DOE/PC/91154--T12
M96050311

DVORSCAK
Paralegal
Data

DEVELOPMENT OF A HIGH-PERFORMANCE COAL-FIRED POWER GENERATING SYSTEM WITH PYROLYSIS GAS AND CHAR-FIRED HIGH-TEMPERATURE FURNACE (HITAF)

DE-AC22-91PC91154

FINAL REPORT
Volume IV

Prepared for
Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania

FWDC Project 9-41-3492
May 1996

FOSTER WHEELER DEVELOPMENT CORPORATION
12 Peach Tree Hill Road, Livingston, New Jersey 07039

TABLE OF CONTENTS

		PAGE
APPENDIX G: HIPPS REPOWERING DESIGN STUDY		
G.1	INTRODUCTION	G-2
G.2	PLANT PERFORMANCE PREDICTION	G-12
G.3	PLANT ARRANGEMENT	G-17
G.4	BOILER MODIFICATIONS	G-21
G.5	PYROLYZER SUBSYSTEM	G-24
G.6	BALANCE OF PLANT	G-27
G.7	CAPITAL & OPERATING COSTS	G-36
G.8	ECONOMIC ANALYSIS	G-42
G.9	PLANT ARRANGEMENT DRAWINGS	G-51
G.10	BOILER MODIFICATIONS AND PYROLYZER SUBSYSTEM DRAWINGS	G-52

APPENDIX G

HIPPS REPOWERING DESIGN STUDY

G.1 INTRODUCTION

An outgrowth of our studies of the FWDC HIPPS concept was the development of a concept for the repowering of existing boilers. The initial analysis of this concept indicates that it will be both technically and economically viable. A unique feature of our greenfields HIPPS concept is that it integrates the operation of a pressurized pyrolyzer and a pulverized fuel-fired boiler/air heater. Once this type of operation is achieved, there are a few different applications of this core technology. Two greenfields plant options are the base case plant and a plant where ceramic air heaters are used to extend the limit of air heating in the HITAF. The greenfields designs can be used for repowering in the conventional sense which involves replacing almost everything in the plant except the steam turbine and accessories. Another option is to keep the existing boiler and add a pyrolyzer and gas turbine to the plant.

A simplified schematic diagram of this repowering concept is shown in Figure G-1. The design and operation of the pyrolyzer will be the same as in the base case, greenfields plant. The fuel gas produced will be used as fuel in a gas turbine. In the repowering concept, the compressor discharge air will not be taken off the machine so a standard gas turbine can be used. The char from the pyrolyzer is transported to the existing boiler where it is used as fuel along with coal. The gas turbine can be sized such that all the exhaust air is used for combustion or a larger gas turbine can be used and some of the gas turbine exhaust can go to heat recovery devices. The base case repowering concept has been designed around using all of the gas turbine exhaust as combustion air for the boiler. This approach results in a simpler system with only one flue gas exhaust stream.

The repowering application of HIPPS is similar to hot windbox repowering where gas turbine exhaust is used as combustion air in a boiler. This approach to repowering has found favor in Europe and Japan. One of the major differences between HIPPS and hot windbox repowering is that HIPPS is a coal based system for use on coal-fired boilers. Coal is the predominant fuel for the generation of electricity in the U.S. and HIPPS has the potential for rapidly increasing the efficiency of these plants.

In order to assess the technological and economic aspects of HIPPS repowering, a study was done on a specific boiler. Doing this study allowed us to work through the real world problems of site restrictions and equipment compatibility. The repowering concept evolved as a result of trade-off studies made during this design effort. We now believe that we have a practical system that can be commercialized in the short term.

The study was done on an Eastern utility plant. The owner is currently considering replacing two units with atmospheric fluidized bed boilers, but is interested in a comparison with HIPPS technology. After repowering, the emissions levels need to be 0.25 lb. SO_x/MMBtu and 0.15 lb. NO_x/MMBtu.

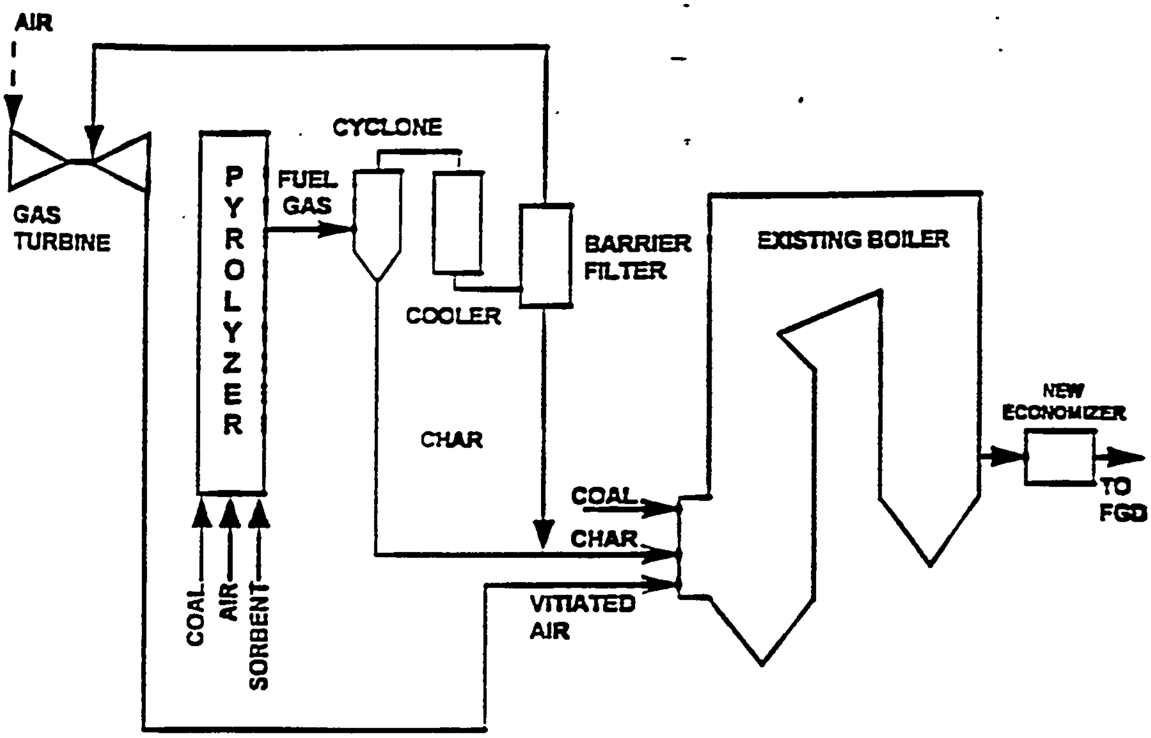


Figure G-1 Simplified HIPPS Repowering Process Flow Diagram

Table G-1 shows a performance comparison between the HIPPS repowering arrangement and the original power plant. The net power output of the unit increases from 94 MW to 116 MW, and the efficiency increases from 33.6 percent to 39.2 percent.

The cycle is based on a modified Westinghouse 251B12 gas turbine. A block diagram of the system is shown in Figure G-2, and discussion of each subsystem follows. The design goals of the HIPPS repowering system were a little different than those for the greenfields plant, and this situation resulted in some differences in design. One of the main goals for the greenfields plant was an efficiency of greater than 47 percent. In repowering, a primary consideration is the integration of the new equipment with existing systems. Also, the approach taken in the repowering study is that it should be even more near term than the greenfields plant. It should be a system that will bridge the gap between current PC-fired boilers and the optimized HIPPS plant.

Pyrolyzer Coal/Sorbent Preparation and Feeding. A process flow diagram for the pyrolyzer coal/sorbent preparation and feeding system is shown in Figure G-3. Coal is taken from the existing coal bunker. The limestone is received on site already sized. It will also be held in a storage bin. Gravimetric feeders are used to proportion the coal and char as they are fed to lockhoppers. Lockhoppers pressurize the coal and sorbent. These feedstocks are then pneumatically injected into the pyrolyzer. The coal/sorbent preparation and feeding system is composed of commercially available equipment.

Pyrolyzer. The pyrolyzer subsystem is shown in Figure G-4. A jetting bed pyrolyzer is used for the generation of fuel gas and char. The fuel gas goes to the gas turbine and the char is depressurized, cooled and then conveyed to the boiler pulverizers. A circulating fluidized bed pyrolyzer system designed to yield char of suitable size for combustion could also be used. A system of this type is being developed for the greenfields plant, and it would likely be lower cost. The jetting bed pyrolyzer system with char pulverization uses equipment that is either commercial or being demonstrated on a large scale. For this reason, it was used in the study for near term applications.

Char is separated from the fuel gas in much the same manner as for the greenfields plant. The main difference is that approximately 50 percent of the char will come directly from the bed. The char is depressurized in Restrictive Pipe Discharge (RPD) systems and then cooled to about 200°F. It is then transported to the pulverizer system in a conveyor system that is purged with inert gas.

The fuel gas is cooled to around 1000°F to condense the alkalies. To keep the repowering system as simple as possible, water quench cooling is used. The barrier filter will be of the same design as the greenfields plant with the filter elements being either iron aluminide or ceramic.

Char Feed System. The char feed system to the pulverizers is shown in Figure G-5. Rotary valves meter the cooled char into a series of chain conveyors that transport the solids to the char surge bin. The rotary valves are controlled to maintain the proper level of material in the RPD system. Although the char will be cooled to well below the

Table G-1 Typical Repowering Application

Description	Base Case	HIPPS Repowering
Coal Flow to Pyrolyzer, M lb/h	0.00	61.25
Coal to Boiler, M lb/h	73.02	16.40
Total Coal Flow, M lb/h	73.02	77.65
Pyrogas Flow, M lb/h		130.8
Char Flow, M lb/h		32.6
Coal HHV, M Btu/lb	13.05	13.05
Gas Turbine		
Inlet Temperature, °F		2100
Inlet Temperature, psia		164
Outlet Temperature, °F		1047
Gross Power, MW		32.6
Steam Turbine		
Inlet Pressure, psia	1815	1815
SH/RH Temperature, °F	1005/990	1005/990
Steam Flow, MM lb/h	0.666	0.508
Exit Pressure, psia	0.728	0.728
Outlet Temperature, °F	91.3	91.3
Condenser Duty, MM Btu/h	481	455
Gross Power, MW	98.93	90.2
Total Gross Power, MW	98.93	122.8
Total Coal LH, MM Btu/h	921.70	980.4
Total Coal HH, MM Btu/h	952.93	1,013.3
Auxiliary Power, MW	5.21	6.4
Total Net Power, MW	93.72	116.4
Efficiency - HHV	33.6 percent	39.2 percent
Efficiency - LHV	34.7 percent	40.5 percent

