s)	NA	
388 Pressure Reducing Station for Gas Burner(s)	NA	
FIRE EXTINGUISHER DEVICES		
390 Fire Extinguisher Devices		X
SOOTBLOWERS		
401 Steam Rotary Sootblowers	X	
405 Sootblower Control Cabinet	X	
406 Sootblower Valves and Fittings	X	
407 Sootblower Piping	X	
FLUE GAS AIR PREHEATER		
422 Tubular Airheater	X	
426 Heat Pipe Airheater	NA	
INDIRECT AIR PREHEATER		
431 STEAM COIL AIR PREHEATER(s)	X	
FANS AND BLOWERS		
441 Primary Air Fan(s)	X	
441 Secondary Air Fan(s)	X	
441 I.D. Fan(s)	X	
441 Gas Recirculation Fan	NA	
443 High Pressure Fan for Loopseal	X	
FLUE AND DUCTS		
451 Air Ducts	X	
452 Flue Gas Ducts	X	
453 Circulating Gas Ducts	NA	
454 Windbox(es)	X	
458 Air Flow Measuring Devices	X	

		Supplied By PpC	Supplied By Others
470	Stack		X
	CENTRIFUGAL ASH SEPARATORS		
501	Multicyclone Ash Separator	X	
	DUCT COLLECTORS		
511	Electrostatic Precipitator(s)	NA	
515	Pulse Jet Baghouse	X	
	FLY ASH HANDLING EQUIPMENT		
531	Fly Ash Conveyors		X
532	Fly Ash Reinjection System	NA	
537	Fly Ash Silo		X
	BOTTOM ASH HANDLING EQUIPMENT		
541	Bottom Ash Conveyors		X
542	Fluidized Bed Ash Removal System(s)	NA	
543	Center Drain Ash Removal System(s)	X	
547	Bottom Ash Silo(s)		X
	ADDITIVE HANDLING AND FEED EQUIPMENT		
584	Sand Feed Equipment	NA	
585	Limestone Feed Equipment	NA	
586	Ammonia/Urea Equipment	NA	
587	Other Additive Feeding Equipment	NA	
	PUMPS		
611	Water Circulating Pumps	NA	
612	Feedwater Pumps		X
	AUXILIARY PIPING		
621	Atomizing Steam Piping		X
621	Steam Coil Airheater Piping		X
622	Heat Tracing Piping	NA	
623	Cooling Water Piping		X
624	Steam Blow Piping (Temporary)		X
626	Instrument and Plant Air Piping		X
627	Loopseal Air and Seal Air Piping	X	

		Supplied By PpC	Supplied By Others
	FUEL PIPING UPSTREAM OF VALVE GROUP		
631	Oil Piping		X
633	Gas Piping	NA	
634	Ignition Gas Piping		X
	WATER TANKS		
671	Blow Down Tank		X
672	Continuous Blow Down Tank		X
	AUXILIARY EQUIPMENT FOR PIPEWORK		
691	Silencers for Safety Valves	X	
	ELECTRIC MOTORS		
701	Squirrel Cage Motors	X	
702	Variable Speed Drive Equipment	NA	
	ELECTRICAL		
711	Engineering for Electrical		X
712	Motor Control Centers		X
713	Motor and Control Wiring		X
714	Sootblower Wiring		X
715	Electrostatic Precipitator or Baghouse Wiring		X
717	Field Wiring for Electrical Devices		X
718	Motor Starters		X
	AUXILIARY ELECTRICAL EQUIPMENT		
721	Electric Tracing	NA	
	BOILER INTERLOCKING SYSTEM		
732	Burner Management System (BMS) for Auxiliary Fuel Fired Burners	X	
732	Burner Management System (BMS) for Auxiliary Fuel Fired Burners and Solid Fuel Equipment	NA	
732	Engineering and Design of Boiler Logic Diagrams in Boolean Format	X	

	Supplied By PpC	Supplied By Others
INSTRUMENTATION		
741 Engineering and Documentation of Instrumentation	X	
742 Primary Field Elements	X	
742 Analyzers	X	
743 Flow, Pressure and Temperature Transmitters for Steam, FW and Combustion Control	X	
744 Feedwater Control Valve	X	
744 Superheater Spray Water Control Valves	X	
744 Reheater Spray Water Control Valve	NA	
744 Steam Supply Control Valve for Steam Coil Airheater		X
744 Electromatic Relief Valve	X	
745 Instrument Piping and Tubing Material		X
746 Installation of Basic Instruments		X
747 Installation of Transmitters, Analyzers, Valves etc.		X
748 Installation of Instrument Piping and Tubing		X
748 Field Wiring for Instrumentation		X
BOILER CONTROL SYSTEMS		
751 Analog Boiler Control System	NA	
752 Engineering and Design of Functional Control Diagrams in SAMA Format	X	
752 Distributive Control System (DCS) for Control and Monitoring	X	
754 Programming of Control System	X	
755 Installation of Control System		X
BOILER STRUCTURAL STEEL		
801 Engineering of Structural Steel	X	
802 Supporting Columns and Beams	X	
803 Platforms, Stairs and Handrails	X	
804 Boiler Enclosure Walls and Roof	NA	
HEATING, VENTILATING AND AIR CONDITIONING		
811 Heating Devices		X
812 Air Conditioning Devices		X
813 Elevators		X
816 Sprinkler System		X

		Supplied By PpC	Supplied By Others
	FOUNDATIONS AND CONCRETE WORK		
821	Engineering of Foundations		X
822	Concrete Foundations with Anchor Bolts		X
	WATER TREATMENT		
831	Feedwater Treatment Equipment		X
	SILOS AND SOLIDS HANDLING EQUIPMENT		
841	Fuel Day Silo		X
842	Limestone Silo	NA	
843	Sand Silo	NA	
846	Dust Control System for Silo Vent		X
847	Storage Silo(s)		X
849	Conveyors and Crusher(s)		X
	QUALITY CONTROL		
870	Quality Control	X	
	SPARE PARTS		
891	Spare Parts Inventory		X
899	Spare Parts for Start-Up	X	
	FREIGHT AND TRANSPORTATION		
910	FREIGHT AND TRANSPORTATION F.O.B. NEAREST PORT TO MANUFACTURE	X	
	ERECTION (REFER TO SECTION 14)		
928	Erection Site Management	X	
931	Erection of PpC Supplied Equipment		X
936	Painting at the Site		
	Touch-up Painting		X
	Final Painting		X
	CHEMICAL CLEANING		
961	Acid Cleaning		X
	•Supply and Disposal of Chemicals		X
962	Boilout		X
	•Supply and Disposal of Chemicals		X

COMMISSIONING AND TRAINING (REFER TO SECTION 8)

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		Supplied By PpC	Supplied By Others
971	Plant Personnel Onsite Training	X	
972	Advisory Services for Commissioning	X	
973	Auxiliary Labor for Start-up		
974	O&M Manuals		X
975	Performance Testing	X	
	Advisory Services for Performance Testing		X
	Emissions Tests and Laboratory Tests	X	X
Other			
	Boiler Plant Outside PpC Terminal Points		X
	Consumables for Equipment Operation		X
	Cooling Water, Service and Instrument Air		X
	Applicable ASME Code Stamps	X	
	Protective Coating of Pressure Parts	X	
	Standard Shop Prime Painting of Auxiliaries	X	

3.3. TERMINAL POINTS (Per one boiler)

Fuels and Limestone

a. Oil Shale: Inlet flange to oil shale silo isolation valve.

b. No. 2 oil: No. 2 oil inlet to each start-up burner valve group.

Steam/Water

a. Superheater Outlet: Superheater outlet piping terminating at the outlet of the stop valve located at the superheater outlet with a maximum of ten (10) feet of main steam interconnecting piping.

b. Safety Valves: Outlet of vent stack located eight (8) feet above top of the boiler steel.

c. Electromatic Relief Valve: Outlet of the common ERV and start up valve silencer.

d. Start-up Valve: Outlet of the common ERV and start up valve silencer.

e. Vents: Outlet of second valve. Both valves will be close connected to source.

f. Atomizing Steam: Atomizing steam connection on each start-up burner.

g. Steam Coil Airheater: Inlet to steam connection and outlet to the condensate connection on the steam coil airheater.

h. Economizer Inlet: Economizer inlet terminating at the inlet to the feedwater check valve located at the economizer inlet header elevation. Maximum of ten (10) feet of feedwater piping.

i. Desuperheater spray water: Inlet to each desuperheater control valve set.

j. Drains: Outlet of second Boiler Code valve. The first valve will be close connected to the source with the second valve five (5) feet above the ground floor.

k. Blowdown: Outlet of blowdown metering valve located five (5) feet above the boiler ground level.

l. Cooling Water: Inlet and outlet connections at each individual user.

m. Chemical Feed: Inlet to first of two valves close connected to drum.

n. Sampling Connections: Outlet of second valve close connected to sample connection.

<u>Air</u>

a. Connections for instrument air at each individual user.

b. Connection for service air at each individual user.

Ash

a. Outlet flange of each multicyclone hopper.
b. Outlet flange of each furnace bottom ash screw cooler.
c. Outlet flange of each baghouse hopper.
D. Outlet flange of airheater hopper.

Ducts

a. Inlet to silencers mounted on air fans.
b. Outlet flange of I.D. fan.

Electrical

a. Motor terminals.
b. Boiler field instrumentation (where provided) terminals.
c. Local control panel input and output terminals.
d. Boiler metal thermocouple terminals in local terminal boxes. All other thermocouples will terminate at the thermocouple head connection.

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4. DESIGN REQUIREMENTS

4.1. SITE SPECIFIC SERVICES

The boiler will be located outdoors in Jordan.

Cooling Water

Adequate cooling water will be made available by others as required for miscellaneous service requirements:

	Design
Supply Pressure	50 psig
Return Pressure	30 psig
Design Pressure	150 psig
Supply Temperature (max)	90°F
Return Temperature	110°F

The cooling water shall have a water quality which precludes concerns about the fouling and corrosion of heat transfer surfaces as a result of dissolved solids, corrosion products, mud, silt or other debris.

Instrument Air

Others shall supply adequate instrument air at the following conditions:

Supply Pressure	80-100 psig
Dewpoint	-40°F

Plant Air

Others shall supply adequate plant air. Plant air shall be unfiltered, but reasonably free from dirt, moisture, and oil.

Supply Pressure	80-100 psig

Electric Power

The Buyer shall provide appropriate sources of electric power for motors and electrical equipment supplied by Pyropower.

Site Conditions

a.	Barometric Pressure Average	27.3 in Hg
b.	Site Elevation	2700 feet above mean sea level
c.	Reference Conditions	

- Reference temperature for efficiency calculations: 100°F
- Reference conditions for lagging face temperature

Temperature Difference (Lagging face to ambient)	80°F
Air Velocity	50 ft/min.

d.	Air Temperature	
	Maximum Temp.	110°F
	Minimum Temp.	40°F
e.	Moisture, lb/lb Dry air	0.013
f.	Wind	
	Design Wind Speed	Per ANSI A58.1-1982
g.	Seismic Factor	Zone 2
h.	Snow	
	Design Snow Load	N/A

4.2. DESIGN BASIS

A. DESIGN SPECIFICATIONS

The equipment described in this preliminary design study has been developed jointly with the other project participants.

B. DESIGN CONDITIONS

The boiler design is based on the following conditions, while firing the performance fuel.