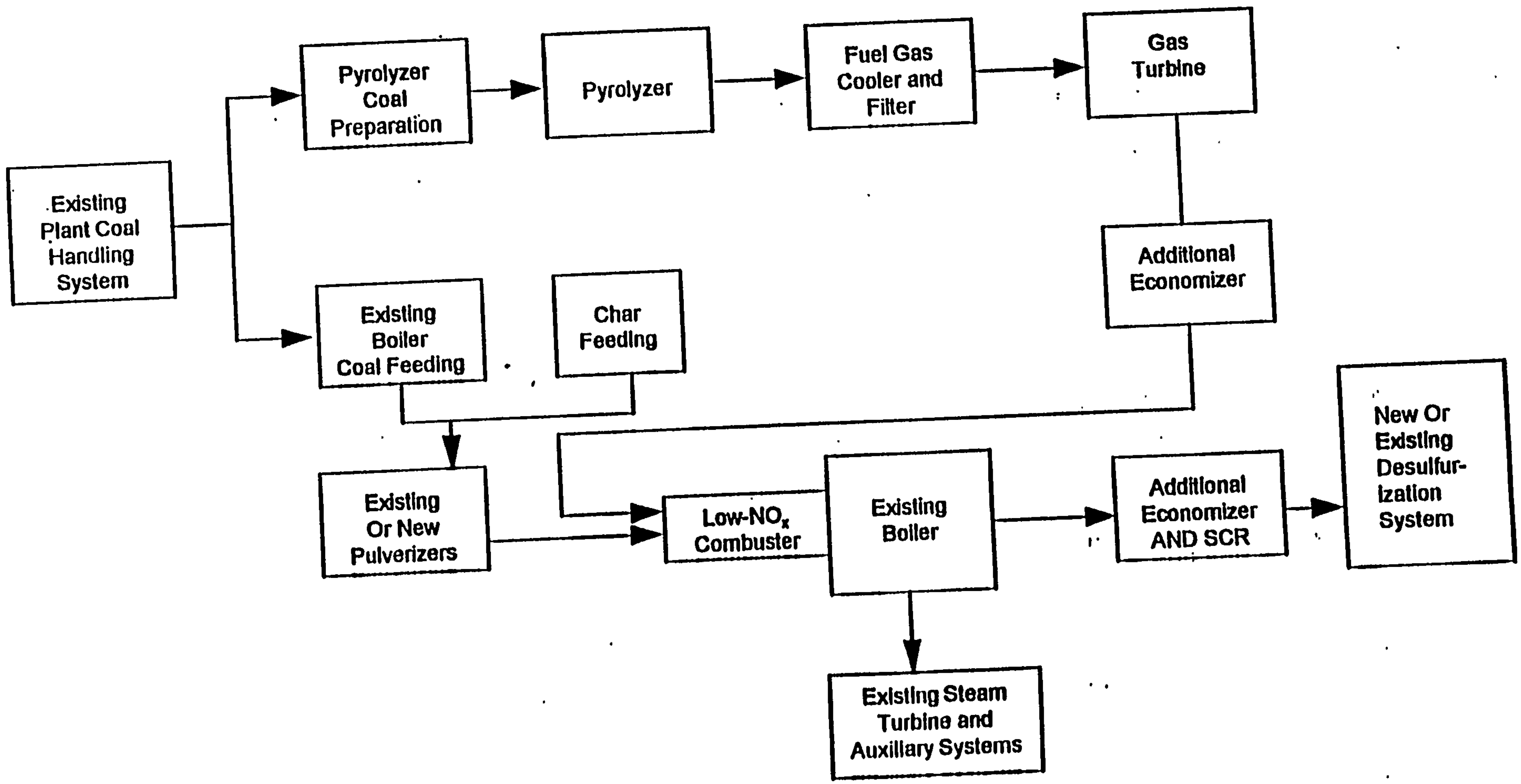


Figure G-2 System Block Diagram of HIPPS Repowering

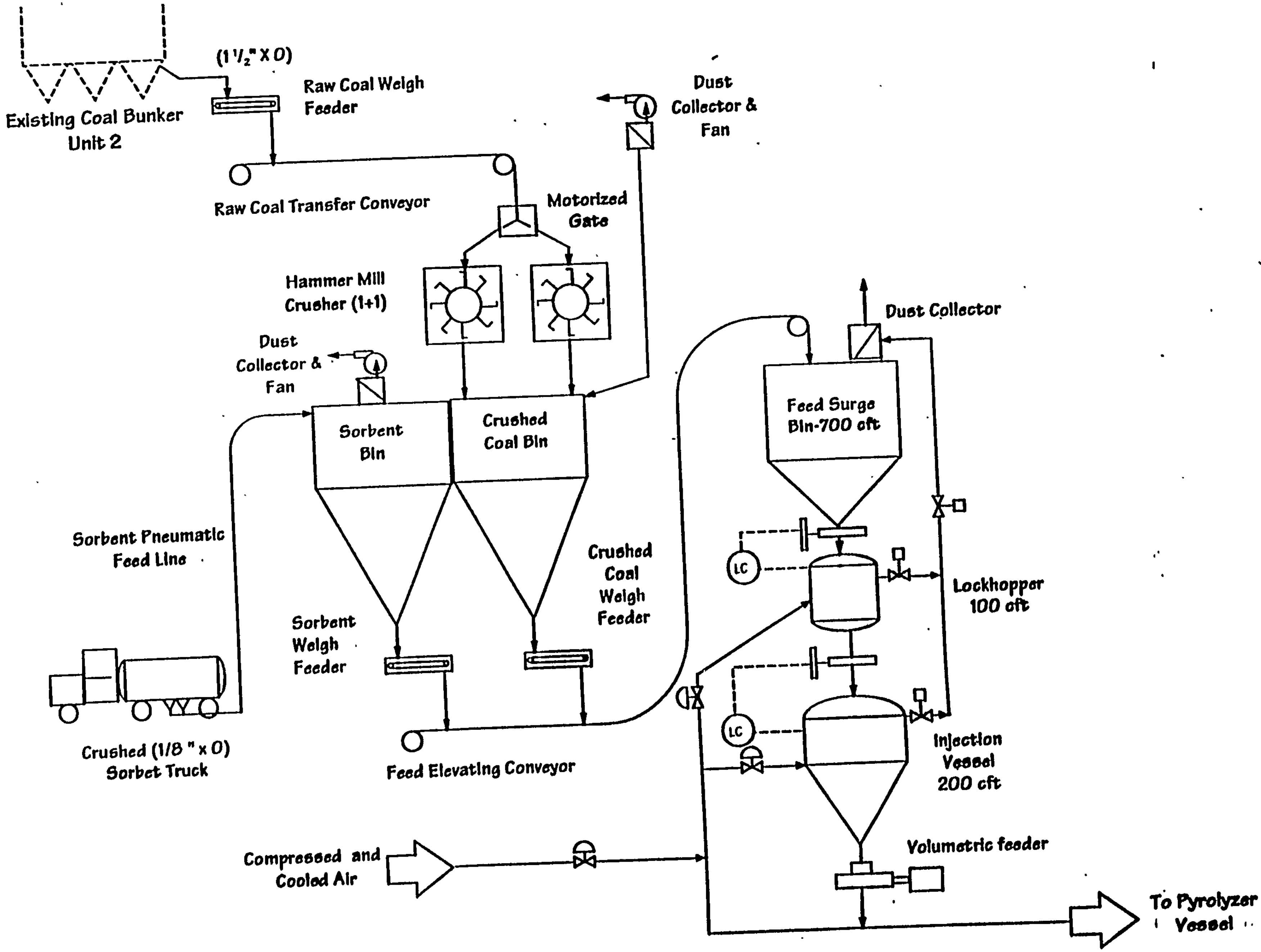


Figure G-3 Pyrolyzer Coal and Sorbent Preparation and Feeding

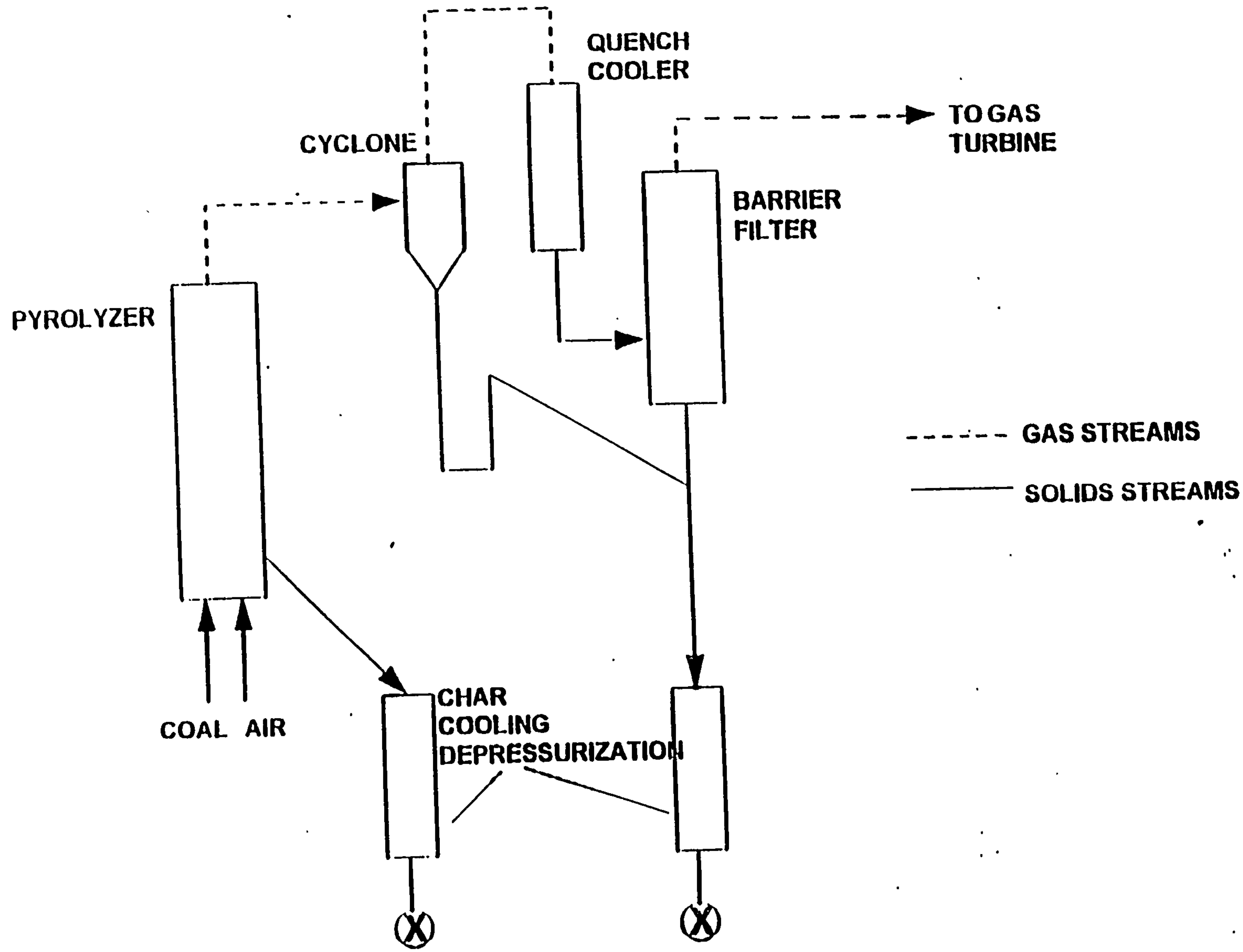


Figure G-4 Pyrolyzer Subsystem

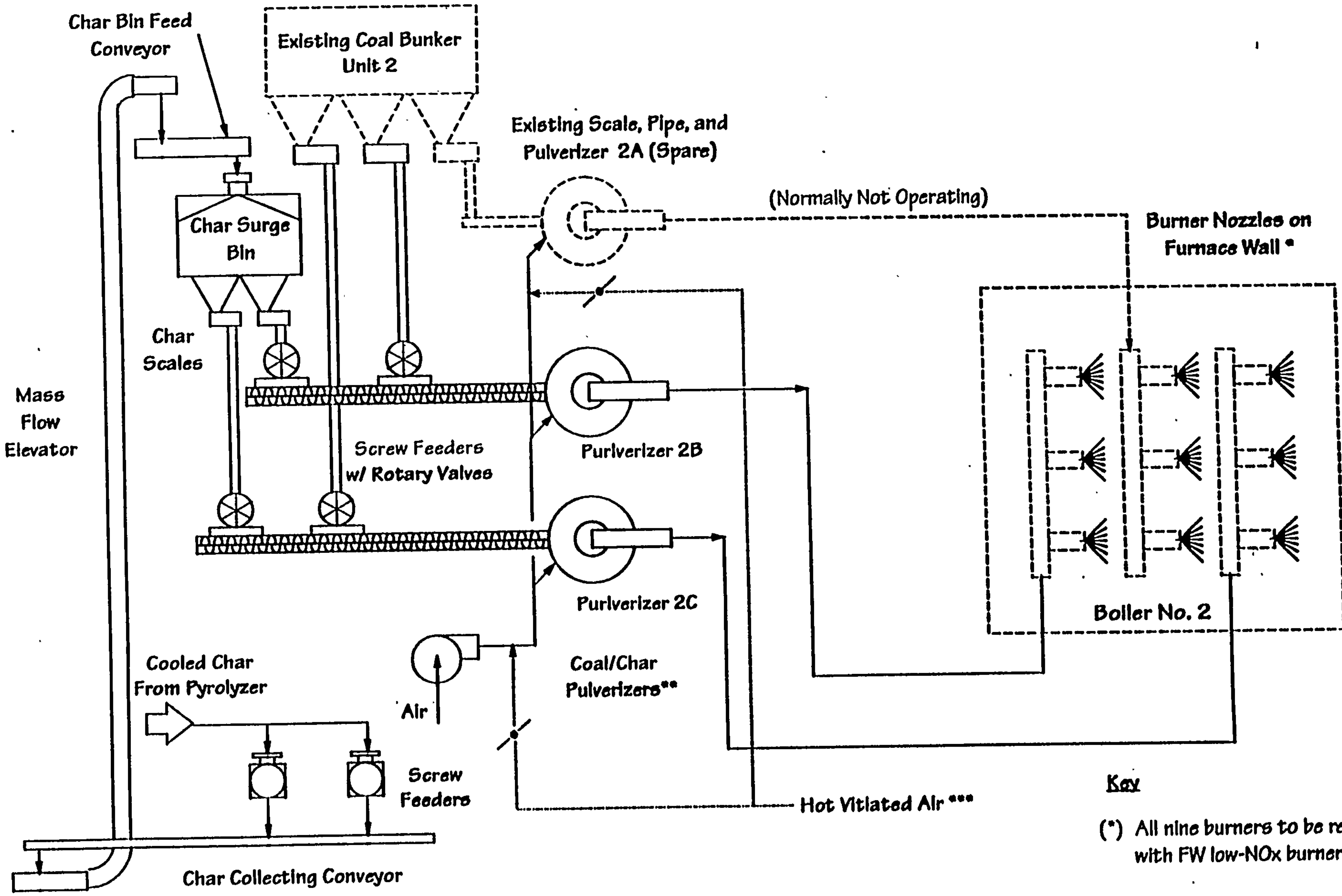


Figure G-5 Coal and Char Feed System to Boiler

Key

(*) All nine burners to be replaced with FW low-NOx burners

(**) Pulverizers (14 tph each) grind any mixture of coal and char between 0 - 50% char

(***) Used only as needed for temperature control ignition temperature, the chain conveyor and bins will be purged with inert gas to prevent the possibility of explosion and to allow more time for any hot particles to cool before the char enters the pulverizers.

Coal and char are fed from their respective bins with weigh feeders. Two of the three pulverizers at the plant are fed with a mixture of coal and char. The output of one char feeder and one coal feeder are combined to feed each of the pulverizers. Constant speed rotary valves are located in the outlet pipes from each weigh feeder to provide sealing.

The coal and char streams are fed to a common constant speed screw conveyor. The mixture enters the pulverizer through one pipe, and it is possible that existing pulverizers could be used in many applications. At this plant, it may be necessary to replace the pulverizers because of their age.

Gas Turbine. The gas turbine is a Westinghouse modified 251B12. Other gas turbines are suitable for HIPPS repowering; however, the Westinghouse machine has some features that make it a particularly good match for the HIPPS system and these boilers. The exhaust gas flow from the gas turbine can be reduced by eliminating two rows of blades in the compressor. Of course, this also reduces the power and efficiency, but it results in a better match with the existing boiler. Another reason for using the Westinghouse machine is that they have developed a combustor that drastically reduces the conversion of fuel gas ammonia to NO_x. The Multi-Annular Swirl Burner (MASB) has been shown limit this conversion to less than 30 percent and in many tests as low as 10 percent.

Gas Turbine Exhaust Economizer. The gas turbine exhaust is used for combustion air in the boiler. This stream is at 1050°F which is above the temperature where carbon steel can be used. In order to make use of the existing ducting and windbox and to lower the cost of new ducting, an economizer has been added to cool the gas turbine exhaust stream to 750°F.

Existing Boiler. We believe that the most promising market niche for HIPPS repowering will be units where the existing boiler can be modified and reused. It is also possible to replace the boiler. The following discussion relates to the modifications necessary to reuse the existing boiler.

Since the gas turbine exhaust is used as combustion air, it is not necessary to have an air heater. The existing air heater is removed and additional economizer surface is used to recover this heat. This added economizer duty replaces heat that was added to the feedwater in the feedwater heaters. The steam extraction is reduced to the amount required only for the deareator. Consequently, the main and reheat steam flows have to be reduced to prevent excessive steam flow in the turbine stages downstream from where extraction is eliminated. Although the steam cycle power output is reduced slightly from these modifications, it is more than made up for by the additional power from the gas turbine.

Many of the changes effected by the HIPPS repowering scheme compliment each other. For example, one concern is the effect that the lower oxygen content of the combustion air will have on boiler heat absorption and flue gas velocities. These effects are mitigated somewhat by the lower steam flow required from the boiler. The use of gas turbine exhaust for combustion air lowers the adiabatic flame temperature and therefore the furnace absorption, but less steam generation is required. Also, although some primary superheater pendants will have to be removed to limit flue gas velocity, no superheater tubes need to be added to make up for the reduction in heat transfer surface. Some loops will have to be removed from each of the reheater pendants to decrease this surface area, and elements will need to be removed from the existing economizer.

The changes to the existing boiler are relatively minor consisting mainly of tube removal. No changes are required for the existing enclosure walls, headers, windbox or air ducts. The air heater is removed, and an economizer bank is added in the same location. In order to achieve the low NO_x emissions required at the site (0.15 lb/MMBtu), an SCR is added behind the boiler, and another economizer bank is located downstream of this device.

Combustors. Because of the significant amount of coal that will be fired with the char, it is possible to use wall burners in the repowering application. It may be possible in some instances to use the existing burners, but in most cases a modification of this system will be required. The effect of lower oxygen combustion air needs to be evaluated for each combustor design. Slagging combustors can be added to the furnace to take advantage of the reduction in ash loadings through the boiler. This approach may lead to somewhat higher allowable flue gas velocities, but further analysis would be required.

G.2 PLANT PERFORMANCE PREDICTION

To conduct cycle analysis of the HIPPS repowering system, an overall plant simulation model has been developed using the GATE/CYCLE program. This program is an IBM-PC-based software application which can perform detailed steady-state analyses of gas-turbine power systems and associated steam cycles. A variety of cycle arrangements can be modeled using the component building modules supplied with the program. Built into the program is a gas-turbine library, which contains design and operating parameters of various models supplied by different manufacturers. This was very helpful when the selection of gas turbine size was initially attempted.

Since GATE/CYCLE does not have a pyrolyzer module, the process yields from the pyrolyzer were determined with a proprietary fluidized-bed gasification simulation code. The amounts of air, fuel gas and char per unit of coal feed and their compositions and heating values calculated from this computer code were used as inputs to the GATE/CYCLE plant simulation model.

The plant simulation model was run with different gas turbines, operating parameters and cycle variations to perform different trade-off studies. GATE/CYCLE has a simplified boiler/furnace module to facilitate the overall heat and mass balances, but it is not intended for an in-depth boiler analysis needed to match the boiler-performance with the repowering requirements. As a result, a Foster Wheeler in-house boiler-performance program was used to set up a separate boiler simulation model. This model was first tuned by inputting the existing boiler-bank dimensions and a set of plant full-load test data. In this process, individual boiler-bank effectiveness factors were adjusted until the heat absorptions and key stream temperatures closely matched the test data. The tuned boiler model was then run with the repowering conditions estimated by the overall plant model. Results such as changes in heat pickup patterns and gas velocities across tube banks were examined to determine the modifications required for the existing boiler and the adjustments needed for the design parameters of the related new components. These modifications and adjustments were fed back to the overall plant model, and more runs were made to finalize the plant heat and mass balances, state-point conditions and the prediction of the net power output and the overall efficiency.

Figure G-6 is a process flow diagram for the repowered plant. The corresponding heat and material balance is listed in Table G-2.

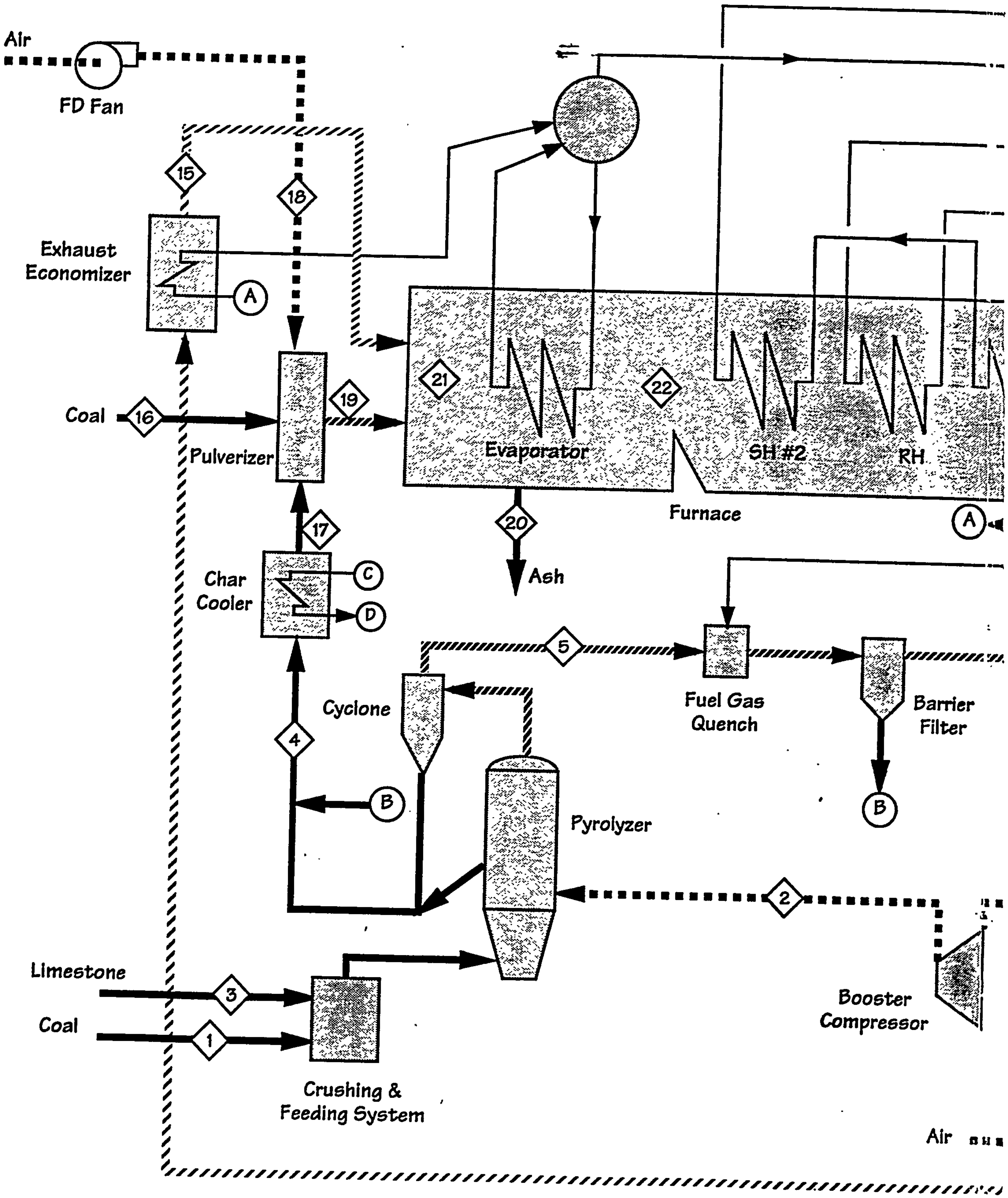
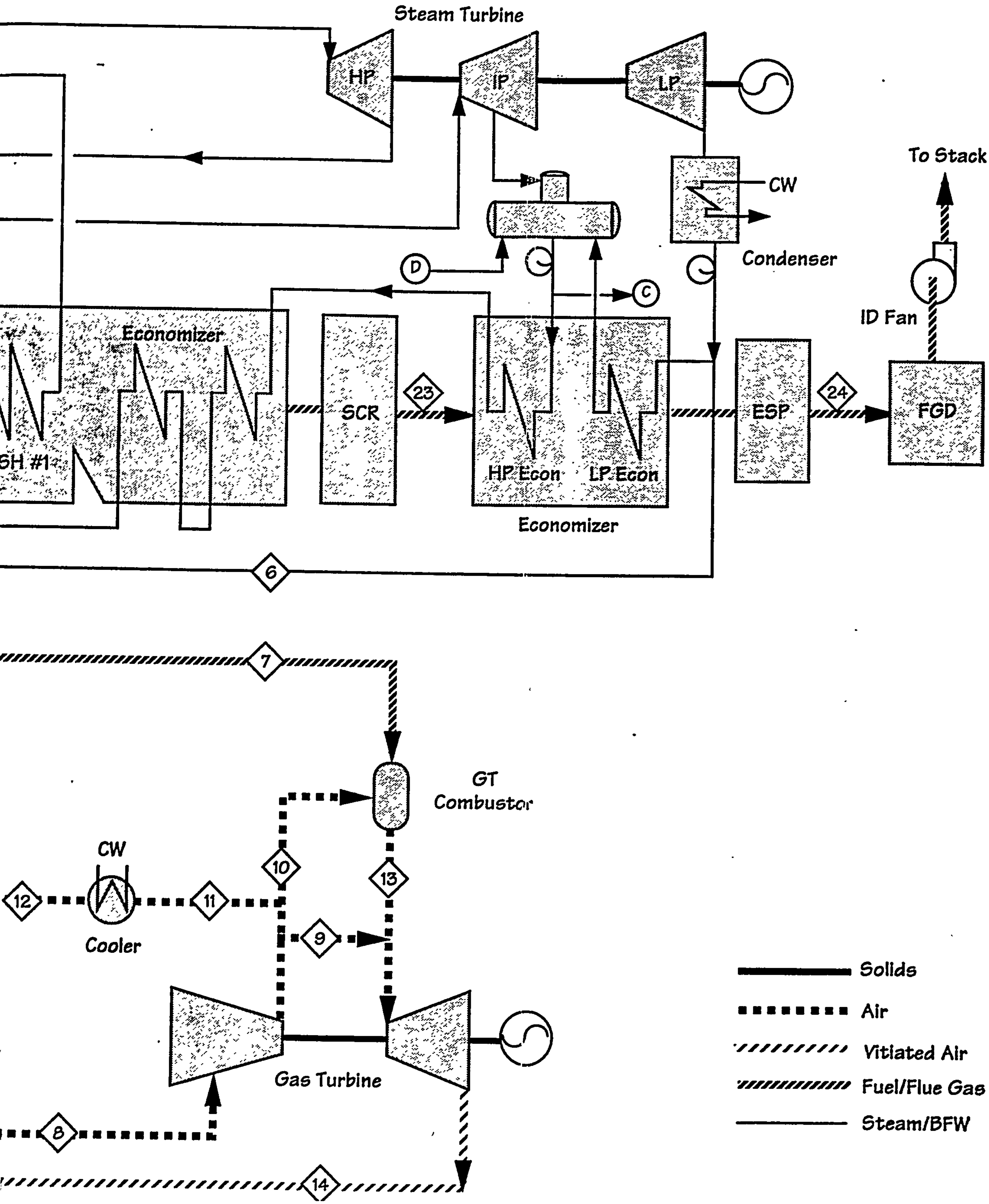


Figure G-6 Flow Diagram of the I



HIPPS Repowering Cycle

Table G-2 Repowering Process Flow Streams

Stream	Stream No.	1		2		3		4		5		6		7		8	
		Coal to Pyrolyzer		Air to Pyrolyzer		Sorbent to Pyrolyzer		Char fm Pyrolyzer		Fuel Gas fm Pyrolyzer		Water to Quench		Fuel Gas to GT Comb.		Air to Compressor	
		%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr
	Carbon	73.76%	45,178					75.43%	24,591								
	Hydrogen	4.62%	2,829					0.47%	155								
	Oxygen	4.05%	2,482														
	Nitrogen	1.34%	821					1.32%	430								
	Sulfur	1.39%	850					1.25%	407								
Solids	Ash	9.29%	5,689			3.00%	61	17.64%	5,749								
lb/h	Moisture	5.61%	3,435			3.00%	61					100.00%	20,826				
	CaCO3					92.00%	1,857										
	MgCO3					2.00%	40										
	CaO							0.95%	309								
	MgO							0.06%	19								
	CaS							2.88%	940								
	CaSO4																
	CH4									2.72%	3,560			2.35%	3,560		
	C2H4																
	C2H6																
	C3H8																
	CO									28.16%	36,840			24.29%	36,840		
Gases	H2									1.40%	1,825			1.20%	1,825		
lb/h	CO2			0.05%	47					6.57%	8,593			5.67%	8,593	0.05%	428
	H2O			0.82%	819					2.50%	3,268			15.89%	24,094	0.82%	7,387
	O2			22.95%	23,000											22.95%	207,409
	N2			74.90%	75,054					57.39%	75,082			49.51%	75,082	74.90%	676,831
	H2S									0.02%	27			0.02%	27		
	COS																
	SO2																
	C6H6+																
	Argon			1.28%	1,280					0.98%	1,280			0.84%	1,280	1.28%	11,545
	NH3									0.27%	350			0.23%	350		
	NO2																
	Total Gas, lb/h	100.06%	61,247	100.00%	100,200	100.00%	2,018	100.00%	32,601	100.00%	130,824	100.00%	20,826	100.00%	151,649	100.00%	903,600
					3,445						5,521				6,677		31,063
					29.09						23.70				22.71		29.09
	Pressure, psia		212.49		194.80		212.49		194.80		194.80		253.10		188.90		14.20
	Temperature, °F		70.00		70.79		70.00		1,700.00		1,700.00		98.20		1,000.00		59.00

Table G-2 (Continued)

Stream	Stream No.	9		10		11		12		13		14		15		16	
		Bypass Air		Air to GT Combustor		Air to Booster Clr		Air to Booster		Flue Gas fm GT Comb.		V.A. fm GT		Vitiated. Air to Furn		Coal to Pulverizer	
		%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr
	Carbon	-														73.76%	12,097
	Hydrogen	-														4.62%	758
	Oxygen	-														4.05%	665
	Nitrogen	-														1.34%	220
	Sulfur	-														1.39%	228
Solids	Ash	-														9.29%	1,523
lb/h	Moisture	-														5.61%	920
	CaCO3	-															
	MgCO3	-															
	CaO	-															
	MgO	-															
	CaS	-															
	CaSO4	-															
	CH4	-															
	C2H4	-															
	C2H6	-															
	C3H8	-															
	CO	-															
Gases	H2	-															
lb/h	CO2	0.05%	59	0.05%	321	0.05%	47	0.05%	47	9.22%	76,562	8.02%	76,621	8.02%	76,621		
	H2O	0.82%	1,020	0.82%	5,548	0.82%	819	0.82%	819	6.57%	54,515	5.81%	55,535	5.81%	55,535		
	O2	22.95%	28,646	22.95%	155,764	22.95%	23,000	22.95%	23,000	12.63%	104,848	13.98%	133,494	13.98%	133,494		
	N2	74.90%	93,480	74.90%	508,297	74.90%	75,054	74.90%	75,054	70.27%	583,379	70.87%	676,859	70.87%	676,859		
	H2S																
	COS																
	SO2									0.01%	51	0.01%	51	0.01%	51		
	C6H6+																
	Argon	1.28%	1,595	1.28%	8,670	1.28%	1,280	1.28%	1,280	1.20%	9,950	1.21%	11,545	1.21%	11,545		
	NH3																
	NO2									0.11%	944	0.10%	944	0.10%	944		
Total Gas, lb/h		100.00%	124,800	100.00%	678,600	100.00%	100,200	100.00%	100,200	100.00%	830,249	100.00%	955,049	100.00%	955,049	100.00%	16,401
			4,290		23,328		3,445		3,445		28,889		33,179		33,179		
			29.09		29.09		29.09		29.09		28.74		28.78		28.78		
Pressure, psia			174.09		174.09		174.09		172.39		163.99		15.20		15.20	-	15.20
Temperature, °F			665.11		665.11		665.11		655.11		2,121.00		1,053.16		750.00	-	64.00