	Temp. Control Load (75% MCR)	Maximum Continuous Rating
Superheater, Outlet		
Flow, lb/hr	150,000	200,000
Pressure, psig	1550	1550
Temperature, °F	955	955
Feedwater to Economizer		
Temperature, °F	370	370
Feedwater to Desuperheater		
Temperature, °F	370	370
Ambient Air		
Temperature, °F	80	80
Relative Humidity, %	60	60
Blowdown		
Percent blowdown, %	1	1
Flue Gas Exit Temperature		
Temperature, °F	278	300

4.3. FUELS

General

The boiler has been designed to burn oil shale as listed below:

JORDAN OIL SHALE ANALYSIS
(Percent by Weight)

	Performance	Worst Case	Best Case
Moisture	3.20	3.20	3.20
Ash (less CO_2 in $CaCO_3$)	66.80	67.30	66.25
CO_2 (in $CaCO_3$)	13.87	14.14	13.37
Carbon (Organic)	11.32	10.20	12.50
Hydrogen	1.13	1.02	1.25
Nitrogen	.48	.58	.38
Sulfur	2.55	2.38	2.71
Oxygen (by diff.)	.65	1.18	.34
TOTAL	100.00	100.00	100.00
HHV, BTU/lb	2,250	2,000	2,500
Oil Content, %	8.40	7.50	9.25

Size, 1/4"x0

All fuel fired in the boiler must have an acetic acid soluble sodium (Na) and potassium (k) less than 0.05% (500 ppm) on a dry basis.

No. 2 fuel oil will be used as a start-up fuel.

4.4. LIMESTONE

Due to the inherent calcium carbonate in the oil shale, limestone injection is not required for this application.

4.5. EMISSIONS

The boiler will be designed to reduce boiler emissions to the following levels at MCR when firing the performance shale oil.

Pollutant	
NOx	0.6 lb/MMBtu of fuel heat input
Particulate	0.03 lb/MMBtu of fuel heat input

4.6. BOILER FEED WATER AND DESUPERHEATER WATER

Feedwater and desuperheater water shall be supplied to the boiler with a quality better than or equal to that listed below:

Total Dissolved Solids	1	ppm
Silica	0.02	ppm
Total Iron	0.01	ppm
Total Copper	0.01	ppm
Total Organics	0.01	ppm
Oxygen	0.007*	ppm
Chlorides	0.01	ppm
Hydrazine	0.02	ppm
Sodium	0.01	ppm
pH (Copper Free System)	9.2-9.4	
pH (Copper Alloy System)	8.8-9.2	

* Lower levels to be achieved with oxygen scavenger

4.7. BOILER CHEMICAL TREATMENT

In the operating pressure range of 1550 psig, the coordinated phosphate/pH method of boiler water treatment is recommended. This system provides for application of materials in such a way that internal passivation by phosphate occurs and the boiler chemistry is maintained in such a manner that corrosion by caustic attack can not occur.

4.8. CODES AND STANDARDS

This preliminary study is based on the supply of equipment and services which comply with the governing United States of America codes, standards and regulations in effect at the time of the proposal. Equipment design and fabrication will be in accordance with the applicable sections of the following industrial codes, standards and publications:

- The design and fabrication of the boiler and its component elements will comply with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and American Boiler Manufacturers Association (ABMA) codes and standards.

- Power piping and related work will conform to the Power Piping Code (ANSI B-31.1).

- Pipe, fittings, flanges and bolting will conform to the product standards of the American National Standards Institute (ANSI).

- Materials will be furnished in accordance with the American Society for Testing and Materials (ASTM) specification or the American Iron and Steel Institute (AISI).

- Electrical and electronic components and enclosures will conform to the National Electrical Manufacturer's Association (NEMA).

- Instrumentation, controls and related work will conform to the Instrument Society of America (ISA) standards.

- Welding and related work will, as a minimum, conform with the American Welding Society (AWS) standards, and ASME Section IX.

- Other recognized codes and standards will be used where required to serve as guidelines for the design, fabrication, and construction, when not in conflict with the codes and standards listed above.

5. EQUIPMENT DESCRIPTION

All equipment information is preliminary.

5.1. PRESSURE PARTS

General

All material, equipment and accessories supplied will be of high quality and suitable for the conditions expected. All material and equipment offered are new and unused.

The design, materials, manufacturing methods and factory testing will comply with the ASME Boiler Code and will bear the standard ASME power boiler (S) stamp.

All welding will be performed in accordance with qualified welding procedures. Procedure qualifications and welder performance qualifications will be in accordance with either ASME Boiler and Pressure Vessels Code or the ANSI B 31.1 of Code for Pressure Piping.

Pyropower will provide the services of a competent representative to assist the erection subcontractor in ensuring that erection procedures and the assembled pressure parts are in accordance with Pyropower's design standards.

The field assembly of the pressure parts will be performed by a competent erection subcontractor possessing an assembly (A) and a pressure piping (PP) stamp. It will be the responsibility of the erection contractor to provide for inspection in accordance with ASME code requirements, apply the required stamp and execute the "Certificate of Field Assembly" as required by local and state laws.

Steam Drum

The steam drum is made of carbon steel plate, welded construction, with a cylindrical shell and dished heads. Manholes with hinged covers are provided at each end of the drum. All drum nozzles are provided with ends prepared for welding.

Steam drum internals provide for proper feedwater distribution, steam/water separation, collection and transfer of continuous blowdown water and internal chemical treatment distribution. A deflection plate and centrifugal water separators are located in the steam drum to provide optimum separation of the steam water mixture leaving the combustion chamber membrane walls. Separators have bolted connections to facilitate removal prior to boiler chemical cleaning. A demister and a perforated distribution plate are provided in the steam drum to ensure high quality steam leaving the drum.

Combustion Chamber

The combustion chamber is a gas-tight enclosure which is fully water-cooled by membrane walls. The lower combustion chamber is a refractory lined, water-cooled enclosure. Openings are provided in the combustion chamber walls to allow for the following connections:

Solids return and fuel inlet (loopseal).
Front wall fuel feed.
Ash outlets.
Limestone inlets.
Burner inlets.
Temperature and pressure instrument
penetrations. later
Gas ducts to cyclone.
Access openings.

Seal plates at wall penetrations, headers, and piping are provided. All headers, distribution piping, and feed-pipes are provided. Each lower distribution header is equipped with one or more openings closed by welded caps for internal inspection and cleaning.

The complete combustion chamber assembly is arranged for natural circulation. Saturated water from the drum is delivered via downcomers to the downcomer bottles. From the downcomer bottles, supply pipes feed the combustion chamber lower headers via natural circulation, eliminating the need for circulation pumps and reducing mechanical complexity. The steam/water mixture from the combustion chamber wall tubes is collected in the upper combustion chamber headers and returned to the steam drum via riser tubes. Steam/water separation takes place in the drum.

The combustion chamber operates at a positive pressure and the membrane walls incorporate buckstays and tie bars arranged and designed to withstand a design pressure of ± 35 inches w.g.

Economizer (Bare tube)

The economizer is a bare tube, in line, horizontal serpentine type. The economizer tubes are supported by straps. The tubes of the final economizer bank are bent up and welded to the economizer intermediate headers. Hanger tubes connect the intermediate header to the outlet header.

Convection Cage

The convection cage is constructed of gas tight, membrane walls braced with buckstays and tie bars. It is cooled with dry saturated steam from the steam drum.

Primary Superheater

The primary superheater is arranged in banks with a sootblower cavity between the banks. Each bank is top supported by hangers.

Radiant Superheater (Wing Wall)

A radiant wing wall superheater is located in the upper portion of the combustion chamber. The radiant superheater consists of multiple banks of membrane wing walls perpendicular with the upper front wall of the combustion chamber. Steam from the primary superheater is distributed to the lower radiant superheater headers, up through the wing walls to the outlet headers, and on to the final superheater. The superheater is supported by hanger rods from the boiler steel.

Final Superheater

The final superheater is arranged in one (1) bank. The bank is top supported by hangers.

Desuperheater

Desuperheater stations are located between the primary superheater and the radiant superheater and between the radiant superheater and the final superheater. The desuperheaters are designed to operate so that a portion of the required capacity is supplied from each stage. This offers faster response, better control, and minimizes tube metal temperature excursions.

The desuperheater will be venturi/spray type design. A complete system will be furnished including spray desuperheater, control valve, block valves and piping.

ASME Boiler Code Piping

The following boiler interconnecting piping is furnished:

a) Feedwater piping from the terminal point to the economizer.

b) Feedwater piping from economizer to steam drum.

c) Downcomer pipes with bottles.

d) Supply pipes from the downcomer bottles to the combustion chamber lower headers.

e) Riser pipes from the combustion chamber upper headers to the steam drum.

f) Steam pipes from drum to convection cage.

g) Connecting pipes between superheaters.

h) Main steam pipe from final superheater outlet to terminal point.

i) Blowdown and vent piping as defined by terminal points.

j) Spray water piping from the inlet to each control valve set to each of the desuperheaters.

l) Sootblower steam piping.

<u>Non-Boiler External Piping (within terminal points)</u>

a. Vent piping as defined by terminal points.
b. Drain piping as defined by terminal points.
c. Trim piping.

<u>Boiler Valves and Fittings</u>

Included are drum and main steam safety valves, electromatic relief valve, start-up vent valve, main steam stop valve and feedwater inlet stop and check valves.

For the boiler drum, two bulls-eye, bi-color drum level water gauge glasses are furnished. One glass will be equipped with an illuminator for direct viewing. The other glass will be equipped with a fiber optics viewing system including primary element 500 feet of cable, remote indicator, and hood assembly.

One steam drum full-range pressure gauge is provided in accordance with ASME Boiler and Pressure Vessel Code, Section I, with valves and piping.

5.2. FABRICATED STEEL STRUCTURES

Structural Steel (top supported)

Pyropower will provide all structural steel required for support of the boiler and Pyropower provided auxiliaries. Pyropower will provide hanger rods and lugs. Pyropower will provide platforms, walkways, grating, and handrails including structural steel for their support. The Buyer will provide the structural steel to support the silos and all other equipment supplied by Others.

The following describes the general supporting scheme of the boiler. The steam drum is supported by U-shaped hangers hung from the top grid steel. The combustion chamber is supported off the grid steel using hanger rods attached to the combustion chamber upper walls.

Hanger tubes which form rows are welded to the economizer outlet header. The economizer outlet header and hanger tubes have welded lugs and are supported at intermittent points by hanger rods attached to the structural steel. Support for the convective superheaters is discussed in section 5.1. The airheater is bottom-supported and expansion joints are provided as required.

The cyclones are supported by welding brackets to the sides and supported on the structural steel. The primary air fan, secondary air fan and induced draft fan are supported on individual foundations at grade.

Hot Cyclone Separator, Expansion Joints, and Loop Seal

The hot cyclone separator and nonmechanical loopseals are fabricated from carbon steel complete with gussets, supports and access openings as required. The separator and loopseal are lined with a two-layer refractory.

The inlet to the cyclone separator is equipped with a high temperature expansion joint. An expansion joint is also provided at the hot gas outlet duct connection to the convective cage and at the cyclone separator down spout to the loop seal.

The expansion joints are high temperature fabric joints which are capable of independent lateral and axial movement without stress. They are designed to withstand combustion chamber temperature and are abrasion resistant.

Casings (uncooled)

The economizer and tubular airheater sections of the boiler have uncooled casings, consisting of an inner steel casing, which is externally stiffened, insulated and aluminum lagged. The steel casings are selected for the temperature environment and consist of flanged panels reinforced and seal-welded at all joints to prevent gas leakage.