Table G-2 (Continued)

Stream	Stream No.	17		18		19		20		21		22		23		24	
		Char to Pulverizer		Air to Pulverizer		CC to Furnace		Ash fm Furnace		Flue Gas to Furnace		Flue Gas to Superhtr		Flue Gas to Back end		Flue Gas to FGD	
		%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	%wt	lb/hr	wt%	lb/hr
	Carbon	75.43%	24,591			29.97%	36,688										
	Hydrogen	0.47%	155			0.75%	912										
	Oxygen					0.54%	665										
	Nitrogen	1.32%	430			0.53%	650										
	Sulfur	1.25%	407			0.52%	635										
Solids	Ash	17.64%	5,749			5.94%	7,272	87.25%	7,200		73						
lb/h	Moisture					0.75%	920										
	CaCO3																
	MgCO3																
	CaO	0.95%	309				309	12.52%	1,033		7						
	MgO	0.06%	19			0.02%	19	0.23%	19		0						
	CaS	2.88%	940			0.77%	940										
	CaSO4																
	CH4																
	C2H4																
	C2H6																
	C3H8																
	CO																
Gases	H2																
lb/h	CO2			0.05%	35	0.03%	35			19.74%	211,084	19.74%	211,084	19.74%	211,084	19.74%	211,084
	H2O			0.82%	600	0.49%	600			6.10%	65,209	6.10%	65,209	6.10%	65,209	6.10%	65,209
	O2			22.95%	16,853	13.77%	16,853			4.19%	44,770	4.19%	44,770	4.19%	44,770	4.19%	44,770
	N2			74.90%	54,994	44.92%	54,994			68.51%	732,503	68.51%	732,503	68.51%	732,503	68.51%	732,503
	H2S																
	COS																
	SO2									0.20%	2,154	0.20%	2,154	0.20%	2,154	0.20%	2,154
	C6H6+																
	Argon			1.28%	938	0.77%	938			1.17%	12,483	1.17%	12,483	1.17%	12,483	1.17%	12,483
	NH3																
	NO2									0.09%	944	0.09%	944	0.09%	944	0.09%	944
Total Gas, lb/h		100.00%	32,601	100.00%	73,420	99.75%	122,431	100.00%	8,252	99.99%	1,069,228	100.00%	1,069,148	100.00%	1,069,148	100.00%	1,069,148
					2,524		2,524						36,018		36,018		36,018
			#DIV/0!		29.09		48.51						29.68		29.68		29.68
Pressure, psia			15.20		15.20		15.20		14.70		14.30		14.60		14.60		14.50
Temperature, °F			300.00		67.80		125.30		2,560.00		2,560.00		1,800.00		1,065.00		299.70

G.3 PLANT ARRANGEMENT

Using the HIPPS technology for repowering of an existing coal fired power plant has been shown in other sections of this report to provide an increase in power coupled with improved performance. Another aspect of the implementation of any repowering technology is its ability to be incorporated into the existing facilities.

In order to demonstrate how a HIPPS repowering option might be added on to an existing power plant, a series of plant layout drawing have been developed for Unit No. 2 of a specific utility plant. In addition to an overall plot plan there are four Overall Arrangement drawings that provide overall plan and side views of all the major facilities related to the plant and twenty General Arrangement drawings that provide more details for specific sections. All these drawing are included in Section G.9 Plant Arrangement Drawings.

As stated earlier, the design philosophy for the repowering option was based on maximum use of existing equipment. It follows that for developing the layout of the new equipment, considerable effort was taken to minimize the modifications to the existing facilities. From a layout perspective the placement of the new equipment can be divided into three general categories: equipment located inside the existing boiler building; equipment located in the unused space behind the boiler building; and the equipment which either replaces or coexists with existing equipment located behind the boiler building.

G.3.1 Equipment Located Inside Boiler Building

The equipment within the boiler building includes a portion of the back end heat recovery system with its associated ducting, the coal/char solids handling systems, and the modifications to the BFW heaters.

Partially cooled vitiated air from the gas turbine (Section G.3.2) enters the building about 40 ft. above grade where it is then split, with two new ducts joining the existing secondary air ducts leading to the furnace windbox.

On the backend of the furnace the existing superheaters and reheaters have been modified by removing a portion of the existing tubing to account for changes in temperature distribution, gas velocities and duties within the furnace. New ducting, including two new economizers, replaces existing ducting leading the partially cooled flue gas outside the building where it passes to the SRC (Section G.3.2). The new economizers will be located in the same general area as the existing primary air heaters. The air heater is expendable since there is hot air available from the gas turbine. Refer to Figures SK-GA-202, 203, 204, 205, 210 (Shown in Section G.9).

A new char bin is located adjacent to the existing coal bunkers at the front of the furnace. A new char conveyor will bring the char from the pyrolyzer system (Section G.3.2). Char from the bin will be transported by screw conveyors to two new pulverizers that will replace two of the existing coal pulverizers. The third pulverizer will remain as a spare. The two new pulverizers will be about 15 percent larger so that the boiler can operate at full capacity on six of the nine available burners. A second series of conveyors will be added to take coal from the existing tripper conveyor to the coal crusher located in the pyrolyzer system.

Also within the greater boiler building is the existing steam turbine. Since the primary air heater has been replaced by economizers there is no longer the need to use the existing BFW heaters. Removal of the heaters is not required for the repowering effort. Local management would have the option of either removing them or just blocking them out of the system.

G.3.2 Equipment Located Behind Boiler Building

The bulk of the major new equipment is located in the existing free space behind the boiler building that houses the boilers for Units I and 2. Within the existing space limitations, the majority of equipment has been located behind Unit No. 2. The one exception is the gas turbine which had to be centered on the line between the two units in order to avoid existing support columns and equipment. The major equipment located in the free space behind Unit No. 2 includes the SCR and associated ducting, and the pyrolyzer system, including pyrolyzer, cyclone, filter, char coolers, and crushed coal and sorbent feed bins.

The gas turbine was found to be the most difficult piece to place within the available free space at the site. Although location of the discharge and inlet ducting is somewhat flexible, the general configuration of main gas turbine, air compressor, and generator requires a space over 100 ft. long. To minimize hot side ducting it was desirable to locate the GT exhaust adjacent to the boiler building. As the gas leaves the turbine it passes through an economizer. New ducting then directs the partially cooled vitiated air vertically before entering the building where it ties into the existing secondary air ducting as discussed in Section G.3.1

Positioning the gas turbine between the two units allows the placement of the SCR directly behind Unit No. 2, thereby minimizing the new flue gas ducting required. A low-pressure economizer is located under the SCR to cool the gas prior to being sent to the FGD system discussed in Section G.3.3. The relative locations of the gas turbine and SCR are shown in Figures SK-GA-201 and 210.

Space was found for the pyrolyzer system in the walk space between Units 2 and 3. From a space criteria and physical location relative to the other equipment this location works well. Space requirements for the pyrolyzer system are best depicted in Figures SK-GA-202, 203, 204, and 211. It should be noted that the pyrolyzer system does block off one of the current access ways and that any future studies of repowering at this site should include a more detailed examination of the impact of this location relative to reduced maintenance access to existing equipment located in the same general area.

G.3.3 Equipment Replacing or Coexisting with Existing Equipment

Almost all the equipment in this category belongs to the FGD system. Generally, a dry lime scrubber incorporates a downstream baghouse as an integral part of the system. Passing the flue gas through the dust cake collected on the bags helps capture the residual SO_2. As a result, there did not appear to be any way to utilize the existing ESP in the new FGD system.

Currently, the ESP for Unit No. 2 is located on a direct line behind the boiler adjacent to the ESP for Unit No. 1. This is a suitable location for the FGD scrubber vessel which at 40 ft. in diameter fits well into the footprint occupied by the existing ESP. For this examination of the repowering option it was therefore decided to remove the existing ESP and use the space for the scrubber as shown in Figures SK-GA-202, 203, 204, 205, and 210.

The ability to replace the ESP with a scrubber is not meant to be representative of all possible repowering options but does provide a real example of how existing equipment or space can be used when a unit is repowered rather than being totally replaced.

Having replaced the ESP, space had to be found for the new baghouse. Since the exit ducting from the scrubber is some 70 ft. above grade it offered the opportunity to place the baghouse over the existing water treatment center since the existing roof is only about 30 ft. high. This allows the two systems to share roughly the same plot space without interfering with each other. The dust from the baghouse is routed to the new recycle flyash silo located south of the existing stack. From there, part of the ash is recycled to the scrubber vessel and the rest is pneumatically transferred to the existing ash transfer building. Clean gas from the baghouse joins existing ducting leading to the ID fans and subsequently to the stack, which handles flue gas from both Units 1 and 2. The location of the baghouse system is shown in Figures SK-GA-303, 304, and 310.

G.3.4 Alternative FGD System

During the early examination of the layout for the FGD system it was suggested that a wet FGD system may offer some advantages over the dry system because:

- Its inherent ability to achieve greater sulfur capture

- It could make better use of existing equipment and space, including the ESP and ducting.

A brief examination was made to determine a possible configuration for a wet FGD system.

A wet FGD scrubber is normally located between the ID fans and the stack. This turned out to be a problem for Unit No. 2. The stack is located directly behind the ID fans with a very short duct between the two. A brief examination indicated that sufficient room is available for a wet scrubber, but not by much. The auxiliary equipment could be located south of the stack in about the same location as the ash and lime silos used in the dry system. See Figures SK-OA-175, 176, and 180.

Although the system seems to fit, it is very tight and whether the scrubber could be located that close to the stack from operations. maintenance, and safety aspects, will require further examination. If necessary additional ducting could be provided to move the scrubber away from the stack at increased cost. It should be noted that this situation is unique to Unit No. 2 and had we used Unit No. 1 as our basis there would have been more than sufficient area for the wet FGD scrubber.

In the end, a wet FGD system was rejected, however, based on increased capital cost and increased difficulty of disposing of the wet solid waste. In addition, the selected dry FGD system was able to meet all current emission requirements.

G.4 BOILER MODIFICATIONS

To deal with the boiler in HIPPS repowering, there are two options. One is to reuse the existing boiler, the other to replace it with a new one. The latter may be a viable option for older boilers. However, we believe that the best candidate plant for HIPPS repowering would have a coal-fired boiler capable of 20 years of operation without too extensive a refurbishment. Therefore, the repowering design and cost estimates have been developed both on the basis of reusing the existing boiler with modifications. In this section, the boiler modifications that are required and the reasons for the modifications are described.

The required modifications and additions summarized below. They are identified in Drawing No. RD960-4 by encircled numbers. Their plan view arrangement is shown in Drawing No. RD 960-5. These drawings are presented in Section G.10 Boiler Modification and Pyrolyzer Subsystem Drawings.

1. Modification of the existing Reheater.
2. Modification of the existing Primary Superheater.
3. Modification of the existing Economizer.
4. Additional Economizer with removal of the existing air heater.
5. SCR inlet duct.
6. New SCR.
7. Additional HP Economizer.
8. Additional LP Economizer.
9. Flue duct from the LP Economizer to the F.D. unit.
10. Gas turbine exhaust duct to the existing secondary air duct.
11. Fan and Air Duct.
12. New GT Exhaust Economizer.

Using the Foster Wheeler boiler performance prediction code as described in Section G.2, analyses were made with the expected repowering conditions in an interactive process to predict the furnace/boiler performance parameters. The results indicate that the reheater and the primary superheater duties decrease because of the steam-flow reductions and changes in gas-temperature distribution in the furnace. Local gas densities and velocities are also affected by the changes in gas temperatures. Based on the repowered gas flow rate, the gas velocities across the existing primary superheater and economizer banks are found to be much higher than the common design practice allows. To compensate for the reduction in required heat absorption and to lower flue gas velocities, the following modifications to the existing boiler banks (the first three items of the above list) are required:

- Reheater (Item 1) -- There are 71 reheater elements across the existing boiler, with each element having 6 tube loops in a series. Removal of the last two tube loops of all the elements (as shown in Drawing RD 960-4 by cross-hatched area), plus the use of spray attemperation will meet the required duty reduction. After the removal of the tube loops, a total of 71 new tube-bend assemblies need to be welded in place.

- Primary Superheater (Item 2) -- There are 71 tube elements across the existing boiler. Removing every third element across the unit will open up the tube spacings to reduce the gas velocity to the acceptable level. At the same time, this also serves as a surface reduction measure. A total of 23 of these elements need to be removed, and the tube stubs at the inlet and outlet headers will be plugged.

- Existing Economizer (Item 3) -- There are 24 elements in the existing economizer. Every other element needs to be removed to provide the reduction in gas velocity as required. A total of 12 tube elements need to be removed, and the tube stubs at the header plugged.

Since all exhaust from the gas turbine is used as combustion air in the boiler, the existing regenerative air heater is no longer needed. At the other end, the flue gas leaving the existing economizer is high enough to provide all feedwater heating duty; hence there is no need for the existing feedwater heaters in the steam cycle. To compensate for these heating duty changes, additional economizers are added upstream and downstream of the boiler in a manner to achieve a most practical, efficient and well-integrated arrangement.

The existing air heater needs to be removed and the furnace back pass extended downward with an additional economizer bank (Item 4). In order to achieve the low NO_x emissions (0.15 lb/10^6 Btu) required at the site, an SCR unit (Item 6) will be added after this bank. The thermal duty of this economizer is sized such that the flue gas temperature entering the SCR is around its optimum point of 715°F. Due to its size, the SCR unit will be located away from the existing furnace and connected to the furnace discharge port by an inlet duct (Item 5). A by-pass duct is needed upstream of the additional economizer to control the gas temperature entering SCR during startup or part-load operations.

A new HP economizer (Item 7) and a new LP economizer (Item 8) will be added downstream of the SCR unit to further recover the heat from the flue gas. Finned tubes will be used for these economizer banks. Flue gas exits at 300°F and is transferred by a new duct (Item 9) to the F.D. unit.

The gas turbine exhaust temperature is about 1050°F which is too high for the material used in the ducting and windbox areas of the existing boiler. To avoid the reconstruction of these areas with expensive high-alloy steel, the turbine exhaust is cooled by a GT exhaust economizer (Item 12) to approximately 750°F. Although gas turbine exhaust flow rate is sized to provide adequate excess oxygen for coal/char combustion, its lower oxygen content (approximately 13 percent by volume) may cause concern for the flame stability at the burner. One way to circumvent this is to use fresh air as the drying and transport gas through the pulverizers. The mixture of coal, char and fresh air will provide enough oxygen to stabilize the flame upon initial ignition. A fan and an air duct (Item 11) will be added to feed the fresh (primary) air to the pulverizers. On the gas turbine exhaust side, a new duct work (Item 10) will be added to connect the new heat exchangers to the existing secondary air duct at the rear of the boiler.

In addition to the above modifications, the nine existing burners need to be replaced by nine new, low-NO_x burners. The new burner capacity is 103 MMBtu/h each with a throat diameter of approximately 35-in. Twelve (12) fixed rotating sootblowers are also required for the new economizer tube banks.

G.5 PYROLYZER SUBSYSTEM

The key components of this subsystem consists of the pyrolyzer, cyclone, fuel gas cooler, barrier filter, restrictive pipe discharge (RPD) section, and bulk solids cooler. A side elevation view of their general arrangement is shown in Drawing No. RD 960-3 (All drawings referred in this section are included in Section G.10). Figure G-7 is an outline sketch of these components. A jetting bed pyrolyzer is used for the generation of fuel gas and char. The char is removed from the bed and from the downstream particulate removal equipment. The fuel gas passes through the cyclone and is cooled to 1000°F by the injection of water in the fuel gas cooler. After being cooled, the fuel gas goes through the barrier filter to remove particulates and the condensed alkalies. The fuel gas is then fired in the gas turbine. Solids collected in the cyclone are injected into the filter vessel by means of a J-valve arrangement. The char from the pyrolyzer and the solids from the filter vessel are depressurized and cooled by two separate RPD/bulk solids coolers. The RPD system reduces pressure by taking a pressure drop across a moving bed of solids as the solids are removed from the system. This is accomplished by having a reservoir of solids above and below a standpipe. At the lower reservoir (bulk cooler vessel), a small amount of fuel gas is bled off to maintain the vessel at the lower pressure. A screw feeder is used at each bulk cooler outlet to control the flow of solids. More detailed description the components follows.

Pyrolyzer -- The pyrolyzer is shown in Drawing RD950-21. It is a jetting bed design. This type of reactor will be used in the Pinon Pine Clean Coal project. It is a vertical, refractory-lined vessel approximately 49-ft. high, with a conical bottom. The main bed is of 9-ft. O.D. and the upper (freeboard) zone is expanded to 12-ft. O.D. The refractory lining consists of a 5-in. inner layer for thermal resistance and 3-in. outer layer of hard-faced refractory for erosion resistance. The coal, sorbent and air are fed from a central jet in the bottom of the pyrolyzer. This arrangement creates a recirculation of solids in the bottom of the reactor, which rapidly raises the temperature of the fresh material. Aside from the injection nozzles there are no internals in the vessel. The fuel gas leaves the unit through a nozzle at the top of the vessel and char discharges itself through a nozzle at the bottom. Two manways in the pyrolyzer provide access for maintenance. The whole unit is transportable by rail.

Cyclone and J-Valve -- The cyclone is shown in Drawing RD 950-10. It is also a refractory-lined vessel. It is 18-ft. high and has a 3-ft. 5-in. I.D. barrel with a conical section tapering to a 6-in. I.D. solids outlet. The fuel gas from the pyrolyzer is tangentially fed to the cyclone by a rectangular 11-in. x 2-ft. 9-in. opening, and the cleaned gas leaves the unit through a 20-in. outlet nozzle atop the vessel. Solids collected in the cyclone are injected into the barrier filter vessel by means of a J-valve shown in Drawing RD 950-27. Solids fluidized in the bottom of this component seal the pressure differential between the two vessels while passing the solids from the cyclone dipleg to the filter vessel.

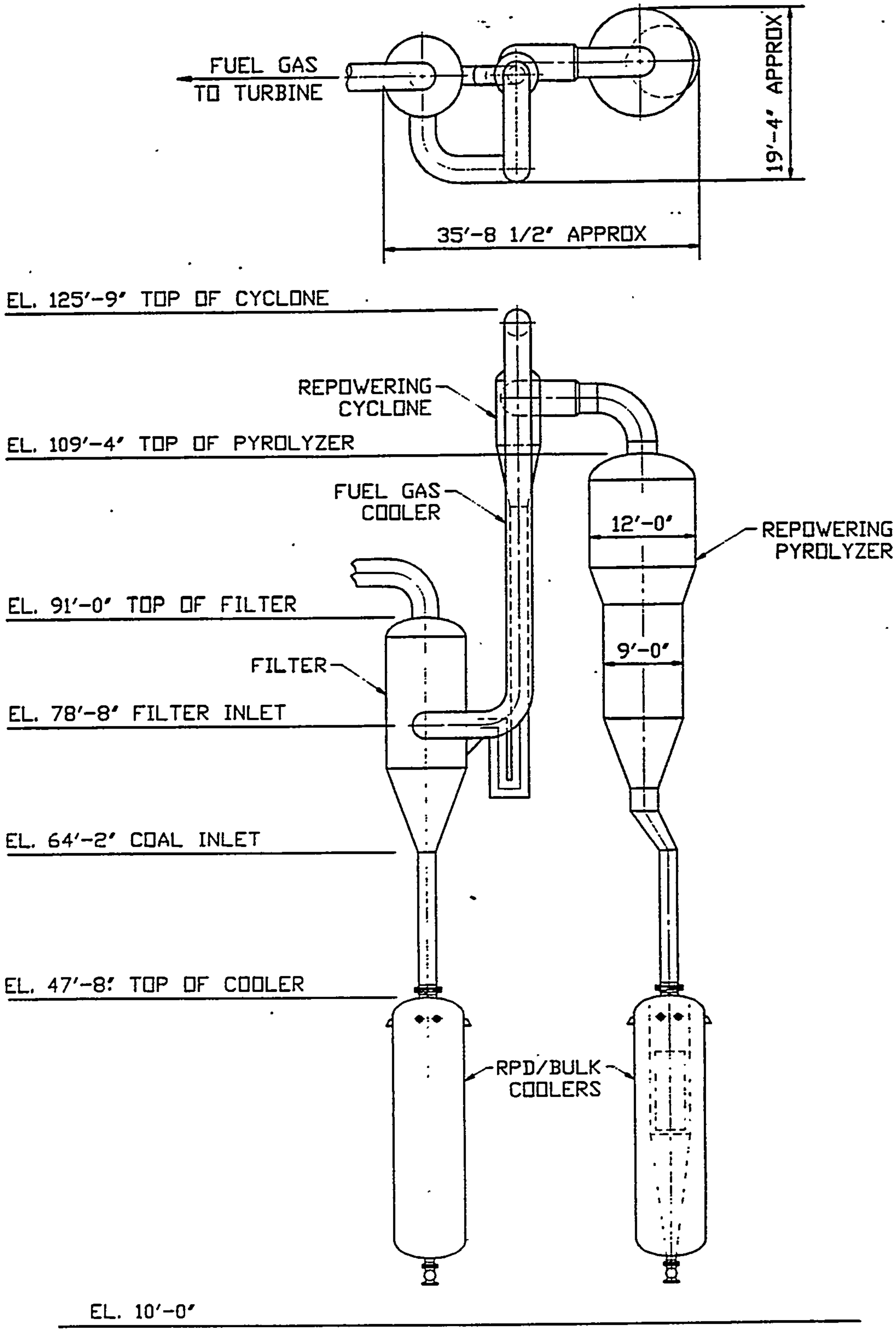


Figure G-7 Pyrolyzer Subsystem

Fuel Gas Cooler -- The fuel gas is cooled to around 1000°F to condense the alkalies. To keep the repowering system as simple as possible, water quench cooling was selected. This is done in a spray cooler shown in Drawing RD 950-25. It consists of two 36-in. O.D. carbon steel pipe sections with a total height of 15-ft. The pipe is internally insulated and has a 20-in. O.D. Incoloy 800H liner. Ring plates, support lugs and sleeves are used to hold the liner in place while providing allowance for thermal expansion. Two spray nozzle assemblies are located at the top pipe section. These special nozzles atomize the water by injection of a small amount of nitrogen so that water can be evaporated rapidly downstream. Feedwater from the condenser is tapped for the quenching purpose.

Barrier Filter -- Preliminary sizing of the filter was done by Pall Advanced Separation Systems (PASS). It is designed to remove virtually all particulate matter (99.995% of influent particles) from the fuel gas stream. To accomplish this, elements constructed with a high efficiency filter medium effectively retain solids at the filter surface. This results in the formation of a solids cake which is dislodged at a predetermined pressure drop by initiating a momentary reverse flow. The filter unit consists of filter elements, a tube sheet assembly, a jet pulse blowback system, and a containing vessel. Either silicon carbide or iron aluminide (metal) filter elements is suitable for this application. The iron aluminide elements, while still under development at Pall, will be commercialized in the near future. The ceramic filters are more expensive to utilize than metal ones because of the additional complexity in mounting the elements in the tubesheet. The filter design using metal elements was consequently selected in the repowering cost estimate. The filter vessel is smaller in diameter because the metal elements can be made longer. This design also reflects the economic benefit of welding the metal elements to the tubesheet rather than the gasketed arrangement as is used with ceramic elements. There are 246 metal elements in the vessel, each 2-3/8-in. in diameter and 96-in. long. Tubesheet is 66-in. in diameter and made from 304 stainless steel. Designed for the jet pulse blowback technique, the tubesheet assembly is divided into six (6) sections for sequential blowback. An internal pulse manifold is included in the tubesheet assembly to deliver a gas (N_2) pulse to the elements in each section being blownback. The jet pulse blowback system comprises of six pulse valves, a blowback reservoir, instrumentation and controls.

RPD/Bulk Solids Coolers -- Each of the two units required consists of a vertical standpipe and a bulk solids cooler. The flanged pipe section is 24-in. O.D. and 16-ft. 6-in. high with two layers of refractory lined inside. It is connected at the bottom to a bulk solids cooler. Preliminary design of the solids coolers was done by Cominco Engineering Services. They are a commercial supplier of solids coolers. A general arrangement sketch of the cooler shown in Drawing FWD-001. The plate coil bank consists of heat exchanger plates, manifolds and high-temperature stainless steel casing. The heat absorbed from the solids (char) is transferred to the low-pressure economizer circuit. The plate bank and the discharge hopper are all contained in an internally insulated pressure vessel which is approximately 8-ft. in diameter and 30-ft. in height.

G.6 BALANCE OF PLANT

Several new BOP components and systems will be required to successfully implement the plant repowering. These mostly include solids handling equipment in addition to SO_2 removal equipment. The plant existing water treatment and supply facilities are assumed adequate for meeting the repowering requirements. Other supporting facilities including service and instrument air supply, electrical distribution, and fire protection, will require modest modifications or upgrading to accommodate the repowering of the plant. These modifications are accounted for in estimating the cost of repowering but will not be discussed here.

G.6.1 Pyrolyzer Coal and Sorbent Preparation and Feeding

Figure G-3 is a process flow diagram representing the conceptual design for this plant system which serves the following functions:

- Draw pyrolyzer feed coal from the existing coal bunker of Unit 2. The bunker will be modified to provide a new and dedicated outlet for the pyrolyzer coal.
- Prepare the coal by crushing it to the size required by the pyrolyzer.
- Receive and store prepared sorbent that will be delivered to the site in trucks.
- Pressurize a measured mixture of coal and sorbent using a lock hopper.
- Feed the pressurized coal and sorbent continuously into a pneumatic transport line to the pyrolyzer.

The transport line will deliver the solids to the pyrolyzer. A slip steam from the air leaving the pyrolyzer booster compressor is pre-cooled to 300°F and is used as the transport medium. The normal feed rate to the pyrolyzer is about 30 t/h of coal and 1 t/h of sorbent.

G.6.1.1 Coal Preparation. Coal for the pyrolyzer will be drawn from the coal bunker of Unit 2 that currently feeds three coal pulverizers. The lower portion of the bunker will be modified to add a new outlet for delivery of coal to the pyrolyzer. This outlet will be provided with a slide gate and a raw coal weigh feeder rated at 60 t/h. The feeder delivers the coal to a raw coal transfer conveyor that carries the coal to the pyrolyzer vessel located outside the boiler building. The raw coal transfer conveyor in turn delivers the coal to one of two hammer mill crushers. Two equal capacity crushers are used, one operating and one spare. A motorized gate diverts the coal to the operating crusher. The crushers are designed to reduce the coal from 1½ inch x 0 size to ⅛ inch and below. The crushed coal will be stored in a bin with a capacity of 60 tons.

G.6.1.2 Coal and Sorbent Feeding. A Crushed Coal weigh feeder, located below the crushed coal bin, delivers the coal from the bin to feed elevating conveyor at a uniform and pre-set rate. The elevating conveyor uses belting with flexible side walls and molded pockets. This type of construction enables belt conveyors to elevate materials vertically. The conveyor has an 'S' type configuration with a horizontal feed section at the bottom and a horizontal discharge section at the top.

The sorbent is delivered to the plant site in tanker trucks which unloads and pneumatically feed the sorbent into a 150-ton sorbent bin. A gravimetric weigh feeder located below the bin delivers the sorbent uniformly at a pre-set rate to the feed elevating conveyor. The feeder is designed to handle up to 2 t/h of sorbent.

The elevating conveyor lifts the coal and sorbent and fill a feed surge bin. The bin is a part of a lock hopper system that feeds the pyrolyzer and which consists of:

- A feed surge bin with a capacity of 700 cubic feet to provide 30 minutes of pyrolyzer feed at rated capacity.
- A lock hopper, with a capacity of 100 cubic feet, located immediately below the feed surge bin. The solids will be pressurized in this unit.
- A dust collector to handle vent gases at a maximum temperature of 300°F.
- Injection Vessel with a capacity of 200 cubic feet located immediately below the lock hopper.
- A volumetric feeder with an adjustable feed rate. This feeder is fitted at the bottom of the injection vessel to introduce a uniform and continuous stream of solids into the transport line at a pre-set rate.
- Valves between vessels for pressurizing gases, and for vessel venting.
- A transport pipe line to the pyrolyzer. This 5-inch diameter pipe receives solids and transport gas at the feed end. The gas will be at a pressure of approximately 230 psia at the feed point.

The flow of solids and the conveying gas through the transport line to the pyrolyzer will be continuous. However, the lock hopper will operate in a batch mode. Thus, the level of solids in the injection vessel will be allowed to float between a high and low level.

The solids feed system for the pyrolyzer designed for a capacity of 35.5 t/h of solids (34.5 t/h of coal and I t/h of sorbent). For this capacity, fifteen lock hopper cycles will be required which means the lock hopper 'fill and empty' cycle will, on the average, be completed in four minutes. The proposed design is estimated to complete this cycle in just 2.5 minutes;

thus, providing adequate operating margin to ensure a steady and continuous flow to the pyrolyzer.

The Injection Vessel operates with an internal pressure of approximately 235 psia and feeds the solids transport line continuously as noted earlier. To ensure a uniform delivery of solids, it will be fitted with an adjustable volumetric feeder which delivers the solids into the pneumatic transport line. Air at 230 psig and 300°F will be used to transport the solids to the bottom feed inlet of the pyrolyzer.

Surface moisture content is a source of concern when pneumatic transport systems are considered for coal. A high surface moisture content could cause coal to flow sluggishly through the lock hoppers and other vessels. Measures such as mass flow/steep angle vessel inserts, high pressure air guns, internal vibrators could be considered for improving coal flow characteristics. Tests are recommended with representative coal samples to identify the most appropriate measure(s) to be adopted so that flow problems are not encountered even at times of maximum coal surface moisture content.

A temperature of 300°F for the transport air at the system inlet appears reasonable from fire/safety considerations. The air will cool significantly and instantly as it hits the moist coal due to evaporation. This view may be confirmed by laboratory or pilot tests.

G.6.2 Char Transportation and Char/Coal Feeding to the Boiler

Figure G-5 shows a process flow diagram of the proposed conceptual system which includes equipment to:

- Receive cooled char from the pyrolyzer,
- Transport the char to a new char surge bin to be located along side the existing coal bunker for Unit 2 in the boiler building,
- Feed a blend consisting of coal from the existing coal bunker and char from the surge bin to two new pulverizers, and
- Grind the coal and char in the pulverizers and deliver the ground coal with air to burner nozzles in the boiler.

G.6.2.1 Char Transportation. Cooled char from the char coolers in the pyrolyzer area first has to be transported to a new char surge bin located in the boiler building. To do this, two screw conveyors will be installed below the two char coolers. These feeders are designed to deliver cooled char (bottom char and char dust from barrier filter) to a mass-flow, chain-type char collecting conveyor. This conveyor and other conveying equipment in the transport chain to the char surge bin are designed to handle char at a temperature of 300°F and will be fully enclosed. The char collecting conveyor delivers the char to a mass flow elevator that uses special chain links to lift the material vertically. A char bin feed conveyor then receives the char from the elevator and moves it to the char surge bin inside the boiler building.

The char transportation system is designed with a capacity of 20 t/h. The char surge bin will have a capacity of 33 tons which will provide 2 hours of char consumption for the boiler. This capacity can be made larger if further investigation of available space at the site makes a larger bin feasible.

G.6.2.2 Char and Coal Feeding to the Boiler. The char surge bin is provided with an inert gas blanket and is fitted with two outlets. Each outlet has a char scale. The coal bunker for Unit 2 currently serves three coal pulverizers. Three coal scales currently exist below the bunker and each scale feeds a pulverizer. Each pulverizer train has a capacity of 12.2 tph or 33% of the current average burn rate of 36.5 tph of coal. For repowering, two of the three existing pulverizers (2B and 2C) and their respective coal scales will be replaced with new 14 tph units. These two pulverizer units are designed to handle the entire solid fuel (coal and char) feed of 24.5 tph. According to current plans, the boiler will need 22.5 t/h of coal when no char is available and the gas turbine will operate on natural gas. The capacities of the new pulverizers, therefore, include a normal design margin. The third pulverizer (the existing 2A unit) and its accessories will serve as a spare and will be operated whenever one of the two new pulverizer trains is not available. When the spare pulverizer is operating, char use will be reduced as no provision is currently made to feed char to this pulverizer. The capacity of the existing spare pulverizer appears to be adequate to meet close to 50 percent of the boiler needs after repowering.

In addition to the new coal and char scales, each new pulverizer will be provided with a screw feeder with two rotary valves. Each screw feeder will be arranged to collect coal and char from one set of coal and char scales. By adjusting the flow rate at the coal and char scales, any desired blend of char and coal can be fed to the pulverizers. Each of the two pulverizer trains will be piped to supply pulverized fuel and air to a set of three burners. The combined capacity of these six burners will be adequate to burn coal or char/coal blend at full load. An additional set of three burners is provided for the spare pulverizing train.

Primary air supply to the three pulverizers (2A, 2B, and 2C) will be provided by a new blower. The design provides for adjusting the temperature of air supply to the pulverizers by blending hot vitiated air, if needed, as shown in the process flow diagram.

G.6.3 Ash Handling and Disposal

G.6.3.1 Bottom Ash. The repowered plant will use existing facilities for removal of the bottom ash from the boiler and its disposal.

G.6.3.2 Fly Ash. Figure G-8 is a simplified flow diagram of the proposed ash handling system. A baghouse dust collector will collect fly ash and FGD spent solids (FGD waste) together as dust in the FGD system (described in Section G.6.4). New equipment will be provided to pneumatically transport the dust collected in the dust hoppers of FGD baghouse to the Ash/FGD waste silo located within the FGD system. A dilute-phase transport system that includes rotary air locks for the baghouse hoppers, air blower, and piping will be provided. The Ash/FGD waste silo has a capacity of about 50 tons. Additional ash handling equipment be provided for removing the ash/FGD waste (which is not recycled to the FGD scrubber) from the bottom of the silo. A densephase transport system will convey the ash/FGD waste to an ash load-out bin that now exists in the plant. The transport system includes a blow- tank- type pneumatic pump, an air compressor, piping and a baghouse for the air vented from the top of the bin. The material collected in the bin is loaded into trucks for final disposal as is currently being done.

G.6.4 Flue Gas Desulfurization

A dry FGD system is proposed for controlling the $S0_2$ emissions. The process, licensed by JOY Environmental Technologies, uses pebble lime in the form of a highly-concentrated water slurry to absorb about 89 percent of the $S0_2$ in the flue gas leaving the low pressure economizer. Table G-3 summarizes the major design parameters and specifications for the proposed FGD system and Figure G-9 is a simplified process flow diagram of the system.

Table G-3
FGD Design Parameters and Specifications

SO_2 emission limit	0.25 lb/million Btu
Inlet gas volume, ACFM	318,450
Inlet SO_2 concentration, ppm	1035
Required SO_2 removal level, %	88.9
Inlet particulates concentration, Gr/ACF	1.5
Gas residence time, sec	10.6
Outlet gas temperature, °F	156
Spray dryer absorber diameter, ft	38.7
Spray atomizer power, hp	350
Bag filter type	Pulse-Jet
Number of filter modules	10
Bags per filter module	280
Filter area per module, sq ft	9046
Total system pressure drop, in. water	~12
Lime consumption, lb/h	2660

The following paragraphs give a brief description of the process operation and design features.

Reagent Preparation. Pebble lime is delivered from bulk tank trucks to a lime storage silo via an onboard pneumatic blowers. A dust collecting system is provided on the roof of the silo to capture dust released during lime discharging. The storage silo is equipped with level indicators as well as pneumatic impactors, at the bottom, to insure an even flow of pebble lime through the bifurcated hopper transition. Lime is fed at a controlled rate by gravimetric weigh feeders to two lime slaking units where lime is mixed with water metered automatically to each slaker tank. Each slaker contains two sets of counter-rotating intermeshing paddles for mixing and a dilution chamber with rakes for agitation.

The slaked lime flows by gravity to two vibrating screens where dilution water is added. Grit larger than 16 mesh is separated from the lime milk and is conveyed to a disposal bin via a screw conveyor. The remainder of the lime milk passes through directly to a storage tank furnished with slow-rotating mixer/agitator.

Reagent Feeding. Lime milk is pumped from the storage tank to the feed slurry line with a progressive cavity pump. The pump speed adjusts automatically to maintain the desired SO_2 level by controlling the quantity of lime slurry delivered to the absorber. Before reaching the absorber's atomizer inlet, the lime milk is mixed with a recycle stream containing unreacted lime and ash dust to obtain the final feed concentration in a head tank. The head tank maintains a constant pressure to a feed control valve which adjust the flow rate automatically to maintain a constant pressure to a feed control valve which adjust the flow rate automatically to maintain the desired absorber outlet gas temperature. This feeding system is designed to provide quick response to changes in SO_2 concentration, gas temperature, and gas flow rate.

Spray Dryer Absorber (SDA). Untreated flue gas enters the SDA via a roof gas disperser and the gas contacts a fine spray of atomized slurry. The SO_2 in the gas is absorbed into the alkaline droplets and reacts to form calcium sulfate as water is simultaneously evaporated. The SO_2 removal efficiency can be varied by changing the lime milk concentration in the atomizer feed.

Careful control of gas distribution, slurry flow rate and droplet size ensures that the droplets are evaporated to dryness before contacting the internal walls of the SDA chamber. The treated flue gas flows from the SDA to a baghouse for particulate collection. A small amount of bleed air is introduced at the bottom of the SDA to ensure that all the solids are carried to the baghouse.

The SDA vessel consists of a sloped, structural topdeck section with checkered plate flooring, cylindrical shell, and a conical bottom section. The lime slurry is atomized in a high-speed rotary atomizer equipped with a vibration monitor to detect spindle bearing failure and/or buildups in the liquid distribution or atomizer wheel. The rotary atomizer housing has feed pipes that take the lime down to a slurry distributor before it enters the atomizer wheel. The roof gas disperser has a scroll inlet which delivers the flue gas to a tapered, annular discharge nozzle around the atomizer. Guide vanes are mounted in the disperser discharge outlet to evenly distribute the gas flow around the atomizer and maintain that distribution.

Solids Removal. The treated flue gas enters a pulse-jet type baghouse to filter out the calcium sulfate, unreacted lime, and entrained fly ash solid particles. The dust collected in the hopper of the baghouse goes through the Ash Handling and Disposal System (see Section G.6.3) which pneumatically transport the dust material to a recycle storage silo (ash silo).

The baghouse consists of ten modules arranged in double-file configuration. Each module contains 280 fabric filter bags and is furnished with clean gas walk-in plenum, housing section, and pyramidal hopper. Gas inlet ducts are located at the side of each module below the bottom of the bags. Each module is also provided with pneumatically operated butterfly dampers at the inlet and pneumatically actuated poppet at the outlet. A high efficiency pulse-jet cleaning system is furnished. The system uses off-line cleaning as the normal mode of operation, but is capable of on-line cleaning as well. The cleaning system uses low pressure, nominal 40 psig, compressed instrument-quality air to dislodge the accumulated filter cake from the bags. The bags are constructed from teflon-coated fiberglass filter media.

Recycle Slurry Preparation. Part of the calcium and ash solids collected in the ash silo is recycled to the absorber and the remaining portion is sent to the Ash Handling and Disposal system for final disposal (see Section G.6.3). Rotary feeder meters the solids to the recycle slurry mix tank where it is mixed with dilution water. The mixture is then pumped to the head tank. An overflow line transports the recycle mixture from the head tank back into the recycle mix tank.