5.3. INSULATION AND REFRACTORY

Insulation

On all insulated surfaces, the thickness of insulation shall be designed to prevent the outside lagging face temperature from exceeding 140°F at MCR based on 80°F ambient air temperature and 50 ft/min air velocity. All insulated flat surfaces will be covered with box ribbed aluminum lagging not less than 0.040 in. thick over a moisture barrier. Insulated piping shall be covered with a flat aluminum lagging not less than 0.016 in. thick with moisture barrier.

Locations of insulated surfaces and the insulating materials are shown in Table 5-1.

Thermal insulation and lagging is provided for all equipment provided in this proposal which require if for conservation of heat, maintenance of operating temperature, and personnel protection.

TABLE 5-1

INSULATION AND LAGGING

Item	Insulation Type
Combustion Chamber	Mineral Wool
Convection Cage	Mineral Wool
Horizontal Top Surface of Convection Cage and Combustion Chamber	Mineral Wool with Reinforced Lagging
Steam Drum	Mineral Wool with Reinforced Lagging
Economizer Casing	Mineral Wool
Tubular Airheater Casing	Mineral Wool
Hot Air Ducting	Mineral Wool
Hot Gas Ducting	Mineral Wool
Interconnecting Piping	Calcium Silicate Block

Surfaces which have internal refractory attached will not be externally insulated and lagged (with the exception of the bottom of the combustion chamber). Therefore, these surfaces will have skin temperatures which exceed that specified for insulated and lagged surfaces. Personnel protection will be provided for those areas with internal refractory which are normally accessible to plant personnel by providing stand-off guards.

Refractory

Refractory linings are used on the following surfaces of the PYROFLOW boiler:

- High temperature cyclone separator and loop seal.
- Cross duct between combustion chamber and high temperature cyclone separator.
- Cross duct between high temperature cyclone and the convection section.
- Lower combustion chamber.

The hot cyclone, the loopseals, and the ducts which connect the cyclone to the combustion chamber and to the convective cage are lined with two layers of refractory secured by anchors. The inner layer is heat and abrasion resistant. The outer layer next to the cyclone surface insulates the cyclone cold face. Both layers are of castable refractory, and method of application will be by casting and/or gunning. Where gunning is used, care will be taken to ensure that surface finish will not initiate premature erosion or steam spalling during initial heatup. For certain applications refractory brick may be used, instead of castable refractory.

The refractory lining of the lower combustion chamber consists of high temperature abrasive-resistant castable or plastic refractory.

The two layer refractory used in the cyclones, connecting ducts and loop seals is shown in Figure 5-1 and the lower combustion chamber refractory liner is shown in Figure 5-2.

Proof tests will be required from the installer to verify that the inplaced material corresponds to the specification. Samples will be prepared by the installer using methods comparable to those used in installation, i.e. gunned for gunned material, cast of cast material. Test will be conducted on samples per ASTM testing methods appropriate to the following locations:

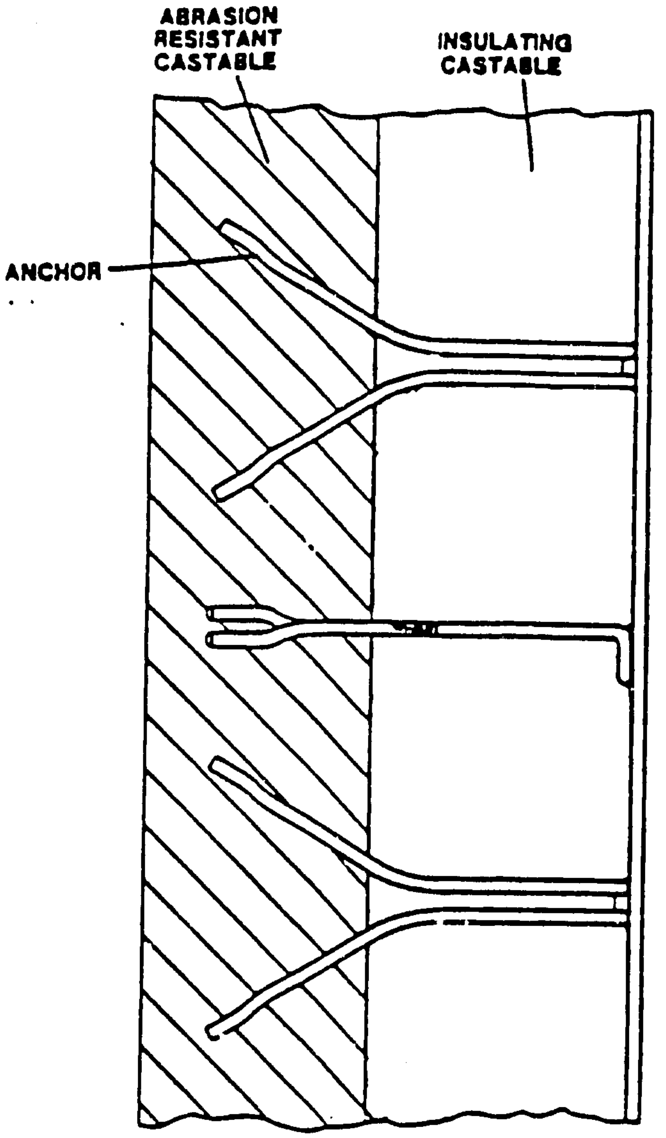
Combustion chamber lower walls	3 samples
Loop seal	3 samples
Cyclone roof	3 samples

If inplacement extends over more than one day, the three samples will be from different days. Additional samples will be taken if there is a significant hiatus in emplacement or a significant change in conditions.

5.4. FUEL

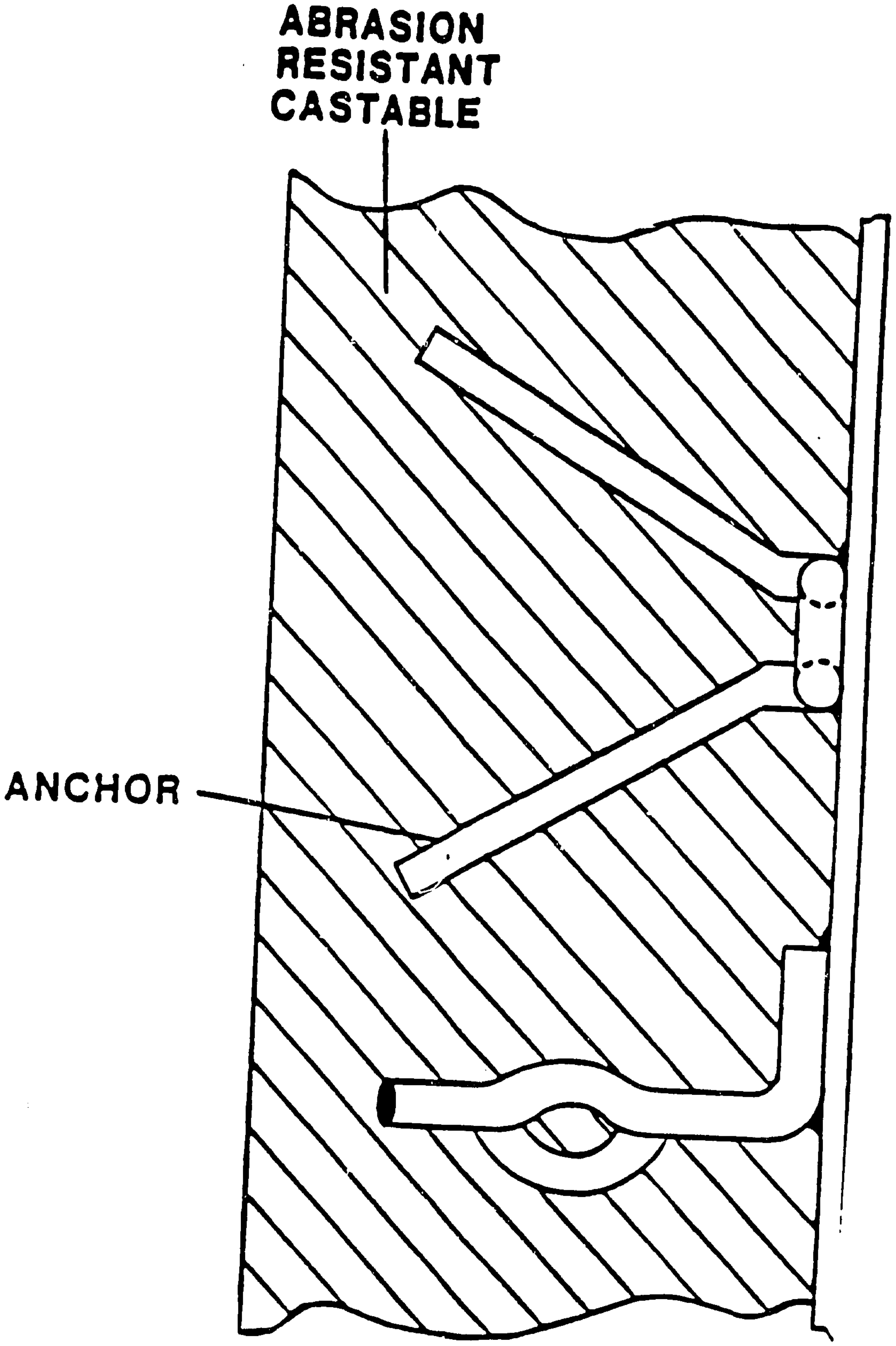
Loopseal Feed

Oil shale flows from the oil shale silo through a manual isolation valve, stand pipe and onto a gravimetric belt feeder. Oil shale in the standpipe minimizes seal air losses. A seal air fan provides seal air to the feeder to ensure higher pressure in the feed chutes than in the combustion chamber.



TWO COMPONENT LINING TYPICAL
FOR LOOPSEAL, AND NON-WATER
COOLED ASH COOLERS

FIGURE 5-1



ONE COMPONENT LINING TYPICAL FOR
WINDBOX WATER COOLED ASH COOLERS

FIGURE 5-2

Oil shale discharges the end of the oil shale feeder onto an chain conveyor and distributes the oil shale to the loopseal(s). Fuel travels from the end of the conveyor, through an isolation valve, feed chute, expansion joint and into the loopseal. Secondary air is introduced to the air bustle in the loopseal feed chute. Loopseal feed chute isolation valves are pneumatically closed in the event of low line pressure or excessive temperature.

Silo isolation valve(s) (manual)	2
Feeders(s) for loop seal feed:	
Quantity	2
Type	gravimetric belt

5.5. BURNERS

Start-up Burners

Start-up burners are to be used during start-up of the boiler using auxiliary fuel as indicated in this proposal. The purpose of the burners is to raise bed temperature sufficiently for solid fuel ignition. The start-up burners will continue in operation until steady state continuous fuel firing has been achieved.

The burners will be supplied complete with electric ignition, flame safeguard equipment, valve trains and local flame supervisory panel. The system will be pre-piped and pre-wired to the maximum extent possible to minimize the amount of field installation. The local panel functions as a flame supervisory panel.

The flame detection system for the startup burners only is a ultraviolet flame detector with a self-checking feature. The flame detector monitors the area of the burner where the root of the flame should be located. The flame intensity is converted to an electrical signal which is used to indicate flame status and initiate the appropriate response. A mechanical shutter is used for the self-checking feature.

The burners will be installed in the lower combustion chamber.

5.6. SOOTBLOWER SYSTEM (Rotary)

A steam operated rotary sootblowing system is used to maintain clean surfaces throughout the boiler.