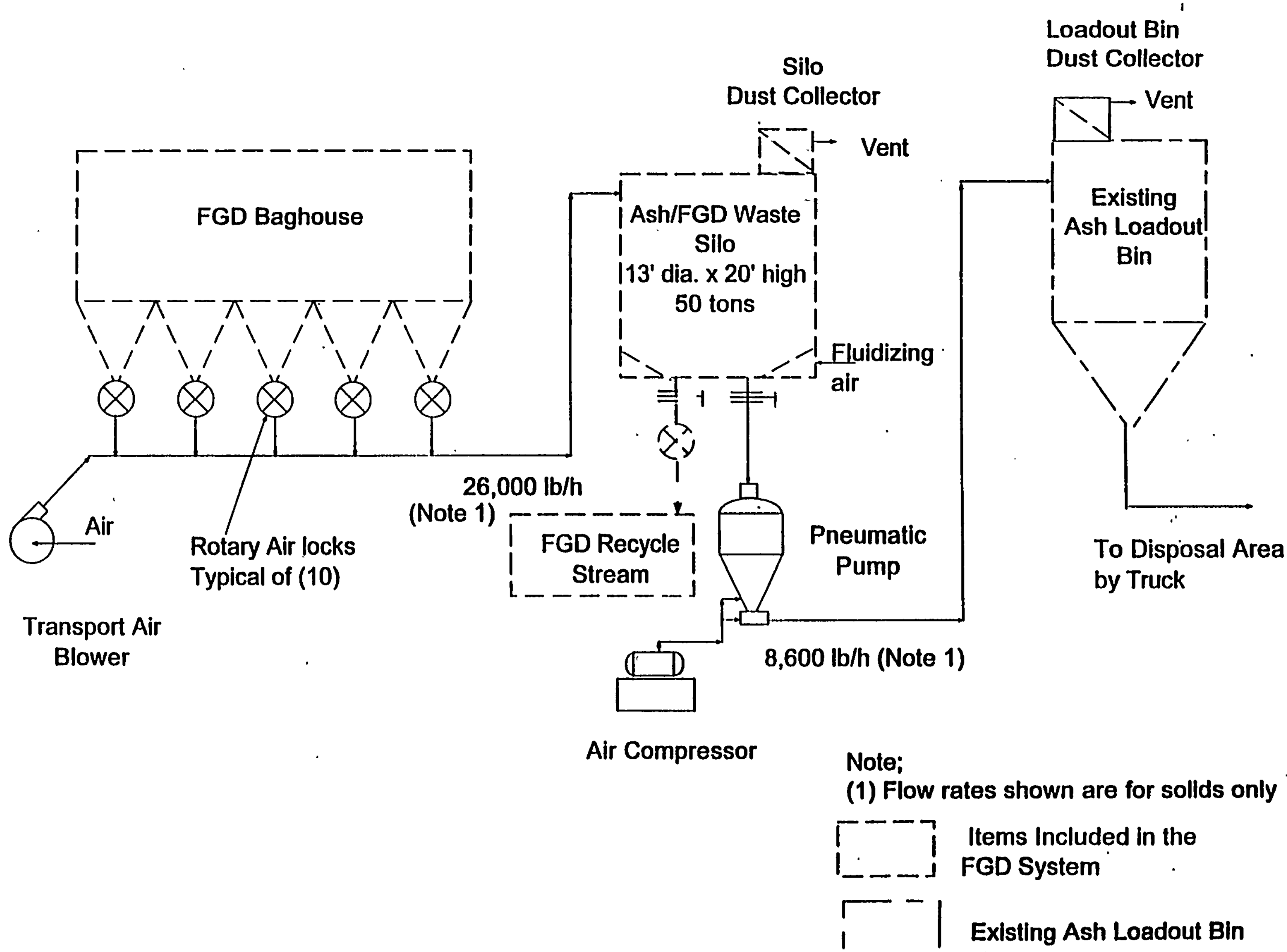


Figure G-8 Ash Handling and Disposal

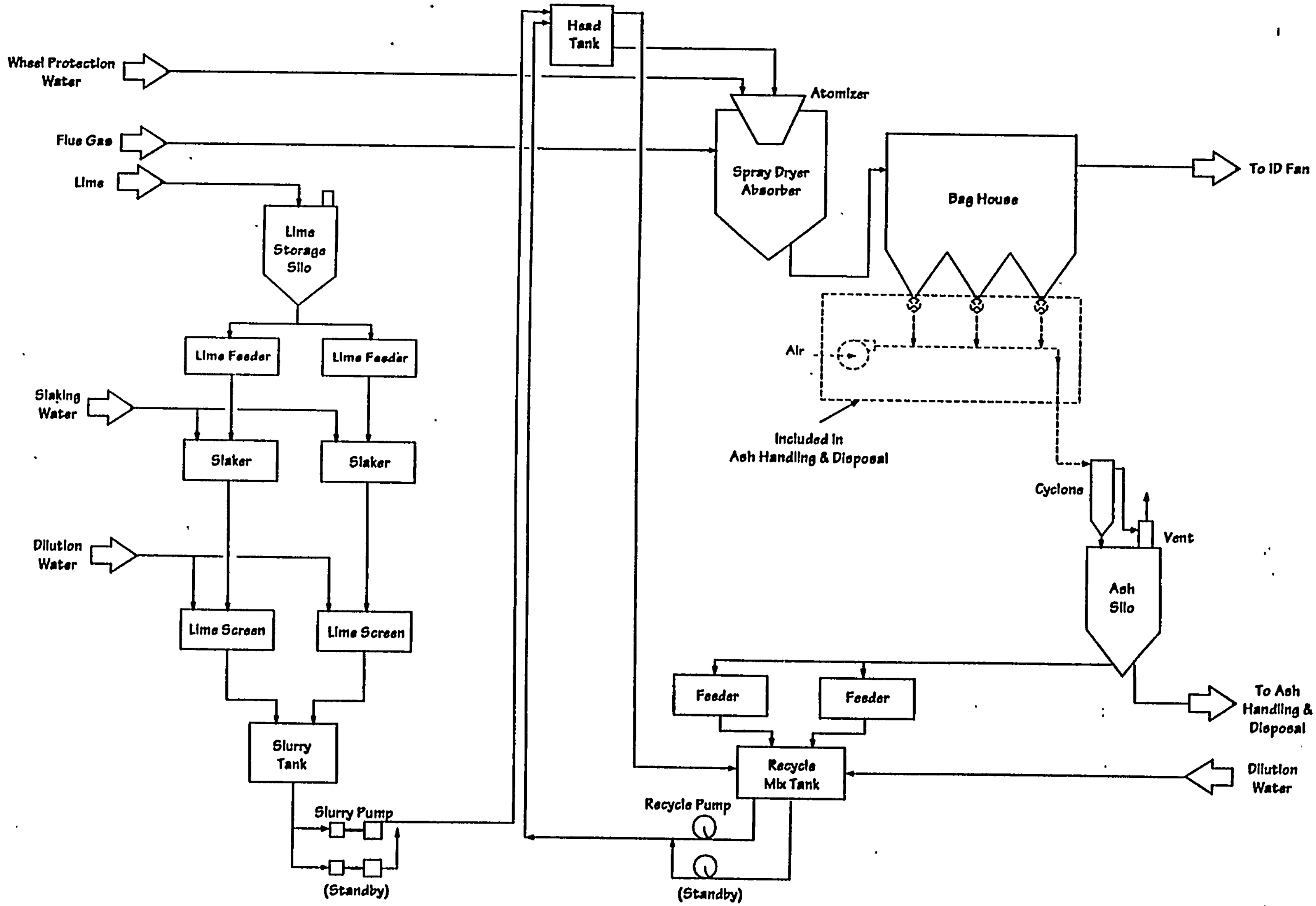


Figure G-9 Dry FGD System

G.7 CAPITAL AND OPERATING COSTS

This section presents the Total Plant Cost (TPC) and the approach used to develop the capital costs for the repowering Unit #2.

G.7.1 Estimating Approach

The estimating approach for both the Power Island and Balance of Plant (BOP) makes maximum use of vendor quotes, including Foster Wheeler, for all major equipment. This information was supplemented by historical data from other constructed facilities using similar equipment.

The estimating approach and the engineering provided to support the estimate are generally consistent with an EPRI Class II Preliminary Estimate, as defined in EPRI's TAG.

Engineering and design information developed and used to prepare the cost estimates consists of process flow diagrams, system descriptions, equipment and facility lists, and other data as required.

The costs presented are for December 1995 with productivity and labor wage rates corresponding to those for south Delaware.

G.7.2 Cost Development Method

A conceptual estimate was prepared by Bechtel by major plant areas. For major components, vendor pricing was used wherever possible.

G.7.2.1 Direct Costs

Major Equipment - Power Island. Major Equipment material costs were provided by FWDC for the following:

- Furnace modifications.
- High temperature exchangers.
- Process systems (except the coal pulverizer).
- Emissions control (except the FGD system)
- Most of the high temperature ducting.

Bechtel sized and estimated the cost of everything else including:

- Solids feeding and removal
- Coal Puliverizers
- Flue gas desulfurization
- Gas Turbine (based on Westinghouse quote for a similar study)
- High Temperature piping and some of the ducting.

Major Equipment - Balance of Plant. Major equipment sizes and estimated costs were provided by Bechtel.

Bulk Material And Installation Costs. The methodology used for estimating the bulk material and installation costs associated with the major equipment incorporates the following.

- Installation labor costs based on Delaware union labor agreements, with an average labor wage rate of $30.50.
- With the exception of modification work, and the high temperature ducting and piping, bulk material cost and installation labor hours were pro-rated from the HIPPS "grassroots" commercial plant estimate developed previously for this project based on the ratio of Major Equipment Costs after adjusting for labor productivity and the additional complexity associated with a revamp plant.
- The cost of plant modification work was estimated by establishing a crew size & duration for each activity. Associated bulk materials and installation were based on judgement of quantities required and allowances.
- High temperature ducting and piping quantities were developed and costs estimated using unit pricing from similar recent projects and studies.

G.7.2.2 Field Indirect Costs

Field indirect costs, "indirects," were developed as follows:

- Manual and Non-Manual Distributables - the commercial plant estimate ratios per direct manual hour are used. The commercial plant estimate unit pricing is escalated by 5 percent to reflect the change in estimate year from 4th qtr '93 to 4th qtr '95.
- Project insurance is estimated at 2% of field costs of total direct field cost.

G.7.2.3 Home Office Engineering

The H.O. Engineering cost is estimated at 15 percent of the total Field Cost, which is typical for a revamp project of this size.

G.7.2.4 Contingency

A project contingency was estimated by taking 10 percent of the total power island cost plus 20 percent of the total balance-of-plant cost. This level of project contingency reflects the level of definitions and details provided for the refurbishment/modifications of existing systems for the project at hand.

G.7.3 Capital Cost Estimate

The total capital requirements (TCR) are summarized in Table G-4. The total plant cost is summarized by plant area in Table G-5.

Included in the TCR is an allowance for process contingency. Process contingencies provide an allowance based on the process uncertainties or lack of commercial demonstration; i.e., risk. Because of the conventional nature of the BOP equipment process contingencies were applied only to the boiler island.

G.7.4 Owner's Costs

Owner's costs are summarized in Table G-6. The initial catalyst and chemical quantities and costs have been factored from previous studies related to similar coal-based combined cycle systems. They include the initial charge of catalyst and chemicals contained within the process equipment.

Table G-4
Total Capital Requirements
(millions of December 1995 dollars)

Plant costs	
Power island	44.91
Balance of plant	3.07
Total direct costs	47.98
Field indirect costs	6.37
Total field cost	54.35
Home office engineering	8.15
Contingency (project)	6.65
Contingency (process)	3.07
Total plant cost (TPC)	72.22
Capital requirements	
AFUDC	3.78
Owner's costs	5.02
Total capital requirement	81.02
Net power to grid, MWe	116.70
Dollar per kilowatt	694.3

Table G-5
HIPPS Repowering Total Direct Field Cost
(millions of December 1995 dollars)

Item	Total
Power island	
1 Solids feed removal	
1.1 Coal prep/feeding	2.93
1.2 Sorbent prep/feeding	0.03
1.3 Ash/slag removal	0.00
	2.97
2 Steam Generator Island	
2.1 Furnace	0.66
2.2 Coal/char burners	0.96
2.3 LP & HP economizers	1.68
2.4 Stacks/ducting	0.99
2.5 ID fan	0.00
	4.28
3 High temperature exchanger	
3.1 GT exhaust economizer	0.35
3.2 Air heater	0.00
	0.35
4 High temperature piping/ducting	0.36
5 Process systems	
5.1 Pyrolyzer	0.64
5.2 Fuel gas combustor	0.00
5.3 Cyclones	0.29
5.4 Fuel gas coolers	0.26
5.5 Barrier filter	1.06
5.6 Char cooling/transport	2.55
5.7 Pyrolyzer compressor	0.24
5.8 Coal/char pulverizers	4.77
	9.80
6 Gas turbine	17.12
7 Steam turbine/BFW	0.00
8 Emissions control systems	
8.1 Particulate removal	0.00
8.2 SO_2 removal	6.80
8.3 NO_x removal	3.21
	10.01
Balance of plant	
10 Solids material handling	
10.1 Coal receiving/handling	0.00
10.2 Sorbent receiving/handling	0.47
10.3 Ash/slag handling & receiving	0.62
	1.08
11 Water systems	
11.1 Cooling water systems	0.00
11.2 Raw water/treatment system	0.00
	0.00
12 Support systems	
12.1 Service/instrument air	0.03
12.2 Natural gas supply	0.00
12.3 Electrical distribution	1.04
12.4 Instrument & controls	0.38
12.5 Interconnecting piping	0.08
12.6 Fire protection	0.13
12.7 General services & mobile equipment	0.00
	1.65
13 Civil/structural	
13.1 Site preparation/facilities	0.18
13.2 Miscellaneous buildings	0.16
Total direct field cost	0.33
	47.98

Table G-6
HIPPS Owner's Cost Summary
(thousands of December 1995 dollars)*

Organization and startup costs	
1 mo. fixed O&M	311
1 mo. var. cost (ex. fuel)	168
1 week fuel	241
Two percent of PFI	1,444
Subtotal	2,165
Working capital	
2 mo. fuel	2,087
2 mo. other consumables	337
Spare Parts Inventory (0.5% of PFI)	361
Subtotal	2,785
Initial catalyst and chemicals	72
Land costs	0
Total owner's costs	5,022
* Based on 100 percent capacity factor	

G.8 ECONOMIC ANALYSIS

The economics associated with repowering a plant must be evaluated differently than a greenfields or comparable facility where the plant is constructed in total with little or no contribution from any existing facility. Using a levelized cost to develop a cost of electricity, as outlined in EPRI's *Technical Assessment Guide* (TAG), can be difficult because it is hard to segregate what portion of the O&M costs and revenue is directly attributable to the new equipment. For this reason, when comparing various options available, it is often better to compare the present value (PV) of each of the options which take into account all expenses and revenues over the life of the project.

This section summarizes the costs and economic analysis results estimated for the HIPPS repowering option. Although EPRI's levelized cost analysis was not used, the input values used match the input formats and organization used by EPRI's TAG. The results have been summarized in Tables and Figures for presentation in this section.

G.8.1 Economic Basis

The economic criteria and ground rules established for this project are discussed below. The methodology used in developing the owner's costs and the operating and maintenance costs is described.

G.8.1.1 Cost Bases for Owner's Costs

Owner's costs are defined as the following:

- Organization and startup costs
- Working capital
- Land costs
- Allowance for funds used during construction (AFUDC)

Organization and startup costs are to cover administrative costs and operator training. equipment checkout, changes in plant equipment, extra maintenance, and inefficient use of coal or other materials during plant startup. These costs are estimated as follows:

- One month of fixed operating and maintenance costs, which consist of operating and maintenance labor, maintenance materials, and administrative and support labor. Insurance and property taxes are not included; they are part of the fixed charges.

- One month of variable operating costs, excluding fuel, at full (100%) capacity; these costs are for limestone catalysts, chemicals, and solid waste disposal.

- One week of fuel cost at fill (100% and 60°F ambient) capacity; this charge covers inefficient operation that occurs during the startup period.

- A charge of 2.0% of the total plant cost (including contingency); this charge covers expected equipment changes and modifications that will be needed to bring the plant up to full capacity.

Working capital is the value of the inventories of raw materials and other consumables. This value is capitalized and included in the working capital account, and is estimated as follows:

- Two months' supply of fuel based on full (100% and 60°F ambient) capacity

- Two months' supply other consumables (excluding fuel) based on full capacity, 60°F ambient operations

- Spare parts inventory, which is assumed to be 0.5% of the plant facilities investment

Since the repowering option utilizes available land, no charges are assigned for land cost.

Allowance for funds used during construction (AFUDC) is the cost due to interest charges which are accumulated between the time money is expended for construction and the time that the construction is completed. (AFUDC) is based on the plant construction expenditure schedule estimated for each case and is calculated according to the procedure outlined in TAG.

G.8.1.2 Cost Bases for Operating and Maintenance (O&M) Costs

Operating costs are divided into fixed and variable components. Fixed operating cost are independent of hours of operation or amount of power produced. Variable operating costs are directly proportional to the amount of power produced.

Total O&M costs and factors used as input for the economic calculations are composed of the following:

- Anual fixed O&M costs, including consumables cost

- Annual variable O&M costs at design capacity

- Annual value of by-products at design capacity

- Fuel cost
- Capacity Factor

The operating labor charge is computed using an average labor rate of $38.67/job-hour (December 1995 dollars). This labor rate includes a 33.5 percent payroll burden.

The total labor cost is calculated based on 2,080 salary hours per year per person.

G.8.1.3 Annual Fixed O&M Costs

The labor charges are estimated as follows:

- Operating Labor - Charges are included for operations manager, shift supervisors, operators, and training personnel.
- Technical Services - Charges are included for plant engineer, control and electrical engineer, chemistry technician, and instrument and computer technician.
- Management - Charges are included for plant manager, administration services, janitors, security guards, and training personnel.
- Maintenance - The usual maintenance charges are estimated at 2.5% of the total plant cost (TPC) to be consistent with TAG.

Estimates of required personnel for each of these categories were based several factors, including:

- Estimates provided by the utility
- Bechtel's experience with AFBC power plants, pulverized coal (PC) fired power plants and where applicable, refinery operations
- Previous EPRI studies by Bechtel and others

Annual fixed O&M costs are estimated for input into the TAG format as the sum of the charges related to plant labor and maintenance.

Annual variable O&M costs represent a sum of the consumables, including catalysts and chemicals, limestones, lime, and solid disposal costs, but excluding fuel charges, which are accounted for separately. The cost per unit of consumables used in this study are:

- Limestone $25.00/ton
- Lime $31.50/ton
- Disposal of solids $18.00/ton
- Catalyst and chemicals Various

Annual Value of By-Products at Design Capacity. No by-products were assumed to be generated for this analysis.

Fuel Cost. The base coal cost used for this study was $1.41 per million Btu's in December 1995 dollars. The base cost of natural gas used in the comparison analysis with other technologies was $2.50 per million Btu's in December 1995 dollars. The annual escalation rate for both was assumed to be 4.5 percent per year.

Capacity Factor. For comparison purposes, a nominal capacity factor of 65% was assumed, based on general TAG guidelines for base-loaded plants. However, it should be noted that the improved performance and reduced operating costs associated with a plant repowered with the HIPPS technology should greatly improve its dispatchability and thereby increase the nominal capacity factor.

G.8.2 Owner's Costs

Owner's costs were presented in Sections 7 as part of the Total Capital Requirement.

G.8.3 Operating Costs

Total operating and maintenance (O&M) costs used as input for tile revenue requirement calculations include:

- Annual fixed O&M costs
- Annual variable O&M costs at design capacity
- Fuel costs
- Annual value of by-products at design capacity

A summary of these costs is presented in Table G-7.

Table G-7
HIPPS Repowering Annual Operating and Maintenance Costs
(thousands of December 1995 dollars)*

Item	Cost
Fixed costs	
Operating Labor	2,895
Technical services	402
Management	643
Maintenance	1,805
Total	5,746
Fixed costs, mills/kWh	4.92
Variable costs - consumables	
Catalyst and chemicals*	133
Ammonia*	23
Limestone/Lime*	530
Solids disposal*	2,022
Total	4,043
At capacity factor	2,628
Consumables, mills/kWh	2.25
Variable cost - fuel	
Fuel cost*	12,521
At capacity factor	8,139
Fuel, mills/kWh	6.97
Total O&M (including fuel) at capacity factor	16,513
Mills/kWe	14.15

* Based on 100 percent capacity factor

G.8.4 Economic Results

A summary of the inputs and results used in the present value calculation are summarized in Table G-8. A summary of the values used in the present value determination is presented in Table G-9.

A similar evaluation was made for three other repowering technologies, including:

- Upgrading the existing pulverized coal fired (PCF) facility and adding the necessary emissions controls systems to meet NSPS standards

- Adding a natural gas fired turbine in a hot-windbox type configuration

Since the escalation for natural gas is unknown, a second evaluation was made assuming a one percent real escalation relative to the cost of coal. A summary of the results of this analysis is presented in Figure G-10.

The results presented in this figure indicate that repowering with the HIPPS technology and repowering with a natural gas hot windbox system offer essentially the same net present value revenue, although the HIPPS option requires a larger initial investment. However, if natural gas escalates as little as 1 percent relative to coal the net present value strongly favors the HIPPS option.

Updating the existing system requires the least capital but since the performance will not be improved, and may diminish due to the addition of a FGD system, the net present value is considerably lower than either the HIPPS or natural gas hot windbox options.

The AFBC option appears to offer the least benefit. This is not surprising since this option requires the replacement of the entire boiler as part of the repowering, and the capacity and efficiency are not improved. This infers that AFBC repowering should only be considered for those systems where the life of the boiler cannot be extended economically.

Table G-8
HIPPS Repowering Inputs and Results
(thousands of December 1995 dollars)

Item	Cost				
	HIPPS Repower	NG Hot Windbox	NG Hot Windbox*	AFBC Repower	Upgrade PCF
Total plant cost	72,205	63,118	63,118	61,846	32,887
Cost of land	0	0	0	0	0
Organizational and startup expenses	2,165	1,908	1,908	2,014	1,267
Working capital	2,785	3,065	3,065	2,830	2,428
AFUDC	3,784	3,307	3,307	4,886	848
Coal cost, \$/MM Btu	1.41	1.41	1.41	1.41	1.41
Natural gas cost, \$/MM BTu	2.50	2.50	2.50	2.50	2.50
Escalation of natural gas cost	0	0	0	0	0
Annual fixed O&M costs	5,746	4,875	4,875	4,844	4,120
Annual variable O&M costs @ 100% CF	2,011	1,706	1,706	1,695	1,442
Power output, MWe	116.7	116.0	116.0	90.0	92.7
Heat rate, Btu/kW	8,687	8,512	8,512	10,459	10,158
Net Present Value	146,307	147,665	134,928	88,302	126,428

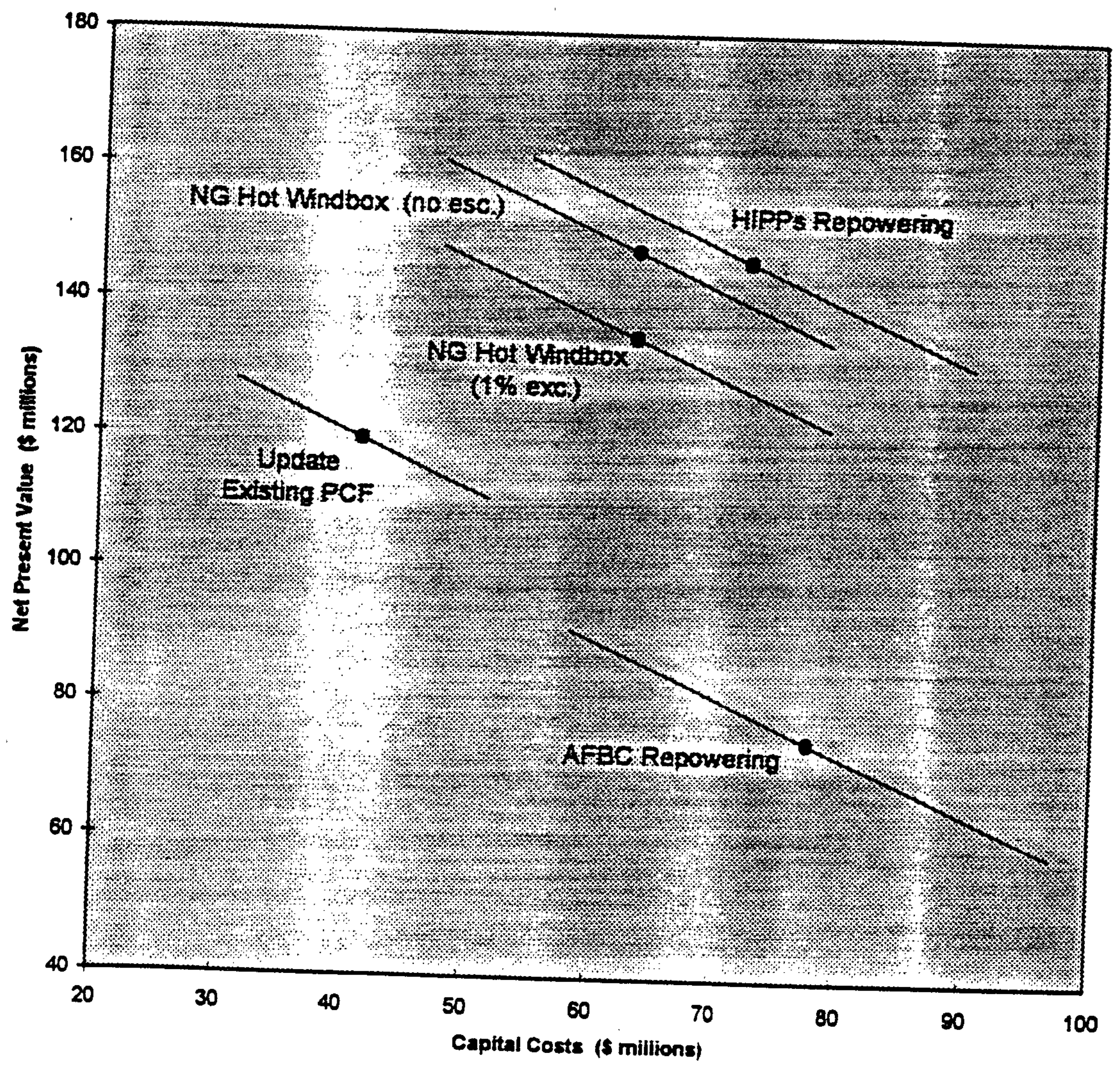
* For the case the cost of NG escalates 1% relative of that of coal.

Table G-9
HIPPS Repowering Net Present Value Analysis
(thousands of December 1995 dollars)

Inflation Rate	4.50%	Discount Rates	
Real Escalation	0.00	After Tax	8.50%
Electrical, $/kWh	0.065	Before Tax	14.51%
Tax Rate	36.6%	Overall	10.23%

		HIPPS Repowering						
Year		Capital	Fuel	Variable	Fixed	Gross Rev	Net Rev	PV
1995	0		0	0	0	0	0	0
1996	1		0	0	0	0	0	0
1997	2		0	0	0	0	0	0
1998	3		0	0	0	0	0	0
1999	4		0	0	0	0	0	0
2000	5	10831	0	0	0	0	0	0
2001	6	33954	0	0	0	0	0	0
2002	7	35482	0	0	0	0	0	0
2003	8		11574	1869	8171	61423	25223	13133
2004	9		12095	1953	8539	64187	26358	12649
2005	10		12639	2041	8923	67076	27544	12182
2006	11		13208	2132	9325	70094	28784	11733
2007	12		13802	2228	9744	73248	30079	11301
2008	13		14423	2329	10183	76544	31433	10884
2009	14		15072	2433	10641	79989	32847	10483
2010	15		15751	2543	11120	83588	34325	10096
2011	16		16459	2657	11620	87350	35870	9724
2012	17		17200	2777	12143	91281	37484	9366
2013	18		17974	2902	12690	95388	39171	9020
2014	19		18783	3032	13261	99681	40933	8688
2015	20		19628	3169	13858	104166	42775	8368
2016	21		20512	3312	14481	108854	44770	8059
2017	22		21435	3461	15133	113752	46712	7762
2018	23		22399	3616	15814	118871	48814	7476
2019	24		23407	3779	16525	124220	51010	7200
2020	25		24460	3949	17269	129810	53306	6935
2021	26		25561	4127	18046	135652	55705	6679
2022	27		26711	4312	18858	141756	58211	6433
2023	28		27913	4507	19707	148135	60831	6196
			89189	14400	62968	473321	194367	
		48060						194367
							Net PV	146307

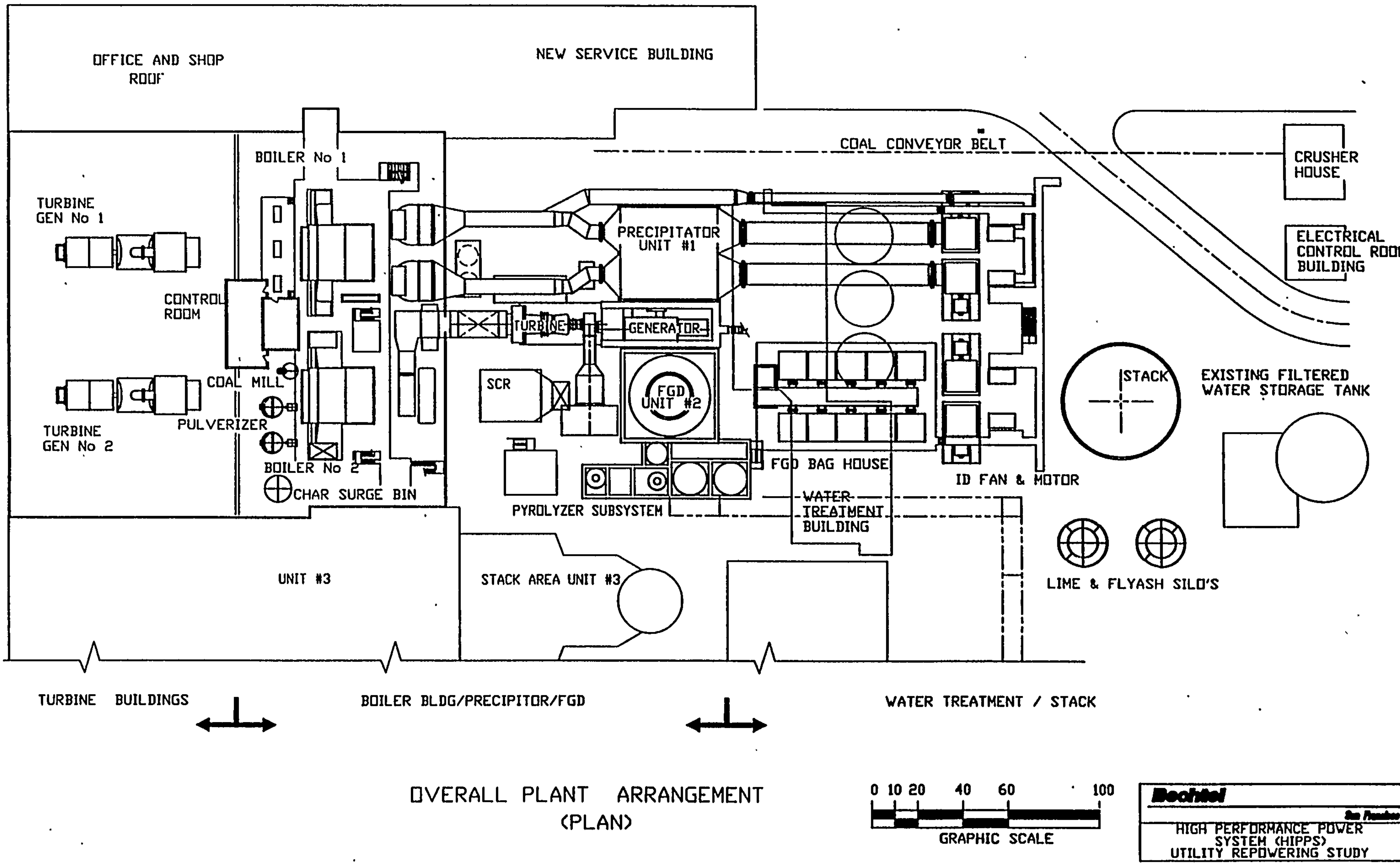
Figure G-10
Comparison of Net Present Value for Various Options



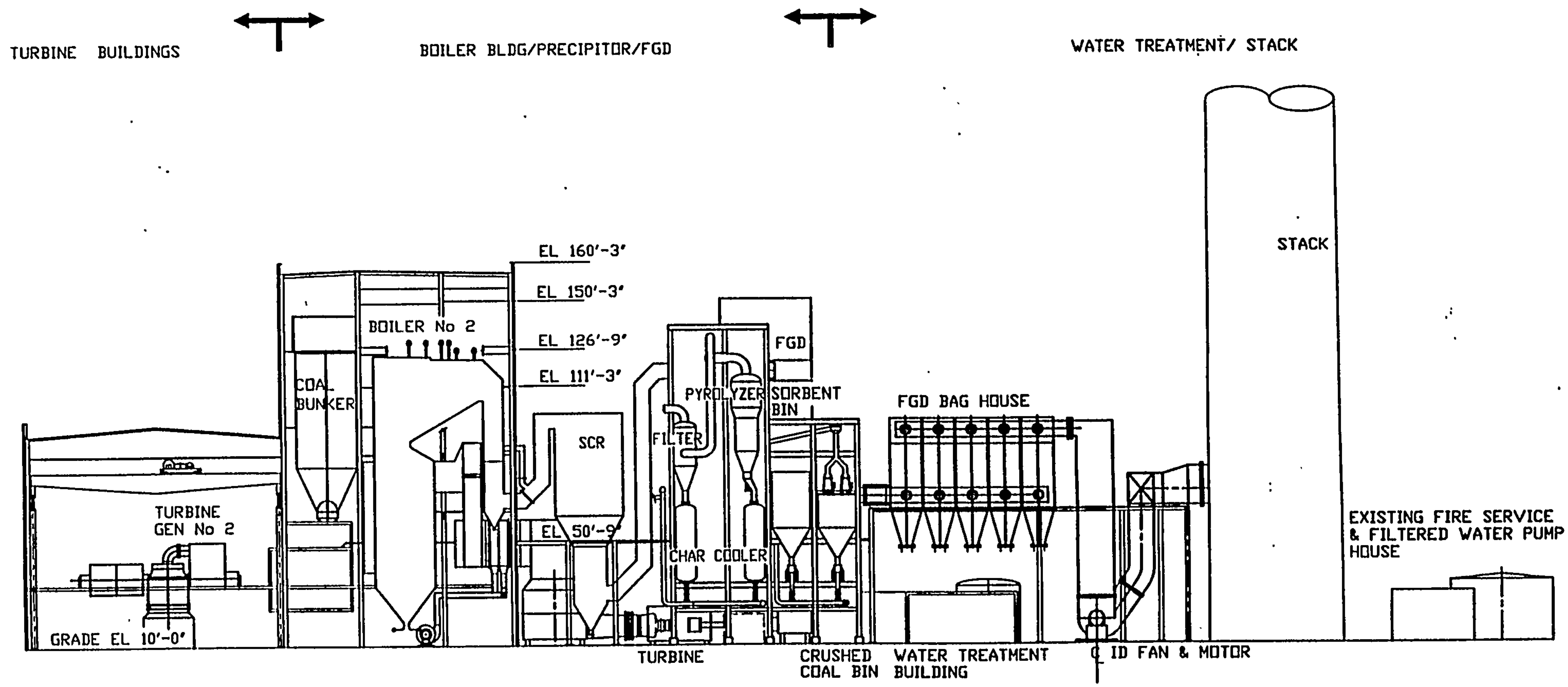
G.9 PLANT ARRANGEMENT DRAWINGS

Following drawings are included in this Section:

- Overall Plant Arrangement (Plan)
- Overall Plant Arrangement (Side View)
- Drawing #'s: SK-PP-050, 075, 076, 080, 081
- Drawing #'s: SK-GA-100, 101, 102, 103, 104, 110
- Drawing #'s: SK-GA-200, 201, 202, 203, 204, 205, 210, 211
- Drawing #'s: SK-GA-300, 301, 302, 303, 304, 310
- Drawing #'s: SK-OA-175, 176, 180, 181



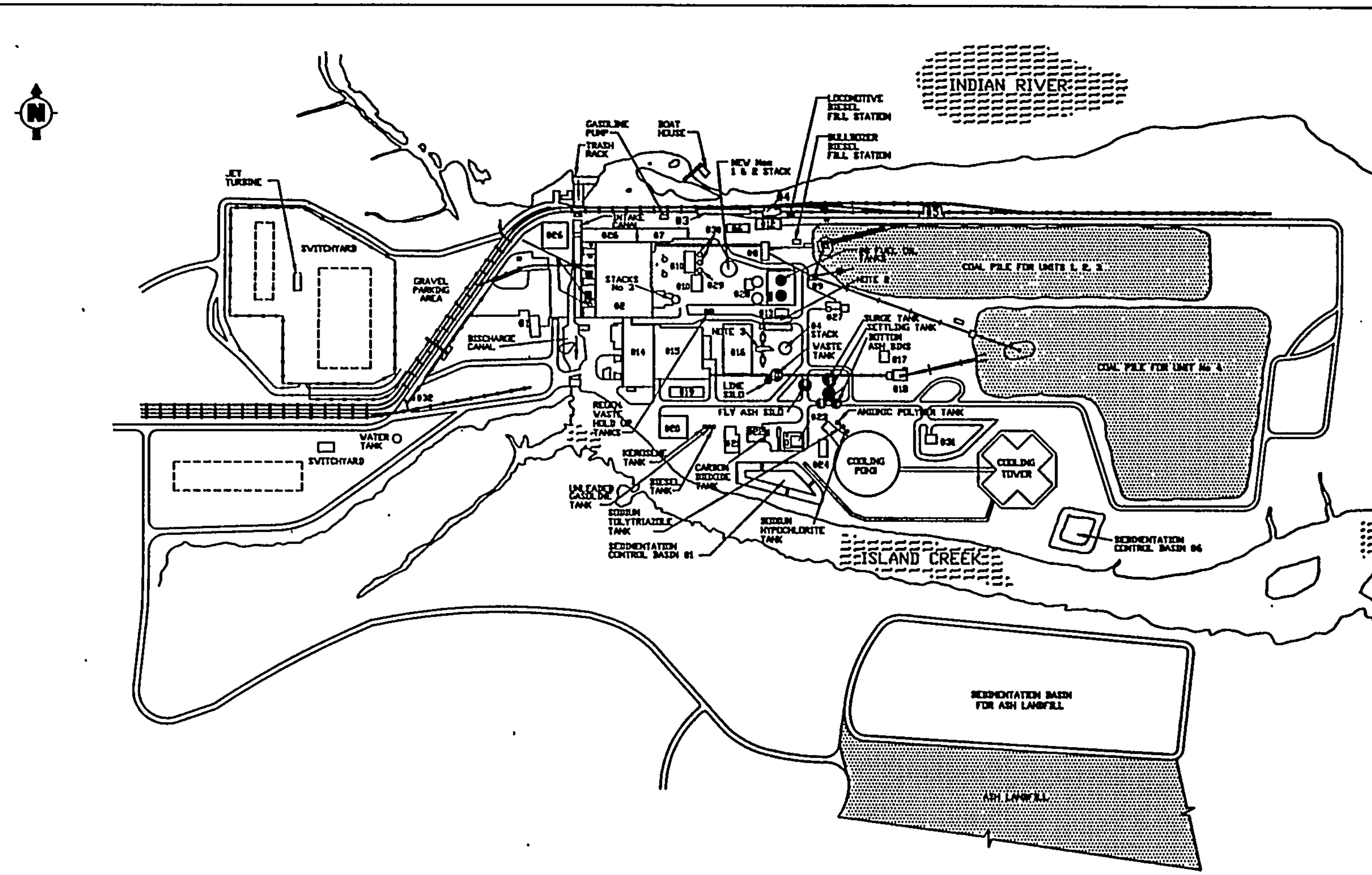
OVERALL PLANT ARRANGEMENT
(PLAN)



OVERALL PLANT ARRANGEMENT
(SIDE VIEW)

0 10 20 40 60 100
GRAPHIC SCALE

Bechtel
San Francisco
HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY



REFERENCES	
SK-GA-100	GENERAL ARRANGEMENT TURBINE BUILDING PLAN BELOW EL 20'-0"
SK-GA-200	GENERAL ARRANGEMENT BOILER BLDG & PRECIPITATOR PLAN BELOW EL 20'-0"
SK-GA-300	GENERAL ARRANGEMENT WATER TREATMENT BUILDING & STACK PLAN BELOW EL 20'-0"

NOTE:

BASE MAP FROM GILBERT ASSOCIATES, INC. DRAWING Nos E-743-300 AND E-743-001 AND AERIAL PHOTOGRAPHS.

BUILDING INDEX		BUILDING INDEX
PERFORMANCE DEPARTMENT	017	COAL HANDLING SWITCH GEAR HOUSE
TURBINE AND BOILER ROOM FOR UNITS 1, 2, & 3	018	CRUSHER HOUSE # 4
THAW SHED	019	MAINTENANCE STORE HOUSE
CAR SHAKER	020	STORE ROOM WAREHOUSE
ROTARY CAR DUMPER	021	GAICO
CHANGE HOUSE	022	INDUSTRIAL WASTE TREATMENT
MAINTENANCE STORE ROOM	023	SEWAGE TREATMENT PLANT
CRUSHER HOUSE (UNITS 1, 2, & 3)	024	COOLING TOWER SWITCH GEAR & CHLORINATION
TRANSFER HOUSE #1	025	CHLORINATION BUILDING (UNITS 1, 2, & 3)
WATER TREATING AND SERVICE BOILER	026	OFFICE BUILDINGS
WATER TREATMENT MAKE-UP	027	AIR HEATER WASH
COAL HANDLING MAINTENANCE SHOP	028	WATER PUMP HOUSE AND WATER TANKS
FUEL OIL PUMPING HOUSE	029	FILTERED WATER TANK
UNIT No 4 TURBINE ROOM	030	DEMINERALIZED WATER TANK
UNIT No 3 BOILER ROOM	031	MID ATLANTIC ASH
ELECTROSTATIC PRECIPITATORS	032	GUARD HOUSE

LEGEND

- ROAD
- FENCE LINE
- RAILROAD TRACKS
- DENOTES SPILL LOCATION (SEE NOTED)
- DIKE
- BULKHEAD

4-1-96	ISSUED FOR INFORMATION	

SCALE 1=200'

Bechtel

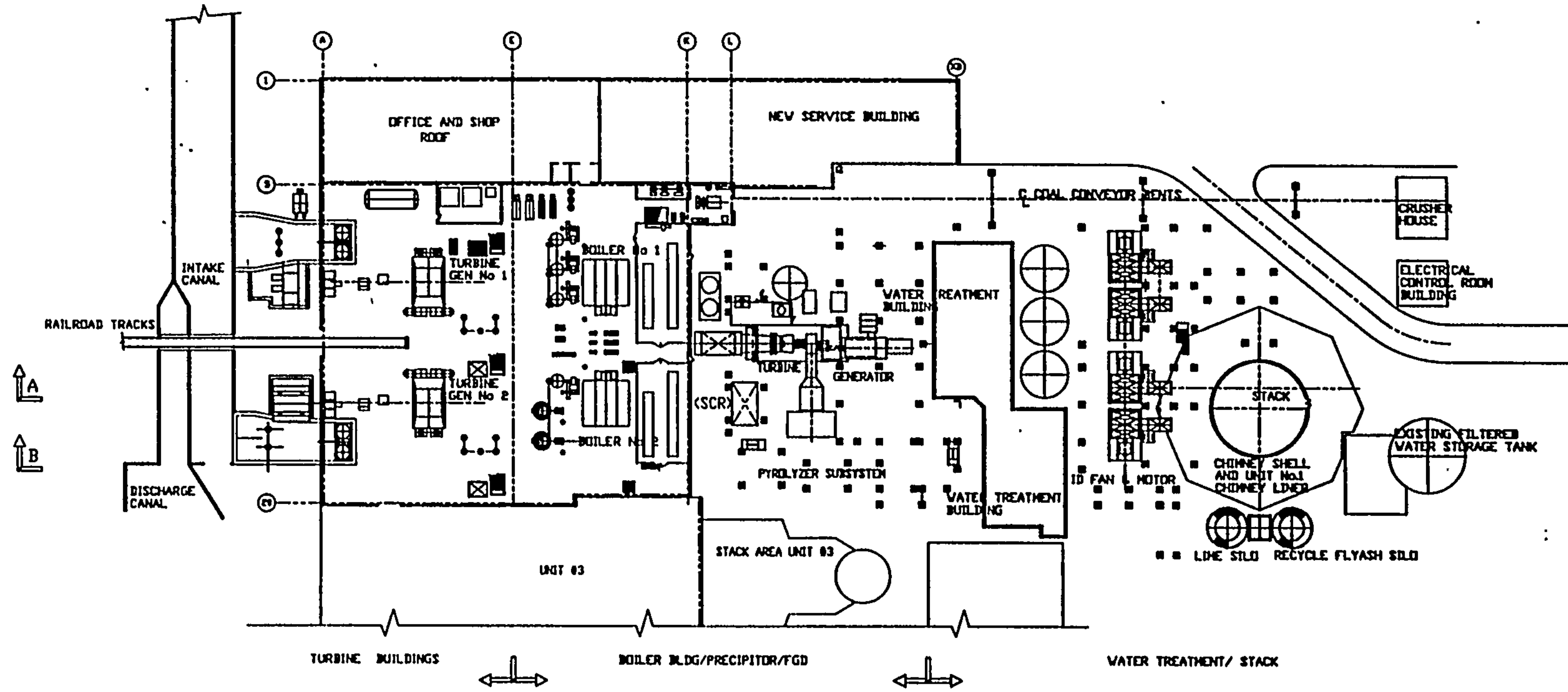
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