Each blower will be furnished with an electric motor, motor starter, and local push button starter.

The control logic will be microprocessor based. It will interface with the main digital control system.

5.7. TUBULAR AIRHEATER

An air-in-tube airheater has been proposed for this application. A two-pass design is used for both primary and secondary air. The secondary air section is nested inside the primary section. Tube bank height is optimized to ensure positive cleaning of tube surface by sootblowers. The tubes are arranged horizontally and are split into sections. Each section has the tubes expanded into both tube sheets.

Also included is a gas-tight, stiffened casing and turn around ducts. The inlet and outlet gas and air connections will be attached with bolted flanges to the appropriate ducts.

5.8. STEAM COIL AIRHEATER

A steam coil airheater is included for the primary air stream. The steam coil airheater is used during boiler low load operation to avoid any condensation on the lower tubular air heater tubes. Steam supply to the airheater will be 150 psig saturated steam provided by the Buyer.

5.9. FANS

Two centrifugal fans and one high pressure centrifugal fan are required to supply fluidizing and combustion air to the PYROFLOW combustor.

The primary air fan provides the fluidizing air flow to the bottom of the combustion chamber. Fan capacity is controlled by inlet guide vanes.

The secondary air fan provides the remaining portion of the combustion air required. The secondary air is injected into the furnace at two (2) elevations. Fan capacity is controlled by inlet guide vanes.

The high pressure fan supplies fluidizing air to the nonmechanical solids recirculation loop seals.

An induced draft fan is provided to extract hot flue gas from the combustion chamber outlet through the hot cyclone, boiler convection section, ducts and baghouse and to discharge the gas into the stack breeching. Fan operation is controlled by inlet guide vanes.

Each fan is complete with flexible couplings, coupling guards, inlet vanes or dampers with actuators, gaskets, sole plates, silencers (where applicable) and motors. Motors, are sized for continuous operation of the fans at their test block rating.

All fan housings are split to facilitate removal of the fan housing without disturbing the inlet and outlet duct connections. Inspection doors and drain connections are furnished on each fan housing.

Fans are furnished with horizontally-split, positively-lubricated, self-aligning sleeve bearings supported by heavy pedestals resting on suitable soleplates. Cooling water piping is at least 1/2-inch Schedule 40 galvanized pipe.

The fans are sized for combustion of the range of fuel listed in Section 4 at MCR load and then the test block margins are applied to obtain the proper fan selection basis.

The high pressure loop seal air fan is furnished complete with inlet filter/silencer, motor and baseplate.

MCR Conditions (Performance Fuel)

	Primary Air	Secondary Air	Induced Draft
Flow, lb/hr	171,320	86,980	296,180
Temp., °F	80	80	300
BHP	534	153	442

High Pressure Loopseal Fan

MCR Conditions

Flow, lb/hr	5,270
Temp., °F	80
BHP	105

5.10. AIR AND GAS DUCTING

The following air and gas ducting is provided:

1. Combustion Air

   Primary air inlet ducting from the silencer inlet to primary air fan.

   Primary air fan discharge to combustion chamber inlet windbox.

   Secondary air inlet ducting from the silencer inlet to secondary air fan.

   Secondary air fan discharge to secondary air nozzles.

   Secondary air to burner system and fuel feed system.

2. Boiler Flue Gas

Airheater ash hopper outlet to baghouse.
Baghouse to induced draft fan.

All main air and flue gas ducting is made of carbon steel. All ducts are properly externally stiffened and reinforced to prevent vibration and to withstand the operating pressures. The ducts are of all welded construction, except at connections to dampers, fans, boiler, etc. Joints are bolted, flanged connections with bolts and gasketing designed for the intended service. The ducting is complete with access doors, dampers, bellows joints and instrument connections.

Clean-out and access doors are provided. The doors are of fabricated steel construction and gas tight.

A hopper is provided below the economizer and at the baghouse inlet. The hoppers terminate with flanged connections which join to the customer's ash removal system.

5.11. MECHANICAL DUST COLLECTOR

A high efficiency multicyclone dust collector will be provided. The multicyclone collector will be installed at the outlet of the tubular airheater. Hoppers are provided below the multicyclone. The hoppers terminate with flanged connections which join the Buyer's ash removal system.

5.12. BOTTOM ASH REMOVAL (Center Drain)

Bottom ash will be removed on a continuous basis from the combustion chamber. At each location bottom ash is discharged through a special bed drain system into a water-cooled screw conveyor.

The cooled bottom ash is discharged from each screw conveyor into the Buyer's ash handling system. The rate of ash removal from the combustion chamber is regulated by the variable speed drive on the screw cooler in order to maintain a constant solids inventory in the combustion chamber.

5.13. BAGHOUSE (Pulse Jet)

General

A pulse jet fabric filter dust collection system is proposed to reduce the flue gas content to meet the required particulate emissions. The dust collection system is designed for either on line or offline cleaning and the cleaning cycle can be initiated by demand or by baghouse pressure drop.

Pulse-Jet Off-Line Cleaning

A high efficiency pulse-jet cleaning system is provided utilizing off-line cleaning as the mode of operation with the alternate mode of on-line cleaning.

Bag Access

Bag access will be provided with the manufacturer's standard lift off door design. Each module will be covered by a gas tight door which will be lifted by a two ton electrically operated chain hoist. Complete bag access is available to a particular module once the door is lifted.

A penthouse is provided above the module access walkways and lift off doors for weather protection. The penthouse roof and siding will be constructed of 26 gauge galvanized steel. One roll-up maintenance door and one personnel door are provided. A ventilating fan, intake louvers and other accessory items will be provided to ventilate the penthouse enclosure.

Bypass

Flue gas can be bypassed from the inlet to the outlet manifold through a pneumatically operated, double-seated poppet valve. The bypass damper is automatically opened if the inlet temperature or baghouse differential pressure exceeds preset limits.

Expansion Joints

Expansion joints have been provided at the inlet and outlet connections to the baghouse and on the inlet and outlet duct connections to each module.

Baghouse Support Structure

The baghouse will include all structural steel for supporting the baghouse. All structural steel will be prime coated and will conform to ASTM Standard A-36. Bolting materials for structural steel connections will be high strength bolts. Bolting materials for miscellaneous structural steel such as stairs, ladders, handrailings, walkways and platforms will conform to applicable code standards.

Controls

The baghouse control system will be microprocessor based and will interface with the digital control system.

Hoppers

One (1) hopper fabricated of mild steel plate with 55° minimum valley angles (from horizontal) will be provided for each module. Each hopper will be provided with one (1) quick-opening hinged access door and will include a outlet flange to accommodate ash handling valves supplied by others.

Inlet and Outlet Manifolds

One (1) inlet and one (1) outlet manifold will be provided per compartment, including transition pieces and appropriate expansion joints. Manifolds will be all welded gas tight construction. Access to the inlet manifold will be through a diameter access door. Manifolds will be tapered to maintain uniform gas velocity and sized to minimize premature settling of dust. Inlet manifold transition pieces to each module will be located at or near the bottom of the manifold to assist in sweeping any settled dust into the module.

Isolation Dampers and Lockout System

Each module will be provided with pneumatically actuated inlet and outlet dampers supplied with limit switches to give positive indication of damper open and closed positions. Dampers shall fail in a fail safe position upon loss of plant air.

Inlet dampers will be butterfly dampers and outlet dampers will be the poppet damper type.

Bags, Cages and Accessories

Bags will be supplied with attachments that permit easy and dust tight installation. Bag cages shall be of one (1) section for ease of installation and constructed. There will be no rough spots on cages to cause bag abrasion or failure.

Design Parameters

MCR gas flow, acfm	98,340
Inlet gas temperature (°F)	300
Inlet loading, gr/ACF	18
Outlet loading, gr/ACF	0.01
Air-to-cloth ratio: gross	3.3
Air-to-cloth ratio: Net (with one compartment out of service)	3.8

5.14. CONTROL & INSTRUMENTATION

General Description

The control system for the CFB boiler will be designed to provide start-up, automatic control and monitoring of the following systems:

- Combustion
- Furnace draft
- Drum level and feedwater flow
- Main steam temperature
- Furnace inventory
- Auxiliary fuel start-up burner
- Safety system

The following control schemes are developed to meet the design requirements for control of the systems listed above.

- Main steam (or boiler) demand
- Fuel feed control
- Air flow control
- Steam drum level/feedwater flow control
- Furnace draft control
- Desuperheater spray flow control
- Bed temperature control
- Bottom ash cooling and removal
- Process monitoring
- Interlocks and permissives
- Secondary air pressure

Control Philosophies

The following descriptions provide the control philosophies used in developing the control schemes discussed above.

Steam (or Boiler) Demand

The boiler master demand controls steam pressure at a selected set point by varying fuel and air flow rates to respond to changes in total steam flow, fuel heating value, etc. This is accomplished by an analog control loop balancing the output of the main steam pressure controller with steam flow. The control loop is characterized for boiler performance to insure that load changes occur at a rate compatible with the dynamics of the boiler. This control loop provides the demand signal for fuel feed and air flow control.

Fuel Feed Control

The combustion control utilizes a lead-lag system to prevent a fuel-rich mixture occurring in the furnace. Air flow is always increased before fuel flow increases and fuel flow is always decreased before air flow decreases.

The fuel feed control loop maintains fuel flow to the bed in balance with boiler demand and combustion air flow. This is accomplished by comparing boiler demands, air flow and fuel flow with the resulting signal used to modulate the fuel feed rate.

Air Flow Control

Total air flow demand is determined as a function of boiler demand and fuel feed rates. This total air flow requirement is satisfied through the primary and secondary air flow rates. Primary air provides the air required for fluidization of the delivered fuel. Secondary air optimizes fuel and air mixing and provides staged combustion to minimize NO_x production.

The primary air flow rates to the grid nozzles are calculated as a function of the demand signal then compared with actual air flow. The resulting outputs are biased by the output of the bed temperature control loop and are used to modulate the air control dampers.

The secondary air flow rates to the air nozzles are calculated as a function of the demand signal then compared with the actual air flow. The resulting outputs biased by the output of the oxygen and bed temperature control loops and are used to modulate the air control dampers.

Primary and secondary air duct pressures are input to pressure control loops which control the primary and secondary air fan to insure that the required air is being provided.

Steam Drum Level/Feedwater Flow Control

A three element drum level control loop is used to control feedwater flow at a rate equal to the steam flow output. The drum level is compared to the setpoint. The resulting output is adjusted by the steam flow measurement which provides feed forward adjustment for rapid changes in process steam usage. This signal is then compared to the feedwater flow with the output used to modulate the feedwater control valve.

Furnace Draft Control

The pressure in the combustion chamber is maintained by imputing an upper furnace draft pressure signal to a pressure controller which controls the induced-draft (ID) fan. A measurement of the combustion air flow from the primary and secondary air fans provides a dynamically compensated feed forward signal for this loop.

Desuperheater Spray Flow Control

Steam temperature is controlled by using a conventional desuperheating spray water system. The steam temperature is regulated by the use of a control valve that controls water flow into the spray nozzle of the desuperheater. The outlet temperature of the superheater is the process variable which is compared to an operator established setpoint. The output of this control loop is the setpoint for the desuperheater outlet steam temperature controller. The final output signal modulates the spray control valve. This type of configuration is a cascade control system which will correct desuperheater outlet temperature before it affects the superheater outlet temperature. Therefore, responds faster to varying desuperheater spray conditions.