FACILITY PLOT PLAN UNITS 1,2 & 3

JOB No.	DRAWING No.	REV
21840	SK-PP-050	A

REFERENCES	
SK-OA-076	OVERALL ARRANGEMENT WATER TREATMENT/ STACK PLAN BELOW EL 60'-0"
SK-OA-080	SECTION A-A
SK-OA-081	SECTION B-B
SK-PP-050	FACILITY PLOT PLAN UNITS 1, 2 & 3
SK-GA-100	GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL20'-0"
SK-GA-200	GENERAL ARRANGEMENT BOILER BLDG/PRECIPITOR PLAN BELOW EL20'-0"
SK-GA-300	GENERAL ARRANGEMENT WATER TREATMENT/ STACK PLAN BELOW EL20'-0"



NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

A SEE DVG SK-OA-080

B SEE DVG SK-OA-081

0 10 20 40 60 100
GRAPHIC SCALE

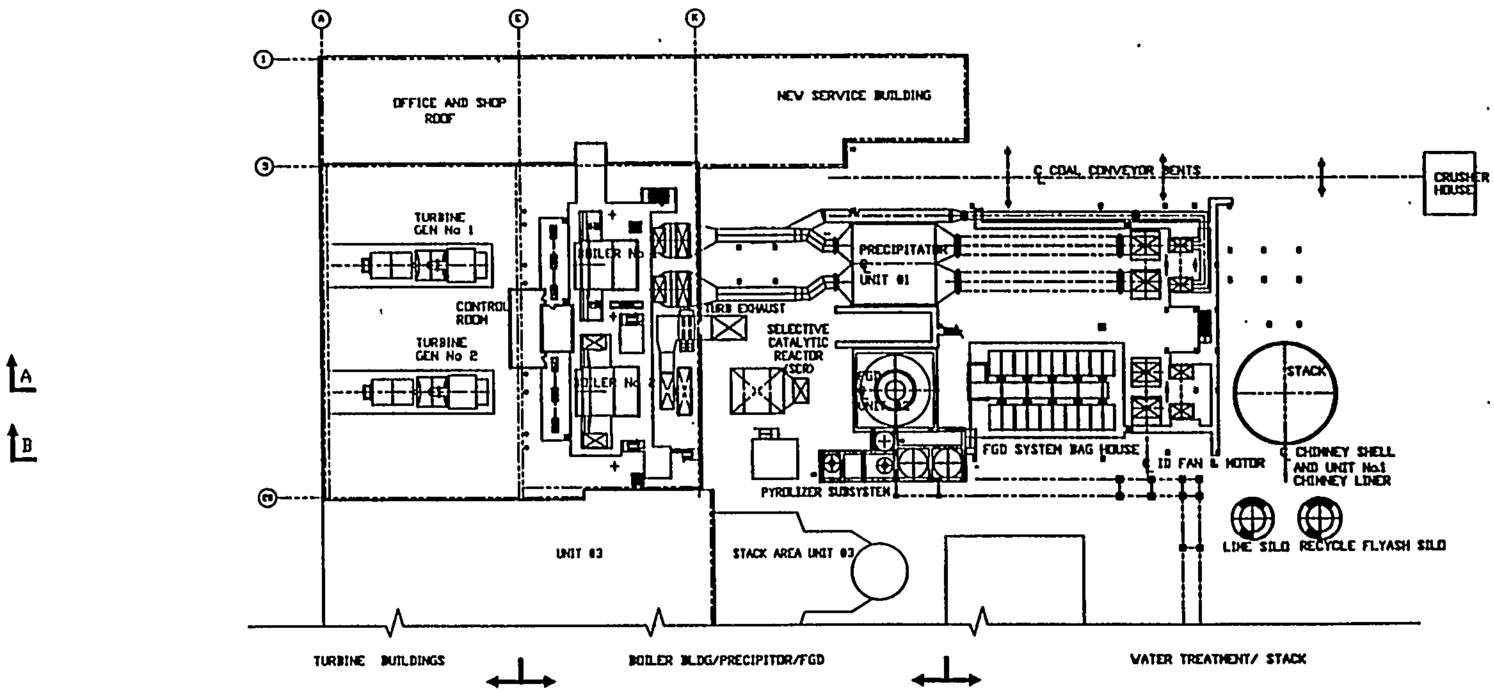
4-1-92	ISSUED FOR INFORMATION	
1/32"=1'-0"	TALCARLSON	ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

OVERALL ARRANGEMENT UNITS 1 & 2 PLAN BELOW EL 20'-0"

Job No.	Drawing No.	Rev.
21840	SK-OA-075	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-OA-075

A — SEE DWG SK-OA-080

B — SEE DWG SK-OA-081

0 10 20 40 60 100
GRAPHIC SCALE

A	4-1-96	ISSUED FOR INFORMATION	

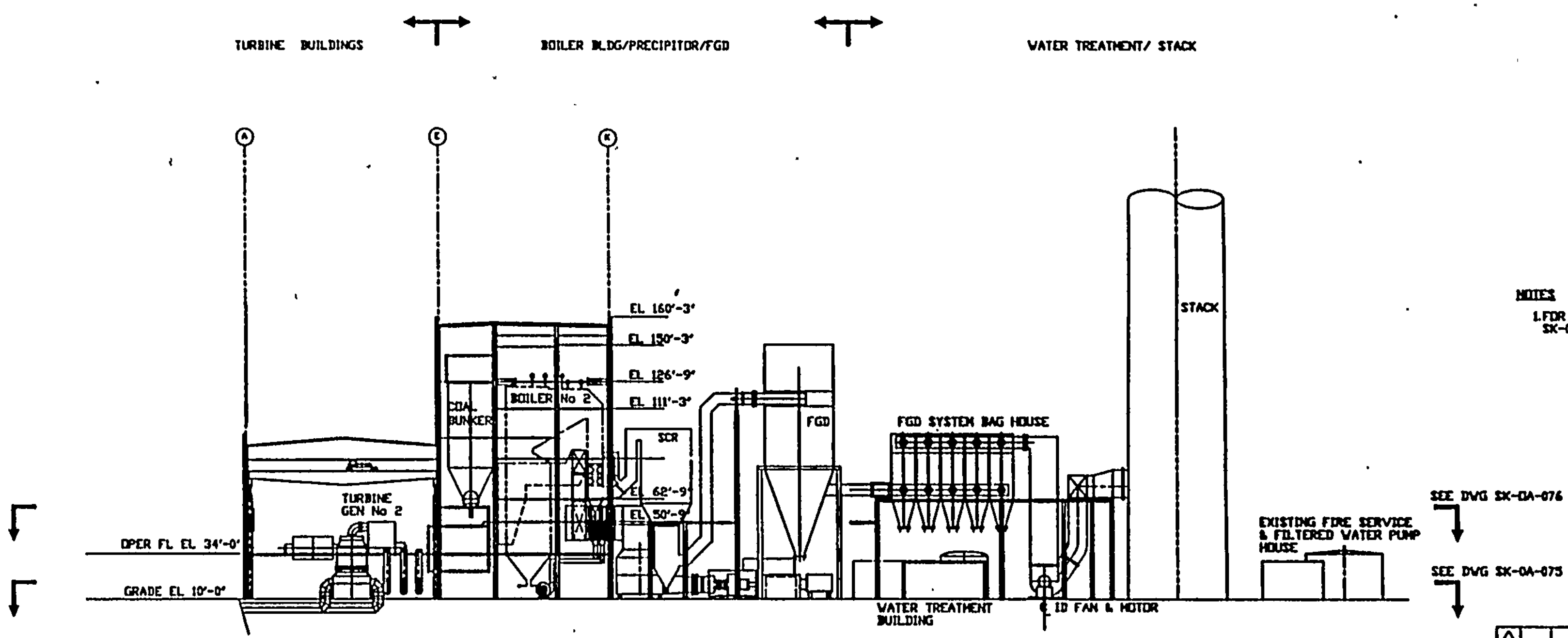
SCALE 1/32"=1'-0" DESIGNED T.ACARLSON DRAWN ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

OVERALL ARRANGEMENT
UNITS 1 & 2
PLAN BELOW EL 60'-0"

JOB No.	DRAWING No.	REV.
21840	SK-DA-076	A



NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

SECTION A-A

0 10 20 40 60 100
GRAPHIC SCALE

A	4-1-96	ISSUED FOR INFORMATION

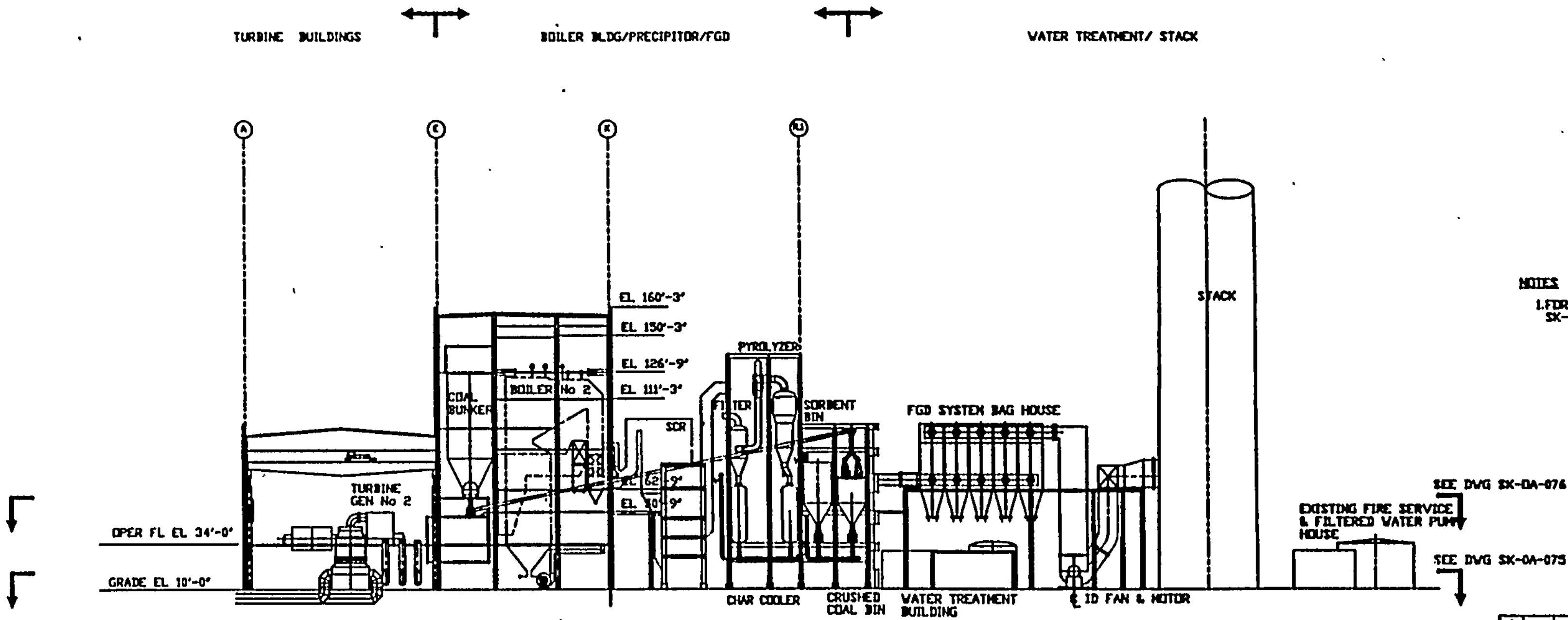
TALCARLSON ACAD

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

OVERALL ARRANGEMENT UNITS 1 & 2 SECTION A-A

Job No.	Drawing No.	Rev.
21840	SK-OA-080	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

SECTION B-B

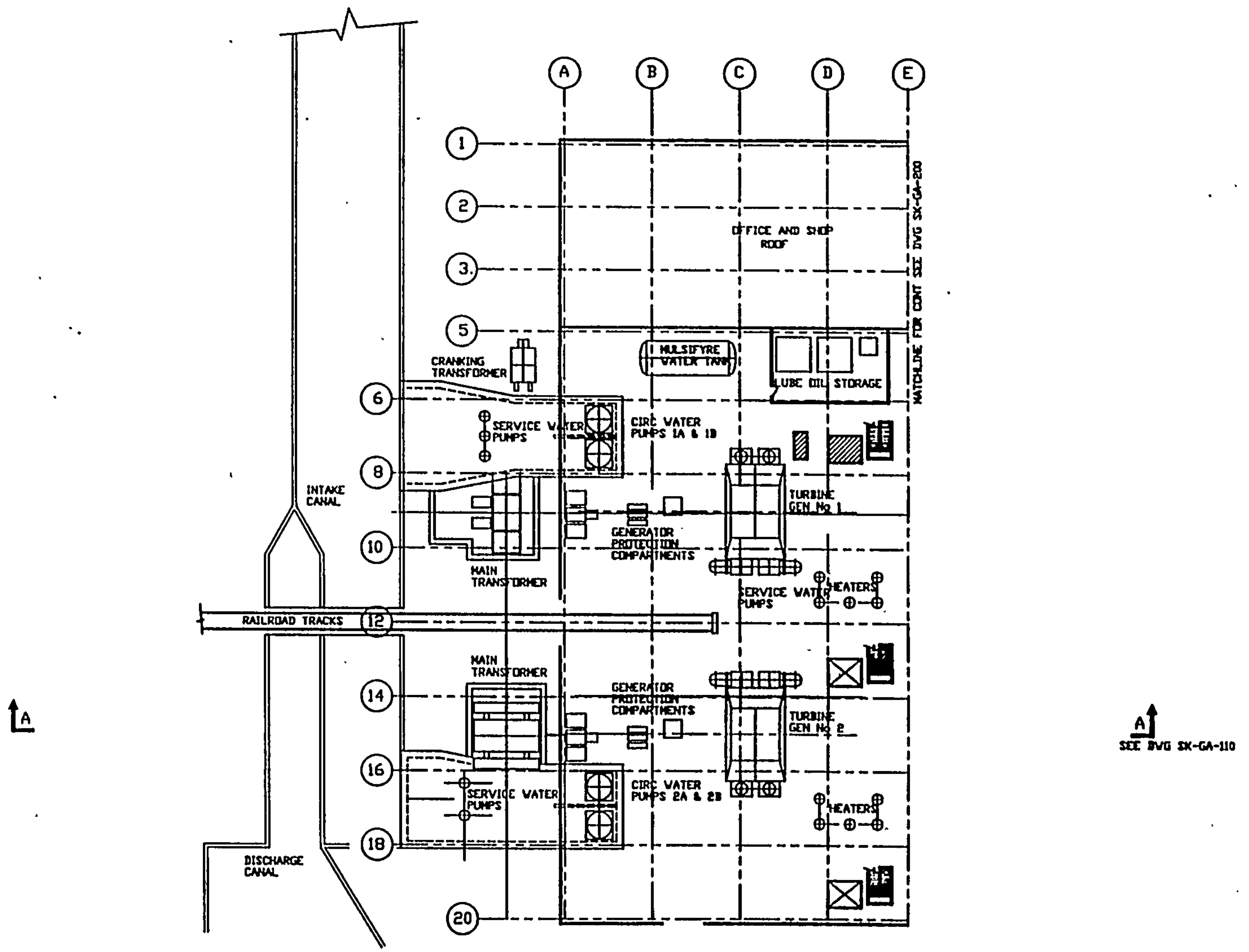
4-1-96	ISSUED FOR INFORMATION
Scale 1/32"=1'-0"	T.A.CARLSON	ACAB

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

OVERALL ARRANGEMENT
UNITS 1 & 2
SECTION B-B

Job No.	Drawing No.	Rev.
21840	SK-OA-081	A



REFERENCES	
SK-GA-101	GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL 30'-0"
SK-GA-102	PLAN BELOW EL 40'-0"
SK-GA-103	PLAN BELOW EL 60'-0"
SK-GA-104	PLAN BELOW EL 82'-0"
SK-GA-110	SECTION A-A
SK-OA-075	OVERALL ARRANGEMENT UNITS 1,2&3 PLAN BELOW EL 20'-0"
SK-GA-200	GENERAL ARRANGEMENT BOILER BLDG/PRECIPITOR PLAN BELOW EL 20'-0"
SK-GA-300	GENERAL ARRANGEMENT WATER TREATMENT/ STACK PLAN BELOW EL 20'-0"
SK-PP-050	FACILITY PLOT PLAN UNITS 1, 2 & 3

0 5 10 20 30 50
GRAPHIC SCALE

A 4-1-96 ISSUED FOR INFORMATION

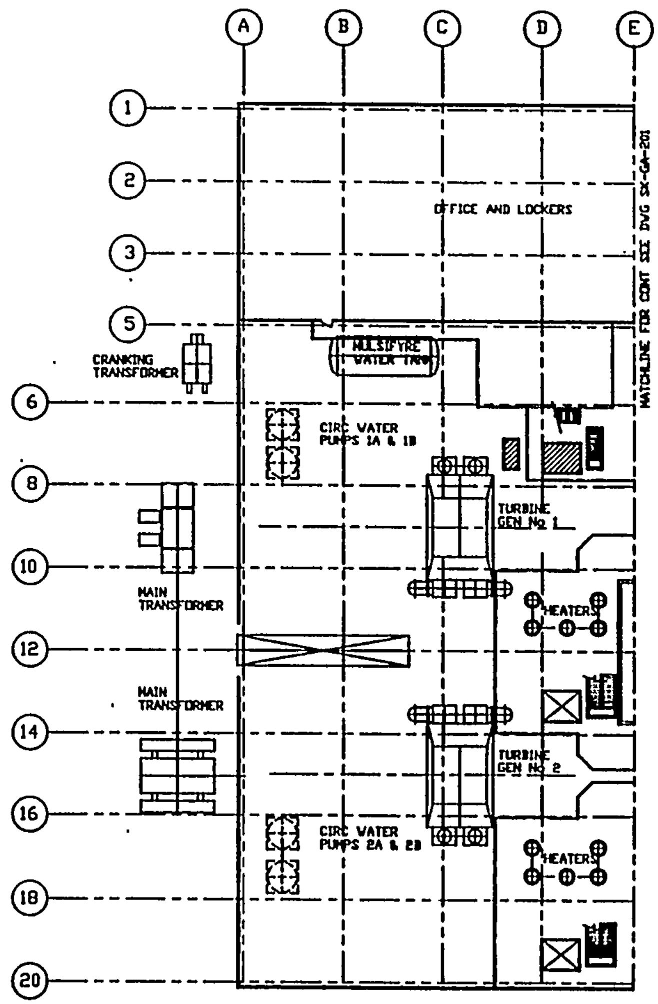
TALCARLSON ACAD

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
TURBINE BUILDINGS
PLAN BELOW EL 20'-0"

JOB No.	DRAWING No.	REV
21840	SK-GA-100	A



A

A
SEE DWG SK-GA-110

NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

0 5 10 20 30 50
GRAPHIC SCALE

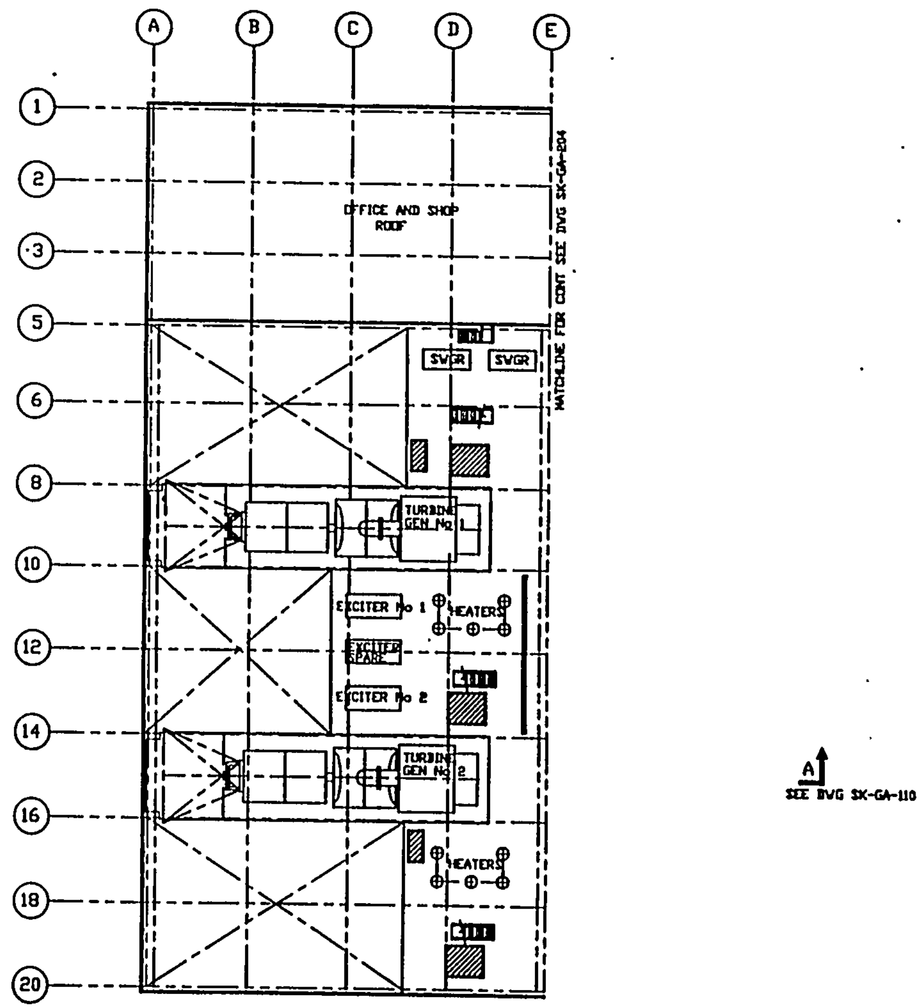
A 4-1-93	ISSUED FOR INFORMATION
SCALE 1/16"=1'-0"	TALCARLSON ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL 30'-0"