Bed Temperature Control

The purpose of this loop is to assist in maintaining bed temperature at its prescribed value due to changes in fuel heating value. Thermocouples are located in the lower combustion chamber to monitor the temperature. The temperatures are averaged to provide a single input signal to the bed temperature controller. Output signals from the bed temperature controllers are input into the primary and secondary air control loops, which modulates both air flows to provide bed temperature control.

Bottom Ash Removal

The purpose of this loop is to maintain the proper bed inventory. The amount of bed material in the furnace is measured by the pressure present in the lower combustion chamber. The rate of ash removal is set by the operator and must be adjusted periodically by the operator based on bed pressure indication.

Process Monitoring

These loops provide the operator with indication of the process parameters necessary for operating the boiler efficiently. These loops consist of pressure, temperature and flow measurements for steam, flue gas, combustion air, fuels and ash.

Interlocks and Permissives

The interlocks and permissives are system designed to provide proper sequencing for start-up and shut down as well as safety and emergency shut down for the following:

- Induced draft fan
- Primary air fan
- Secondary air fan
- Start-up burners
- Fuel feeders
- High pressure blowers

- Bottom ash removal equipment
- Other equipment associated with the PYROFLOW boiler

The interlocks and permissives are designed to comply with the applicable requirements of NFPA, IRI and ASME.

Secondary Air Pressure

The objective of secondary air pressure control is to insure duct pressure for controlling the secondary air flowrates. If secondary air flow is too low or too high, inefficient combustion will occur. This optimal pressure is maintained by feeding a duct pressure signal to the secondary air pressure controller and modulating the secondary air fan damper.

Equipment and Information Description

The Pyropower scope of supply will include instruments as outlined in section 3 of this proposal. As indicated in the start up burner description, a local flame supervisory panel will be provided with the start up burners.

All permissive, interlock, combustion control, and process control and logic will be done by the Distributive Control System (DCS).

5.15. DISTRIBUTED CONTROL SYSTEM (DCS)

Scope of Supply

Control processors.
Field bus modules.
Application processor with 80 MB Winchester disk drive and floppy disk drive.
Work station processors.
Work station color CRT monitors & alphanumeric keyboards.

Equipment Description

The Distributed Control System (DCS) is a microprocessor based Cathode Ray Tube (CRT) system, capable of performing all digital, analog control, data acquisition functions, paging historical storage and retrieval, report generation and alarming.

All control monitoring, computation and data storage elements are completely redundant, as well as all communication paths. All operator displays are independent; no single failure any where in the system can cause loss of control. Operator interaction with the system is totally consistent from any console in the plant. Basic interaction method is pulldown menu approach. System is of the modular component type which facilitates installation and maintenance. Modular design and diagnostic makes the system easy to maintain. If a module failure occurs, the operator is notified at the console. A redundant module takes over the operation. The failed module can then be replaced.

Configuration of applications can be accomplished at a single console for the whole system. Configuration can be through a CRT console or a personal computer.

Control system will be capable of performing the following functions.

- I/O: Analog Input, Contact Input, Analog Output, Contact Output, DIO Multi-point Processing, Flow Calc., Voting.

- Control: PID with options, EXACT, Ratio, Bias, Differential Gap, Pulse Duration.

- Selection: High, Low, Switch Position, Vote.

- Miscellaneous: Universal Ramp, Timer, Trip Recorder, Status.

- Dynamic Compensation: Impulse, Lead-Lag, Dead-Time.

- Computation: Add/Subtract, Multiply/Divide, Square Root, Exponential.

- Compensation and Conversion: Characterize, Pulse Counter, Accumulator, High/Low Clamp, Rate of Charge Clamp, Packed Boolean, Historian.

- Boolean: AND, OR, NAND, NOR, XOR, NXOR.

- Logic: Logic Switch, Compare, Bi-Directional Delay, On-off with Feedback, Motorized Valve.

- Alarm and Analysis: Real Type Alarm, Boolean Type Alarm, Truth Table Alarm, Alarm Priority Change, Sequence of Events.

- PLC: No Contact, NC Contact, Energized Coil, Latch Coil, Unlatch Coil, Retentive Timer On-Delay, Retentive Timer Reset, Up-Counter, Down-Counter, Counter Reset, Compare, Program Flow Control, Immediate Input, Immediate Output.

- Sequential Control: User Written via High Level Batch Language (HLBL).

These control blocks can be combined to form a compound type. The compound types are generic control strategies which can be re-used. Application of a user process data base to a block, or a compound type, makes a compound which is then executed in the Control Processor. Blocks and compound types can be nested to form a compound. A compound has a unique system wide name, and this uniqueness is enforced by the Control Processor station. The parameters in a compound can be linked internally to another compound or externally to compounds running in other Control Processor stations.

Alarms and status messages are generated by specific alarm blocks within a compound, not built into other blocks. Each alarm block can be assigned a GROUP and a PRIORITY number independent of the compound in which the alarm resides. Alarm messages destination devices are globally assigned on a GROUP basis (e.g., annunciator pushbuttons, printers, alarm history station, etc.).

Alarms have five levels of priorities to aid the operator in quickly focusing on the most important plant alarm conditions. These are summarized in a single alarm summary parameter for each compound (contains the highest current alarm in that compound). Additionally up to 8 logical destinations can be configured for distributing alarm status information in the network.

To reduce nuisance alarms, alarms may be inhibited on a per alarm basis. Or all alarms can be inhibited on a per block or per priority level.

Computing and application functions are also provided. The following are the basic functions:

- Compute Resources
- Historizing and Data Base Management
- Load Server for configuration programs and configuration files.

The DCS system consists of control processors, field Bus modules, communication processor, dot matrix printer, application processor with 80-MB winchester disk drive and floppy disk drive for trending and data base storage, work station processors, work station CRT color monitors and APPHA numeric key board.

Pyropower is responsible for supplying any documentation to the DCS vendor for configuration and implementation of Pyropower supplied system, i.e., Boiler, feeders etc. Supplies of balance of plant equipment will be responsible for providing all documentation in the appropriate format to the DCS supplier for configuration and implementation.

5.16. DOCUMENTATION

Pyropower will supply contract documentation in the form of drawings and equipment lists. Detailed shop drawings will not be issued to the Engineer or Customer. Drawings will be in sufficient detail for erection of the equipment.

A typical list of contract drawings is shown in Table 5.16. Pyropower will transmit eight (8) blueprints and one (1) sepia for each issue of a particular drawing.

Pyropower will provide equipment lists which outline equipment information as follows:

- Motor list.
- Valve list.
- Instrument list.
- ISA data sheets.
- Major boiler equipment

TABLE 5.16.

TYPICAL CONTRACT DRAWINGS

		SIZE
1.0	Arrangement drawings	E
	• General arrangement	E
	• Duct layout	E
	• Platform arrangement	E
	• Sectional arrangement	E
2.0	P & ID	
	• Steam/water	E
	• Air/flue gas	E
	• Fuel/limestone/ash	E
	• Startup burner	E
3.0	Control and Instrumentation	
	• Digital Logic Diagrams (Boolean Format)	11" x 17"
	• Analog Control Diagrams (SAMA Format)	11" x 17"
	• Instrument Location Drawings	E
	• Instrument Installation Details (IID)	11" x 17"
4.0	Vendor Drawings	
	PpC purchased equipment	Vendor Standard
5.0	Detail Drawings	
	• Pressure part details	E
	• Structural details	E
	• Auxiliary fuel system	E
	• Main fuel system	E
	• Refractory and insulation	E

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6. PREDICTED PERFORMANCE

6.1. PERFORMANCE DATA

LOAD CONDITION % MCR	100%	75%
TYPE OF FUEL	Jordanian Oil Shale	Jordanian Oil Shale
STEAM LEAVING SH, MLB/hr	200	150
EXCESS AIR, %	20%	20%
CALCIUM TO SULFUR MOLAR RATIO	N/A	N/A
FUEL HEAT INPUT, MMBTU/hr	293.8	224.9
QUANTITY, MLB/hr		
Fuel	121.4	92.9
Air	263.5	201.8
Flue gas	296.2	226.8
Ash (Total)	88.8	67.9
Fly ash, % of total ash	55.0	30.0
PRESSUPE, PSIG		
Econ. inlet	1750	1674
Drum	1715	1643
Superheater outlet	1550	1550
STEAM/WATER TEMPERATURES, °F		
Entering economizer	370	370
Leaving economizer	493	488
Leaving Drum	615	609
Superheater outlet	955	955
AIR TEMPERATURES		
Entering fans	80	80
Leaving fans (weighted aver.)	100	100
FLUE GAS TEMPERATURES, °F		
Leaving furnace	1600	1510
Entering economizer	848	799
Leaving economizer	523	496
Entering airheater	523	496
Leaving airheater	300	279

LOAD CONDITION % MCR	100%	75%
Net efficiency	76.07	74.43

PREDICTED PERFORMANCE IS BASED ON COMBUSTION AIR LEAVING FANS AT A WEIGHTED AVERAGE TEMPERATURE OF 100°F WITH 0.013 LB MOISTURE/LB DRY AIR AND 13.40 PSIA BAROMETRIC PRESSURE.

7. PROJECT SCHEDULE

A schedule depicting the engineering, manufacturing, construction and start-up/testing activities is included in this section. This schedule is predicated on two (2) key milestones:

1. Foundations in place ready for erection by 10-1/2 months after contract award.

2. Turbine roll and synchronization by 27 months after contract award.

Pyropower's project involvement is currently allotted 27 months from the contract award to turbine synchronization. Note that a second unit on the same site would lag this schedule by approximately two months.

Milestone dates associated with Pyropower's scope of work are:

<u>Months after Contract Award</u>

0	-	Notice to proceed.
2	-	Preliminary boiler design completed. Place the major boiler pressure parts order.
3	-	Prepare equipment specifications. Begin material and equipment procurement.

10-1/2	-	Foundations in place ready for erection. Erection contractor mobilized. Begin boiler erection.
20	-	Final major equipment delivered to project site.
21	-	Boiler hydrostatic testing completed.
23-1/2	-	Begin equipment checkout.
25-1/2	-	Ready for steam blows.
27	-	Initial turbine roll and synchronization.

Activities comprising the detailed boiler design portion of the schedule include completion of process and design calculations; preparation of purchased equipment specifications; and completion of general arrangement and layout drawings, piping and instrumentation diagrams, fuel and air flow diagrams, boiler and equipment load diagrams, electrical schematics, control and instrumentation schematics, structural drawings, and all associated detail and routing drawings. Engineering support will continue throughout the procurement, construction, and start-up phases.

Only major component purchases are listed in the equipment procurement phase of the schedule. However, orders for virtually all equipment and materials comprising Pyropower's scope of supply will be placed during this period to assure delivery as required by the construction schedule.

The construction phase is projected to span 14 months. Construction must be closely integrated into both the engineering and procurement phases to assure unimpeded erection and subsequent equipment start-up and successful operation. Receiving and temporary storage of materials and equipment is included in this phase, as well as protection and maintenance of equipment throughout the duration of construction activities. All equipment is erected, leveled, coupled, connected and made ready to operate.

As a top-supported unit, erection will progress from the top downward. Construction of the unit will be essentially completed before start-up and checkout activities begin 23-1/2 months after contract award. (Boiler hydro is scheduled after erection of the pressure parts and prior to refractory installation).

Start-up and testing involves equipment and systems checkout and initial operation. Temporary burners are installed at several locations in the boiler to dry refractory in the cyclones, the ash coolers, the windbox and lower combustion chamber, and the crossover ducts. After the refractory is cured the initial boiler firing (on secondary fuel) occurs. Boilout, chemical cleaning, and steam blows are completed and steam is made available for initial turbine roll and synchronization. Any operational problems which occur with the equipment are corrected during start-up.

In general, the critical schedule path involves the design, specification, ordering, manufacturing, delivery and erection of the pressure parts. These activities must be carefully controlled and expedited.

APPENDIX 11

BECHTEL POWER BLOCK DESIGN - 20 MW

20 MW UNIT

A. DESIGN BASES AND ASSUMPTIONS

1.1 Site Conditions

(See Appendix 9A)

1.3 Buildings

(See Appendix 9A)

2.1 General

The power generating facility consists of one condensing turbine-generator unit. The unit is rated at 23.4 MW gross output at the generator terminals with 103 kg/sq cm Abs (1463.5 psia), 510°C (950°F) turbine throttle steam conditions, 188°C (370°F) final feedwater temperature, and 139.7 mm (5.5 inches) of HgA condenser pressure. Four stages of feedwater heating are used. An air cooled dry condenser is used to minimize plant water consumption.

2.2 Codes and Standards

(See Appendix 9A)

2.3 Design Basis Fuels

(See Appendix 9A)

2.4 Design Fuel Flow Rates

It is assumed that the oil shale mine will do the necessary blending, crushing and sizing of the fuel to make it suitable for firing in the Pyropower boiler.

The design fuel flow rate for the plant is about 59.4 metric tons/hr (65.5 tons/hr), or about 390,000 metric tons/year (430,300 tons/year). The above values are based on an annual plant capacity factor of 0.75.

2.5 Process Makeup Water

Process makeup water for the power plant is assumed to come from two 100% capacity deep well pumps. Well water will be used for cooling tower makeup, pump seals and other uses without treatment. Makeup water for the steam cycle will be provided from this source through a set of demineralizers and domestic water will be treated as required. Cooling tower blowdown will be used for ash handling dust suppression. Estimated annual water consumption for the 20 MW power plant at 75% capacity factor is about 0.15 million cu meters (40.2 million gallons). Well water analysis is shown in Table 3 below:

Table 3

JORDAN SULTANI GROUND WATER ANALYSES

	PPM
Electrical Conductivity	1230
T.D.S	757
Elemental Analysis	
Ca	83
Mg	45
Na	47
K	4.3
Cl	170
SO_3	101
HCO_3	320
NO_3	2.3
TH	392
Ph	7.36

2.6 Environmental Design Bases

2.6.1 Flue Gas Emissions

(See Appendix 9A)

2.6.2 Solid Waste Disposal

(See Appendix 9A)

2.7 Utility and Process Tie-Ins for Cost Estimating

(See Appendix 9A)

3.0 CONTROL SYSTEMS/ELECTRICAL

3.1 Instruments and Controls

The conceptual design assumes the following control concepts:

- A central control room for plant operation and monitoring.
- Local instruments and controls panels for boiler to enable local startup of boiler and auxiliaries. After start-up, control can be transferred to the central control room
- Single Phase uninterruptible source of power supply at 115 V ac for electronic instruments.
- Critical circuits hard-wired to dedicated control panels.
- Instrument air supply at 6.7 to 8.8 kg/sq cm (80 to 110 psig).

3.2 Electrical

The electrical generation is at 11 kV, 3 phase, 50 Hz. An auxiliary transformer steps down the voltage from 11 kV to 6.6 kV to supply electric power to the various auxiliary equipment in the power plant. Auxiliary power demand is assumed to be about 15.6% of the gross generation at the generator terminals. The generation voltage is stepped up to 132 kV with a main transformer. The Single Line Diagram E01 shows the scope for electrical work included in this study.

Power requirements for the mine and crushing plant are assumed to be purchased from the National grid.

20 MW UNIT

B. LIST OF MAJOR EQUIPMENT

A. TURBINE AND AUXILIARIES

QUANTITY	ITEM	DESCRIPTION
1	Turbine/Generator	Condensing w/4 uncontrolled extractions Throttle conditions 90,700 kg/hr (200,000 lb/hr) 103 kg/sq cm Abs (1463.5 psia) 510°C (950°F) Extraction conditions 0.4 kg/sq cn Abs (5.7 psia) 1.9 kg/sq cm Abs (27 psia) 5.2 kg/sq cm Abs (74 psia) 12.8 kg/sq cm Abs (182.5 psia) Exhaust conditions 139.7 mm HgA (5.5 in HgA) Output 23.4 MW Generator 27.5 MVA, 0.9 PF, 11 KV 3 Phase, 50 Hz Including Static exciter Voltage regulator Stop and control valves Lube oil system Electro-hydraulic governor system Gland steam system Turning gear, 10 HP motor Supervisory instrumentation Air cooled generator, exciter, lube oil system

QUANTITY	ITEM	DESCRIPTION
1	Air Cooled Condenser	139.7 mm HgA (5.5 in Hga) 35.5 mm Kcal/hr (141.2 MM Btu/hr)
2	Vacuum Pump	Liquid ring type, 2 stage Motor driven, 125 HP
2	Condensate Pump	Horizontal, centrifugal type Motor driven, 50 HP 83,300 kg/hr (367 GPM), 88.9 m (290 ft) TDH
1	L.P Feedwater Heater No. 1	Closed - shell and tube 0.4 kg/sq cm Abs (5.7 psia) extraction pressure 2,200 kg/hr (4,900 lb/hr) extraction flow
	(L.P Feedwater Heater No. 1)	80,000 kg/hr (176,500 lb/hr) feedwater flow 2.8°C (5°F) TTD, 5.6°C (10°F) DC approach
1	L.P Feedwater Heater No. 2	Closed - shell and tube 1.9 kg/sq cm Abs (27 psia) extraction pressure 6,100 kg/hr (13,500 lb/hr) extraction flow 80,100 kg/hr (176,500 lb/hr) feedwater flow 2.8°C (5°F) TTD, 5.6°C (10°F) DC approach

QUANTITY	ITEM	DESCRIPTION
1	Deaerating Heater	Open - deaerating spray type 5.2 kg/sq cm Abs (74 psia) extraction pressure 5900 kg/hr (13,100 lb/hr) extraction flow 91,900 kg/hr (202,500 lb/hr) outlet flow
2	Feedwater Pumps	Horizontally split case - multistage Motor Drive, 650 HP 95,500 kg/hr (460 GPM), 1325 m (4350 ft) TDH
1	H.P Feedwater Heater No. 1	Closed - shell and tube type 12.8 kg/sq cm ABS (182.5 psia) extraction pressure 6000 kg/hr (13,300 lb/hr) extraction flow 91,900 kg/hr (202,500 lb/hr) feedwater flow 0°C (0°F) TTD, 5.6°C (10°F) DC approach
1	Bridge Crane	30 ton with auxiliary hook

B. BOILER AND AUXILIARIES

QUANTITY	ITEM	DESCRIPTION
1	Steam Generator	Circulating fluidized bed, drum type, subcritical, natural circulation boiler with the following superheater outlet conditions: 109.9 kg/sq cm (1563.5 psia) 512.8°C (955°F) 70,700 kg/hr (200,000 lb/hr) Economizer 188°C (370F) Main fuel: Oil Shale 1250 Kcal/kg (2250 Btu/lb) Auxiliary fuel No. 2 fuel oil

QUANTITY	ITEM	DESCRIPTION
1	Air Preheater	Tubular air heater 25,990 sq.ft
1	Primary Air (P.A) Fan	Centrifugal, motor driven, 800 HP 94,700 kg/hr (208,830 lb/hr) 1824 mm (71.8 in) Wg
1	Secondary Air (S.A) Fan	Centrifugal, motor driven, 250 HP 48100 kg/hr (106,025 lb/hr) 1105 mm (43.5 in) Wg
1	High Pressure Blower	Multistage blower, motor driven 150 HP 2900 kg/hr (6425 lb/hr) 6097 mm (240 in) Wg
1	Induced Draft (ID) Fan	Centrifugal, motor driven, 900 HP 165600 kg/hr (365190 lb/hr) 747 mm (29.4 in) Wg
1	Steam Coil Air Heater	U-tube model, 70/30 cu. ni. Aluminum fins
1	Mechanical Dust Collector	High efficiency, multicyclone type
1	Bag House	Particulate removal equipment, pulse jet type with emergency bypass, inlet flue gas flow 3019 a m^3/min (106610 acfm)/149°C (300°F)
1	Stack	Self-supporting concrete with steel liner, 91 meters (300 feet) high
1	Blowoff Tank	1.2 meters (4 feet) diameter x 2.7 meters (9 feet) high, vertical, carbon steel

QUANTITY	ITEM	DESCRIPTION
C. FUEL HANDLING		
3	Live Storage Silo	Concrete 10 meters (33 feet) diameter 1300 mton (1430 ton) oil shale capacity
3	Vibrating Feeder	40 mtph (44 tph)
2	Fuel Conveyor From Live Storage To Implant Silo	100 mtph (110 tph)
1	Implant Fuel Silo	8 hour storage, 440 mtons (485 tons)
2	Fuel Feeder	Gravimetric type, motor driven 64 mtph (70 tph)
1	Fuel Oil Storage Tank	(44,000 gal)
2	Fuel Oil Handling Pumps	(10 gpm)
D. Ash Handling		
1	Fly Ash Storage Silo	24 hr. storage, 533 mtons, (586 tons)
1	Bottom Ash Storage Silo	24 hr. storage, 437 mtons (480 tons)
2	Fly Ash Vacuum Blowers	2x100% capacity, 125 HP
2	Bottom Ash Vacuum Blowers	2x100% capacity, 120 HP
2	Fluidizing Blowers	2x100% capacity, 75 HP
2	Fly Ash Pug Mills	75 mtons/hr
2	Bottom Ash Pug Mills	60 mtons/hr

QUANTITY	ITEM	DESCRIPTION
E.	PLANT WATER SYSTEMS	
2	Service Water Pumps	Vertical, centrifugal Motor driven, 75 HP 1,020,400 kg/hr (4,500 gpm) 24.4 m (100 ft)TDH
1	Cooling Tower	Mechanical draft, 75°F wet bulb temperature, 6.7°C (12°F) approach 11.1°C (20°F) range, 3.5 mm Kcal/hr (13.6 MM Btu/hr) duty
1	Chemical Feed System	Consisting of three systems, one each for hydrazine, morpholine and sodium phosphate. Each system is made up of one batch tank and two full capacity feed pumps.
1	Make-up Water Treating System	2-trains of 3400 kg/hr (15 gpm) each and consisting of a feed pump, a carbon filter, a cation unit, an anion unit, and a mixed bed unit.
1	Caustic Storage Tank	7.6 cu meters (2,000 gal) - Horizontal cylinder, carbon steel, heat traced
1	Acid Storage Tank	7.6 cu meters (2,000 gal) - Horizontal cylinder, carbon steel
1	Neutralization Sump	37.9 cu meters (7500 gal) - concrete, epoxy lined w/2 full capacity motor driven pumps 11,350 kg/hr (50 gpm)/ 30.5 m (100 ft) TDH, 3 HP
2	Sump Pumps	Vertical centrifugal Motor driven, 1 HP 2250 kg/hr (10 gpm)/6.1 m (20 ft) TDH

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QUANTITY	ITEM	DESCRIPTION
1	Demineralized Water Storage Tanks	38 cu meters (10,000 gal), epoxy lined carbon steel
2	Demineralized Water Pumps	Horizontal centrifugal Motor driven 1 HP 4535 kg/hr (20 gpm)/30.5 m (100 ft) TDH
2	Well Water pumps	Vertical centrifugal Motor driven, 25 HP 45,400 kg/hr (200 gpm) 91.4 m (300 ft) TDH
2	Raw Water pumps	Horizontal centrifugal Motor driven, 7.5 HP 34,000 kg/hr (150 gpm) 31 m (100 ft) TDH
1.	Well Water Storage Tank	190 cu meters (50,000 gal) Epoxy lined carbon steel
1	Fire Pump	Horizontal centrifugal Motor driven, 150 HP 226,700 kg/hr (1000 gpm) 88 m (290 ft) TDH
1	Fire Pump	Horizontal centrifugal Diesel driven 226,700 kg/hr (1000 gpm) 88 m (290 ft)
1	Jockey Fire Pump	Horizontal centrifugal Motor driven, 5 HP 8000 kg/hr (35 gpm) 88 m (290 ft) TDH

F. MISC. SYSTEMS

QUANTITY	ITEM	DESCRIPTION
3	Air Compressors	Reciprocating type, motor driven 400 scfm, 125 psig, 150 HP

QUANTITY	ITEM	DESCRIPTION
2	Air Dryers	200 scfm
3	Air Receivers	--
1	Lube Oil Storage Tank	18.9 cu meter (5000 gal)
1	Lube Oil Centrifuge	1140 kg/hr (5 gpm)

E. ELECTRICAL

QUANTITY	ITEM	DESCRIPTION
1	Generator Step-Up Transformer	20/26 MVA, OA/FA Rating 11-132 KV, 3 Phase, 50 HERTZ 2 ± 2-1/2% Taps
1	High Voltage Circuit Breaker	SF_6 Power Circuit Breaker 132 KV, 3 Phase, 50 HERTZ 1200 A Rating
2	High Voltage Disconnect Switch	Voltage Rating 132 KV Current Rating 600 A
1	Auxiliary Transformer	5 MVA, OA Rating 11 - 6.6 KV, 3 Phase, 50 HERTZ Z = 5.5% 2 ± 2-1/2% Taps
1	Service Transformer	750 KVA, AA Rating 11 KV - 380 V, 3 Phase, 50 HERTZ Z = 5.75% 2 ± 2-1/2% Taps
1	Medium Voltage Switch Gear	Indoor Metal-Clad Switchgear Voltage 6.6 KV 3 Phase MVA 250 MVA Main Bus 1,200 A

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QUANTITY	ITEM	DESCRIPTION	
1	Medium Voltage Supply Circuit Breaker for MV Switchgear	Vacuum Circuit Breaker	
		Rated Voltage	6.6 KV
		3 Phase MVA	250 MVA
		Rated Current	1,200 A
		Opening Time	5 Cycles
4	Load Center Transformer	Ventilated Dry Type	
		750 KVA, AA Rating	
		6.6 KV-380 V, 3 Phase, 50 HERTZ	
		Z = 5.75%	
		2 ± 2-1/2% Taps	
4	Load Center Bus and Switchgear	Metal-Enclosed Switchgear	
		Rated Voltage	380 V
		Main Bus	2000 A
		Dielectric Withstand	2200 V
		Bus Bracing	65 KA Rms. Sym.
8	Motor Control Center (MCC)	Rated Voltage	380 V
		Main Bus	600 A
		Interrupting Rating	25,000 A
1	Power Distribution Panel	Rated Voltage	380 V
		Main Bus	600 A
		Interrupting Rating	25,000 A
1	110 V DC Battery and Distribution System	Lead-Calcium Stationary Cells,	
		53 Cells, 2.2 Volt Per Cell	
		Solid-State Rectifier/ Battery Charger	
		AC Input 380 V, DC Output 115 V	
1	Uninterruptible Power Supply System	Static Inverter	
		Input: Voltage	115 V DC
		Output: Voltage	115 V AC
		Frequency	50 HZ
		Static Switch for Bypass	

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APPENDIX 12

CHEVRON CORPORATION - WORLD ENERGY OUTLOOK

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Overview: Energy Outlook to the Year 2000

World Excluding Centrally Planned Economies

Energy Consumption	1.9% average annual growth – about ⅔ the GNP growth rate
Oil Consumption	0.8% average annual growth – share of total energy declines from 46% in 1986 to 40% in 2000
Oil Supply	production capacity exceeds demand – OPEC crude production rises from 45% of total supply in 1986 to over 55% in 2000
Crude Oil Prices	prices fluctuate in the range of $15–$30 a barrel, with real price increases expected before 2000
Refining	surplus distillation capacity – additional facilities to convert fuel oil to light products may be needed by the mid-1990s
Natural Gas Consumption	2.7% average annual growth – end-user prices return to parity with fuel oil in early 1990s
Natural Gas Supply	89% of gross production is being utilized – flaring still occurring in many countries
Coal Consumption	2.6% average annual growth – price increases at the rate of inflation
Nuclear Power	3.6% average annual growth – predominantly in Europe and Asia

United States

Energy Consumption	0.9% average annual growth – about ⅓ the GNP growth rate
Oil Consumption	0.5% average annual growth – the share of total energy declines from 44% in 1986 to around 40% in 2000
Oil Supply	domestic production declines 2.4% a year – U.S. imports over 55% of oil demand by 2000
Natural Gas Supply	0.3% average annual decline in production – imports increase 9.5% a year

Growth in Energy Demand from 1986 to 2000

	World Excluding CPE		United States	
	Increased Demand*	% of Total	Increased Demand*	% of Total
Oil	5.7	19	1.2	23
Natural Gas	7.9	26	0.4	8
Coal	8.6	29	2.1	41
Hydro & Misc.	3.7	12	0.4	8
Nuclear	4.2	14	1.0	20
Total	30.1	100	5.1	100

* in millions of barrels a day of crude oil equivalent

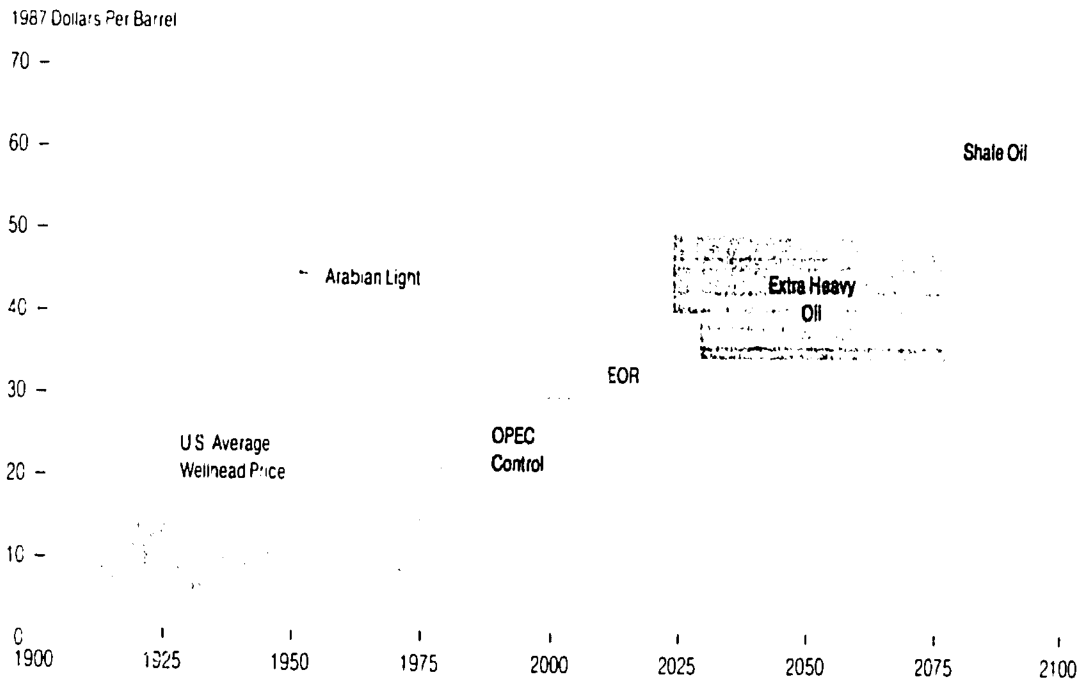
Oil: A Re-emerging Commodity?

Oil prices have made their third major move in a decade and a half. After two upward surges — in 1973 and again in 1979 — a steady five-year decline in oil prices ended in an abrupt collapse in 1986. In just seven months, oil prices fell by more than 50%.

The oil price collapse marked the end of an era. Oil, which had seemed in the 1970s to be in an almost perpetual state of shortage, once again began to be regarded as "just another commodity." The early 1980s saw a growing surplus of oil-producing capacity — the result of conservation by consumers combined with significant new sources of oil production. The price collapse conclusively demonstrated the power of the market place. Petroleum, like any other commodity, will respond to the economic forces of supply and demand.

Oil is now traded on commodity markets where the price is set in transactions between many buyers and sellers, with associated futures and options markets permitting both hedging and speculation. Like other commodities, oil can be expected to exhibit significant price volatility as a result of both seasonal and cyclical variations in the overall supply/demand balance.

Crude Price Outlook



The Historical Perspective

The dramatic events of 1986 — and their influence on the future — are best understood by examining them in historical context. Over the first 70 years of the 20th Century, average U.S. wellhead prices, adjusted for inflation, have been surprisingly level at about $10 a barrel. At the same time, prices have shown considerable volatility around this average.

Examination of the price pattern from the beginning of the modern oil industry suggests that wars and political disruptions raise prices and technology reduces them. Oil prices rose in response to the Civil War, the Spanish-American War, World War I, and World War II. Each time, prices were reduced by technological advances. The introduction of rotary drilling accelerated the development of the Pennsylvania oil fields in the 1870s, an understanding of surface geology led to the discovery of Spindletop in 1901, while several decades of progress in the geological and geophysical sciences were instrumental in the opening of the East Texas Field in the 1930s and the development of the large, low-cost oil deposits in the Middle East after World War II.

More recently, the price increases of the 1970s were associated with the Yom Kippur War, Iranian Revolution and Iran-Iraq War, which coincided with a lack of incremental capacity in OPEC. This combination led to sharp price increases, which in turn stimulated technological advances permitting development of frontier oil provinces, most notably the North Sea, the Alaska North Slope and Mexico. The resulting increase in non-OPEC supply laid the groundwork for the price collapse.

The decline in oil demand in the 1980s was also a significant factor in the oil price collapse of 1986. Technical innovations have enhanced conservation by improving energy efficiency in factories, homes and automobiles, as well as permitting greater flexibility in substituting other fuels for oil.

The Impact of Politics

Oil and politics have always been inextricably intertwined. It is quite probable that future oil supply disruptions will occur as the result of war, revolutions, or political turmoil. In the short term, politics tends to dominate thinking about oil prices; in the longer term, economic forces are a more significant consideration. It is important for both industrial planners and public policy-makers to separate short term behavior from longer term trends.

Oil producers must recognize that the forces of conservation and substitution place real limits on their ability to raise prices. As tempting as it is to raise official prices in pursuit of spot prices during a disruption, the price collapse of 1986 demonstrates how difficult this process can be.

LONG TERM Rising Real Prices?

One of the big questions facing the industry is whether the events of the past decade have signalled a change in the historical profile of relatively level oil prices.

Although uncertainty is inherent in any price outlook, two factors seem overriding:

- For the first time, the cost of the next barrel to be discovered is higher than the cost of the barrel being consumed today.
- The growing concentration of

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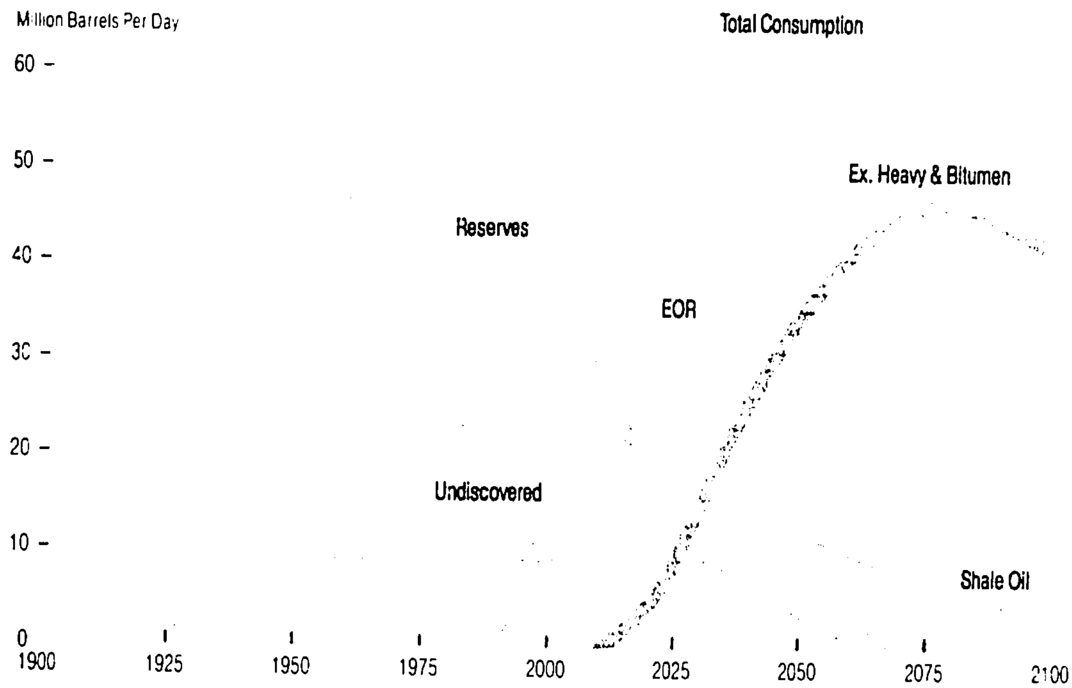
World Crude Oil Supply



onventional oil reserves in the ands of relatively few producing countries will make it easier to exert political control over prices.

Although it is difficult to be precise, the following approach appears to have merit as an aid to facilitate thinking about future oil prices.

The total hydrocarbon resource base is enormous. Although 565 billion barrels of oil have already been produced, proven reserves are still 688 billion barrels. On the order of 525 billion barrels of potential conventional reserves remain to be discovered or developed, followed by an enhanced oil recovery (EOR) target of at least 800 billion barrels. After that, there are even larger resources of extra heavy oil, bitumens and oil shale.

The above two charts relate future price levels to one possible long-term development profile.

The Crude Price Outlook chart shows the development of oil prices through 2100. From now until 2000, OPEC has sufficient reserves to control oil supply and, therefore, price (**OPEC Control**). However, after OPEC's inexpensive reserves begin to be depleted, the cost of finding and producing the next increment of world reserves will be higher. Most undiscovered non-OPEC conventional oil is likely to be found in small fields with complex geology or in remote regions with hostile environments.

The next economic increment of oil, represented by the **EOR** box, will be produced using EOR methods. Conventional production methods recover, on average, only about a third of the original oil in place. A portion of the remaining two-thirds can be recovered by EOR. In any particular field, EOR is more costly than conventional recovery. Improved EOR technology is expected to make significant amounts of oil available at prices in the \$25 to \$40 a barrel range. It is anticipated that ultimate recovery rates will increase to 50% or more of the original oil in place.

After EOR, the next more costly large deposits are in the form of extra heavy oil, oil sands and bitumen (represented by the **Extra Heavy Oil** box). These resources represent potential future sources of hydrocarbons that can be converted to usable liquid fuels, but not until the price reaches approximately twice that of today's conventional oil (\$35 to \$50 a barrel). Some of these resources are being produced today in Canada and Venezuela. These early small-scale projects have demonstrated the technology and reduced costs to the point where, even at today's prices, incremental projects using existing infrastructure are able to proceed.

The last box shown is **Shale Oil**. The cost to produce shale oil today is prohibitive, but will be economic by the late 21st century if crude oil prices approach \$60 a barrel.

Any attempt to attach costs to the future development of these resources implies a technology, rather than an oil price forecast. Improving technology will, over time, help to moderate today's costs. This outlook assumes cost-saving technological advances in all production methods, but could underestimate those advances. However, it is unlikely than even the most optimistic forecaster would envision technical developments which could offset rising real costs of producing unconventional resources.

The placement of the boxes on the time line is a function of expected world oil consumption. The World Crude Oil Supply chart illustrates when each increment of development will be required based on an assumed total consumption curve. For purposes of this analysis, world oil consumption was assumed to grow 0.8% a year until 2000, gradually leveling off and starting to decline by the middle of the next century.

Examination of this potential production profile suggests that these resources can be developed sequentially rather than simultaneously with each one peaking as the previous one declines.

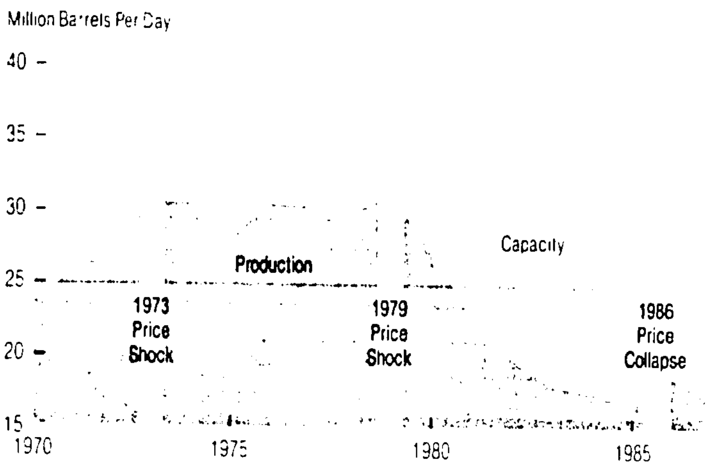
Several observations concerning the long term outlook can be made:

- The uncertainty for both price and timing represented by each box is large.
- Positioning of the boxes along the time line is not particularly sensitive to assumptions about total consumption in the early years.
- The rate of real price growth — about 1% a year — is considerably lower than was generally expected in recent years.

SHORT TERM
The Era of OPEC Control

The experience of the past

OPEC Crude Oil Production and Capacity



ten years leads to the conclusion that there are oil price levels that — under current conditions — are either "too high" or "too low." If price becomes too high or too low, powerful forces of supply and demand are set in motion that tend to bring it back within the range.

With the clarity of hindsight, it appears that both the price peak of 1980 and the trough of 1986, when spot oil prices briefly dipped below $10 a barrel, were outside the sustainable range. In 1980, a 6.9% decline in U.S. oil demand — and, in 1986, an 8.8% decline in U.S. crude oil production — demonstrated the speed with which market forces react to draw prices back into the sustainable range.

If prices rise out of the range, the resulting additional capacity and conservation may force prices below the level they would have attained if the excursion had not occurred. As long as prices are kept within this fairly wide range, a producer cartel such as OPEC, with its vast reserves, can exert considerable influence on oil prices.

In 1987, OPEC reimposed production quotas to bring prices back to around $18 a barrel. For the next few years, OPEC will probably continue to try to restrict production while waiting for the underlying supply/demand balance to catch up.

A range of $15 to $30 a barrel describes the general limits within which OPEC can act unilaterally to set prices. If OPEC elects to increase market share by keeping prices at the lower edge of this range, the demand for OPEC oil will grow rapidly. Eventually, OPEC no longer will have the production capacity to increase output, and prices will rise. Assuming sustainable OPEC production capacity is limited to its previous peak of about 35 million barrels a day, OPEC could hold the price down to $15 a barrel in order to increase market share only for about ten years.

Under the same production capacity assumption, OPEC's reserves are probably large enough to hold oil prices near $30 a barrel for up to twenty years. If prices are at the high end of the range, it is going to be difficult for OPEC to restrict production sufficiently to maintain prices. At the low end of the range, production restrictions will not be required for as long, because surplus producing capacity will be absorbed by growing demand.

In the longer term, OPEC can keep prices under control only by making timely investments to increase production capacity. By maintaining sufficient production capacity, OPEC can minimize the risk of supply disruptions and attendant uncontrolled price increases like those that occurred in 1973 and 1979.

Any price path within the general limits of the "OPEC Control" box depends to a large degree on OPEC production and investment policies. The two trends depicted on the chart suggest alternative price paths which reflect different, possible OPEC policies. They are shown rising because eventually OPEC's ability to control prices will give way to the economics of EOR production.

OTHER ENERGY PRICES

Natural Gas

Because U.S. gas prices initially lagged the 1986 oil price collapse, gas lost market share to oil. As soon as the industry recognized the problem, gas prices dropped to traditional levels relative to fuel oil in order to regain volume. However, as oil prices rose, the oversupply of gas prevented prices from rising in step with fuel oil.

In the U.S., the situation is further complicated by recent Federal Energy Regulatory Commission rulings that are moving toward decontrol of both pricing and transportation. Complete decontrol could release pent-up volumes of "old gas," causing a major restructuring of the industry. Increased competition in the market could potentially hold down gas prices past 1990.

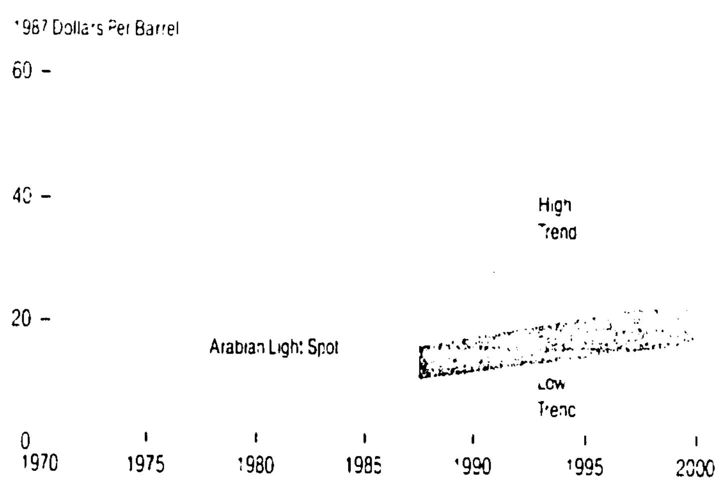
In 1986, international marketers of liquefied natural gas (LNG) also faced contract renegotiations and defaulted liftings as spot crude prices plummeted below the official prices factored into LNG contracts.

This outlook assumes that gas prices in the industrialized countries will return to parity with fuel oil in the early 1990s.

Coal

International coal trade is very competitive. Prices are expected to remain below fuel oil as various countries vie for a share of growing boiler fuel markets. Traditional suppliers will face new challenges from developing exporters such as China, Colombia and Indonesia.

Crude Price Trends — Era of OPEC Control



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