JOB No.	DRAWING No.	REV.
21840	SK-GA-101	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

0 5 10 20 30 50
GRAPHIC SCALE

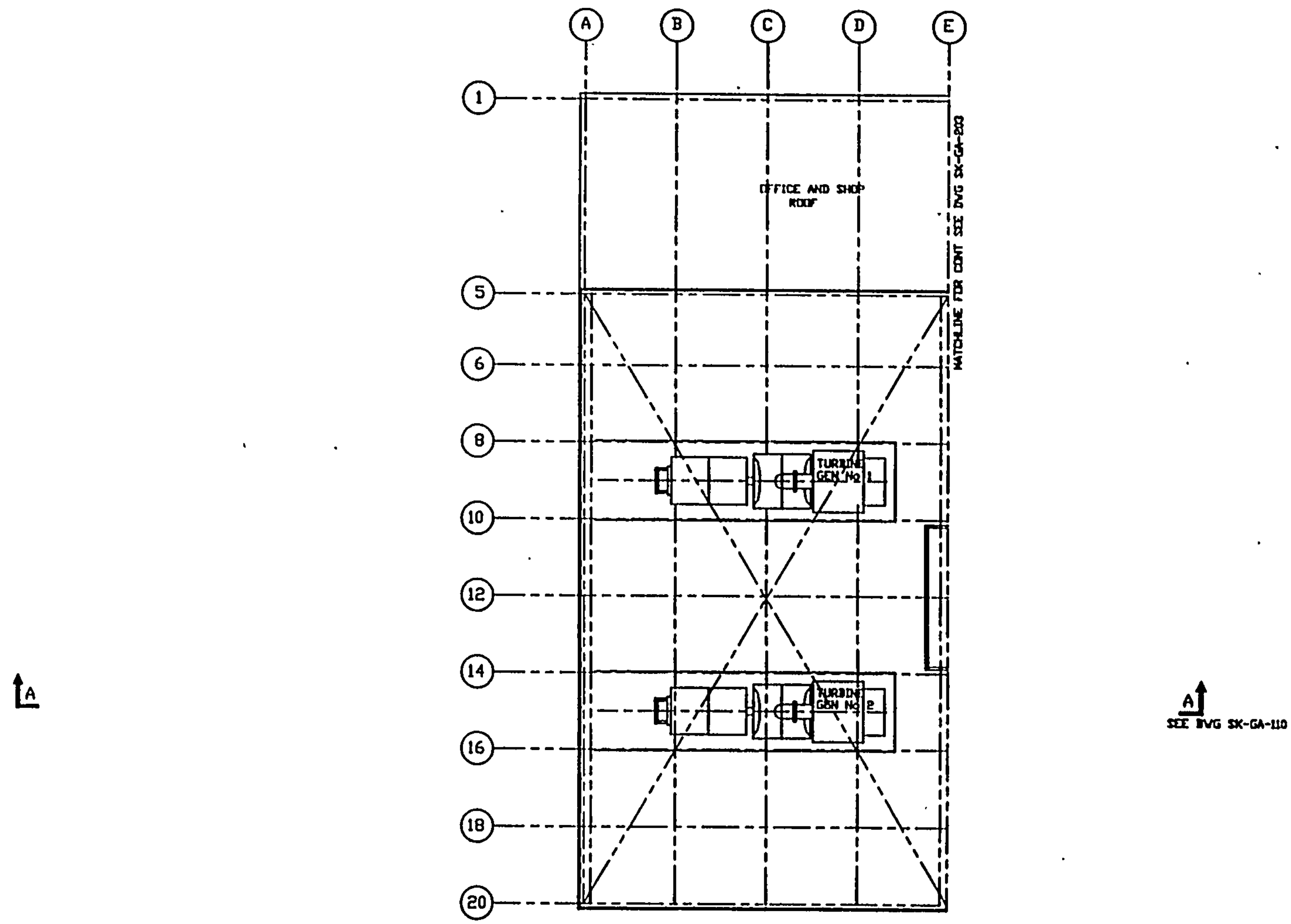
A	4-1-92	ISSUED FOR INFORMATION

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
TURBINE BUILDINGS
PLAN BELOW EL 49'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-102	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

GRAPHIC SCALE 0 5 10 20 30 50

A	4-1-96	ISSUED FOR INFORMATION

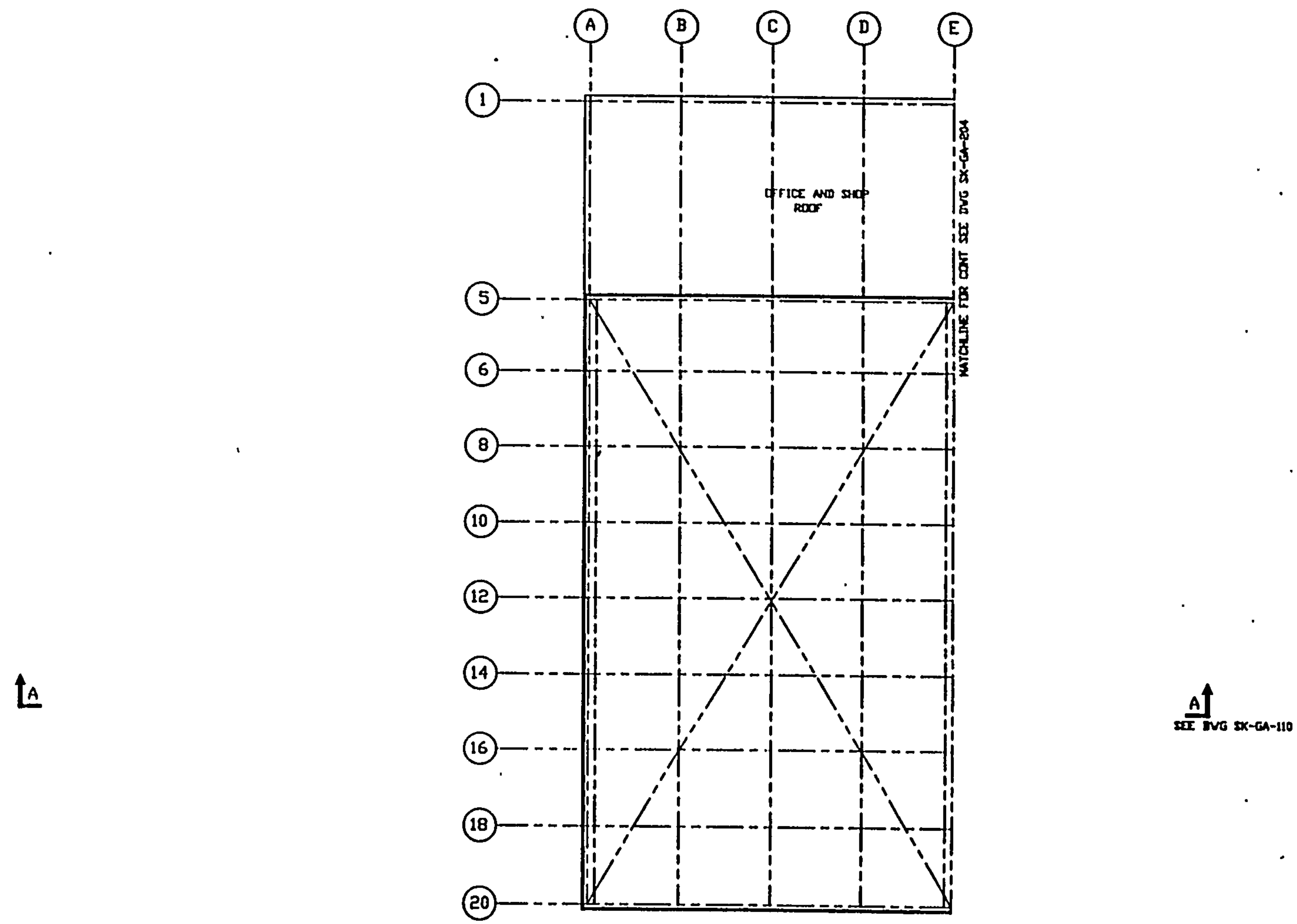
SCALE 1/16"=1'-0" DRAWN T.ACARLSON DWG ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL 60'-0"

JOB No.	DRAWING No.	REV.
21840	SK-GA-103	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

0 5 10 20 30 50

GRAPHIC SCALE

ISSUED FOR INFORMATION

1/16"=1'-0" T.ACARLSON ACAD

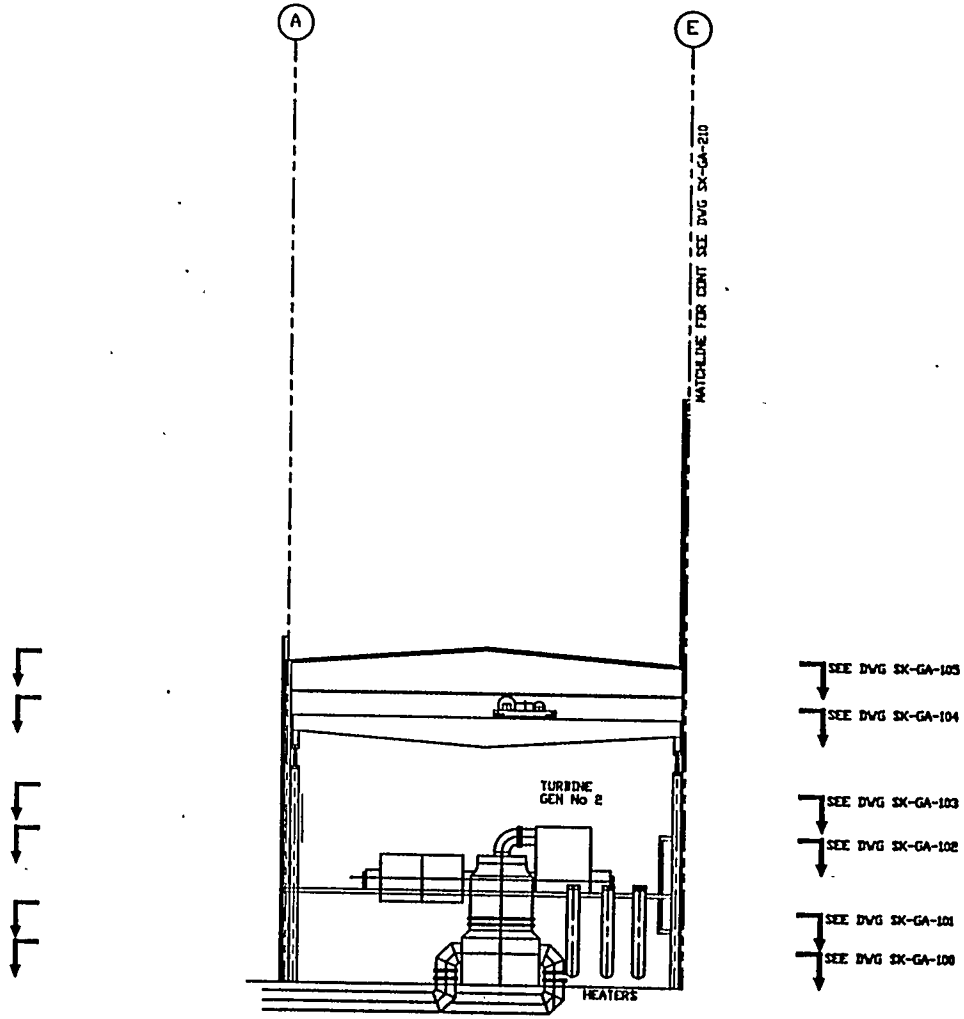
Bechtel

San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL 82'-0"

21840	SK-GA-104	A



SECTION A-A

NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

0 5 10 20 30 50
GRAPHIC SCALE

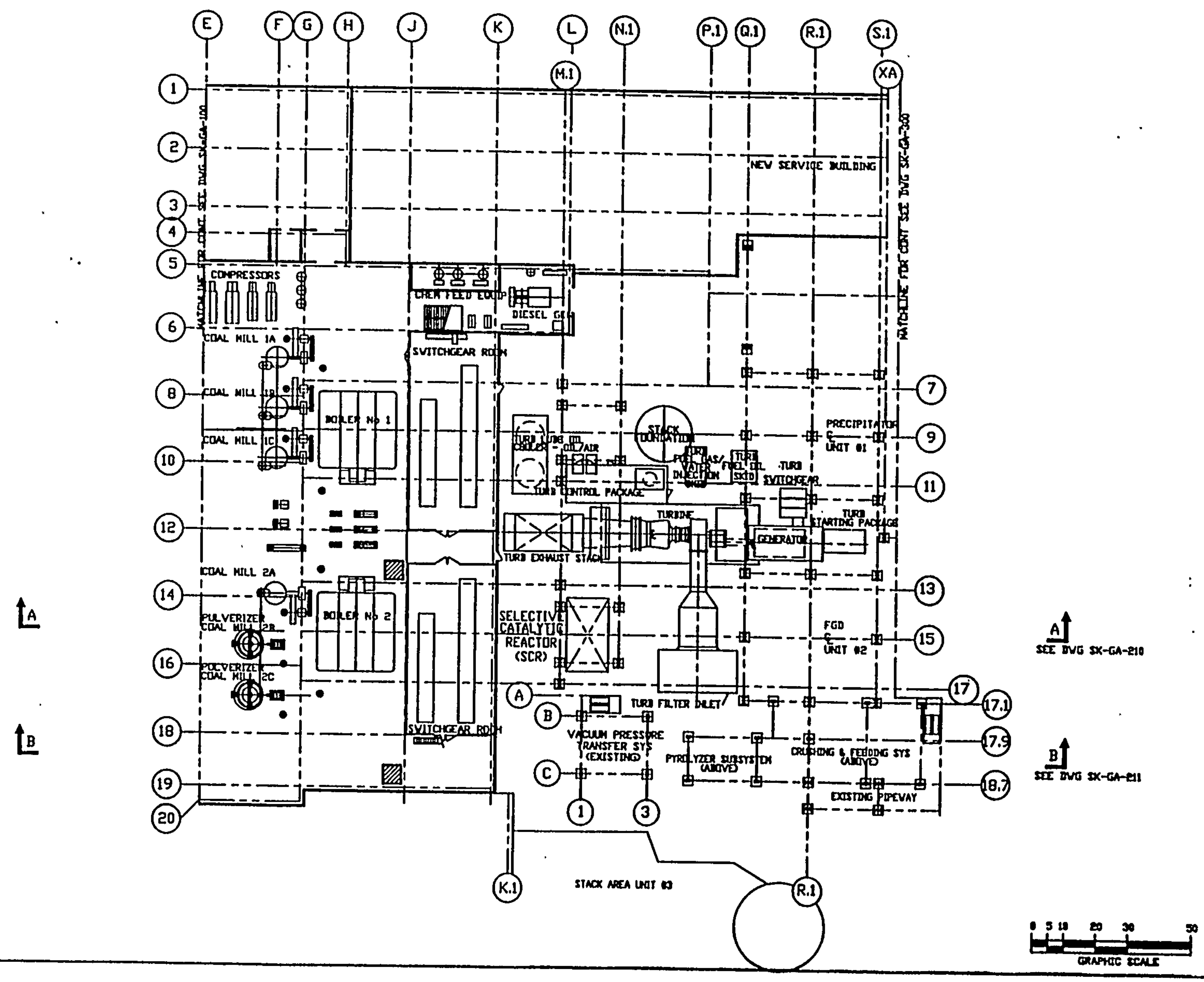
1-1-92	ISSUED FOR INFORMATION	
TALCARLSON	ACAD	

Bechtel
San Francisco

HIGH PERFORMANCE POWER
SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
TURBINE BUILDINGS
SECTION A-A

Job No.	Drawing No.	Rev.
21840	SK-GA-110	A



REFERENCES	
SK-GA-201	GENERAL ARRANGEMENT BOILER BLDG/PRECIPITOR PLAN BELOW EL 30'-0"
SK-GA-202	PLAN BELOW EL 49'-0"
SK-GA-203	PLAN BELOW EL 60'-0"
SK-GA-204	PLAN BELOW EL 82'-0"
SK-GA-205	PLAN BELOW EL 94'-0"
SK-GA-210	SECTION A-A
SK-GA-211	SECTION B-B
SK-DA-075	OVERALL ARRANGEMENT UNITS 1,2 &3 PLAN BELOW EL20'-0"
SK-GA-100	GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL20'-0"
SK-GA-300	GENERAL ARRANGEMENT WATER TREATMENT/ STACK PLAN BELOW EL20'-0"
RD950-46	HIGH PERFORMANCE COAL FWEC/DOE PLAN
RD950-47	ELEVATION
RD950-48	ELEVATION

NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

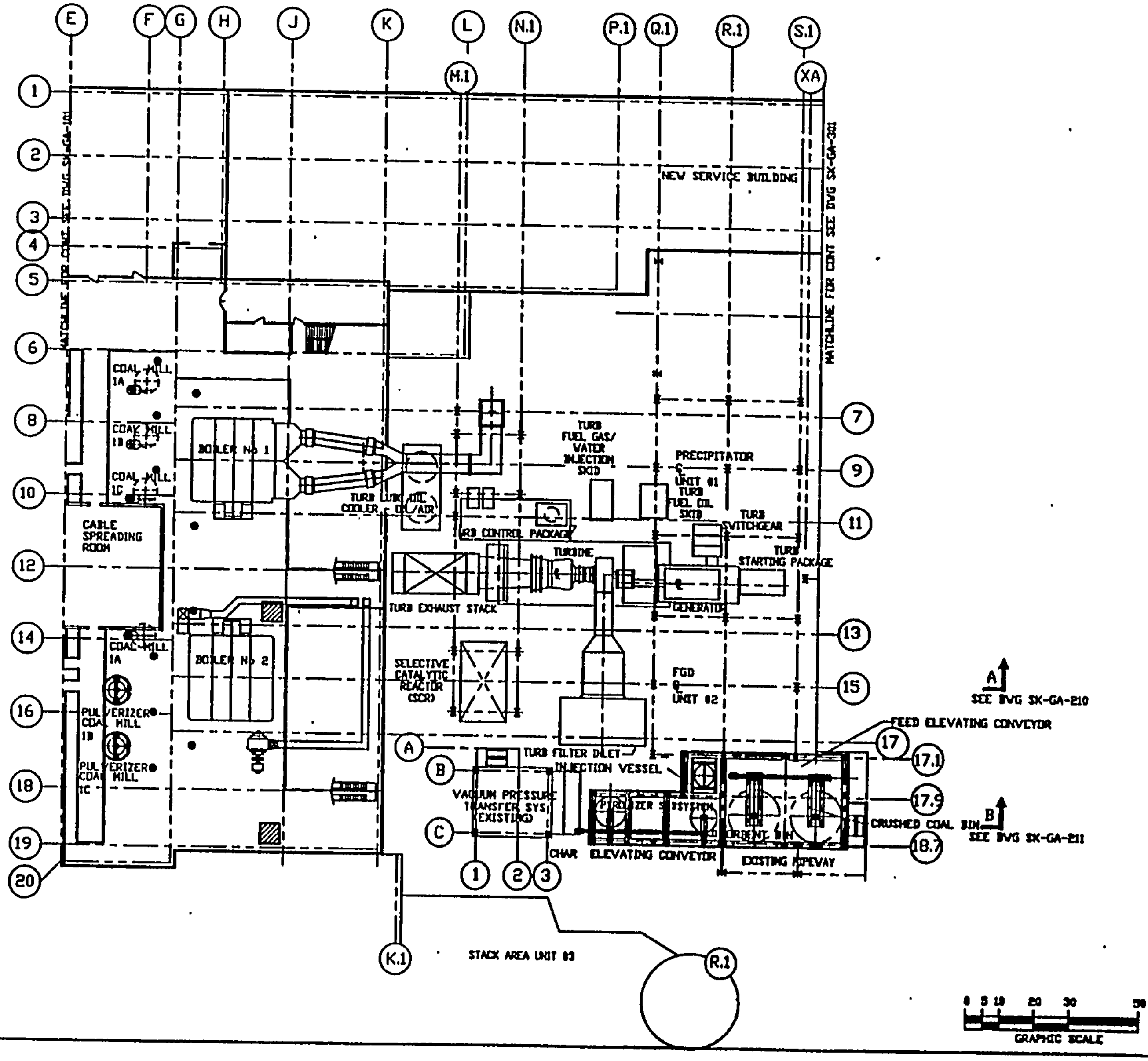
A ISSUED FOR INFORMATION
T.M.CARLSON ACAD

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BLDG & PRECIPITATOR
PLAN BELOW EL 20'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-200	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

4-1-96	ISSUED FOR INFORMATION	
	TALCARLSON	ACAD

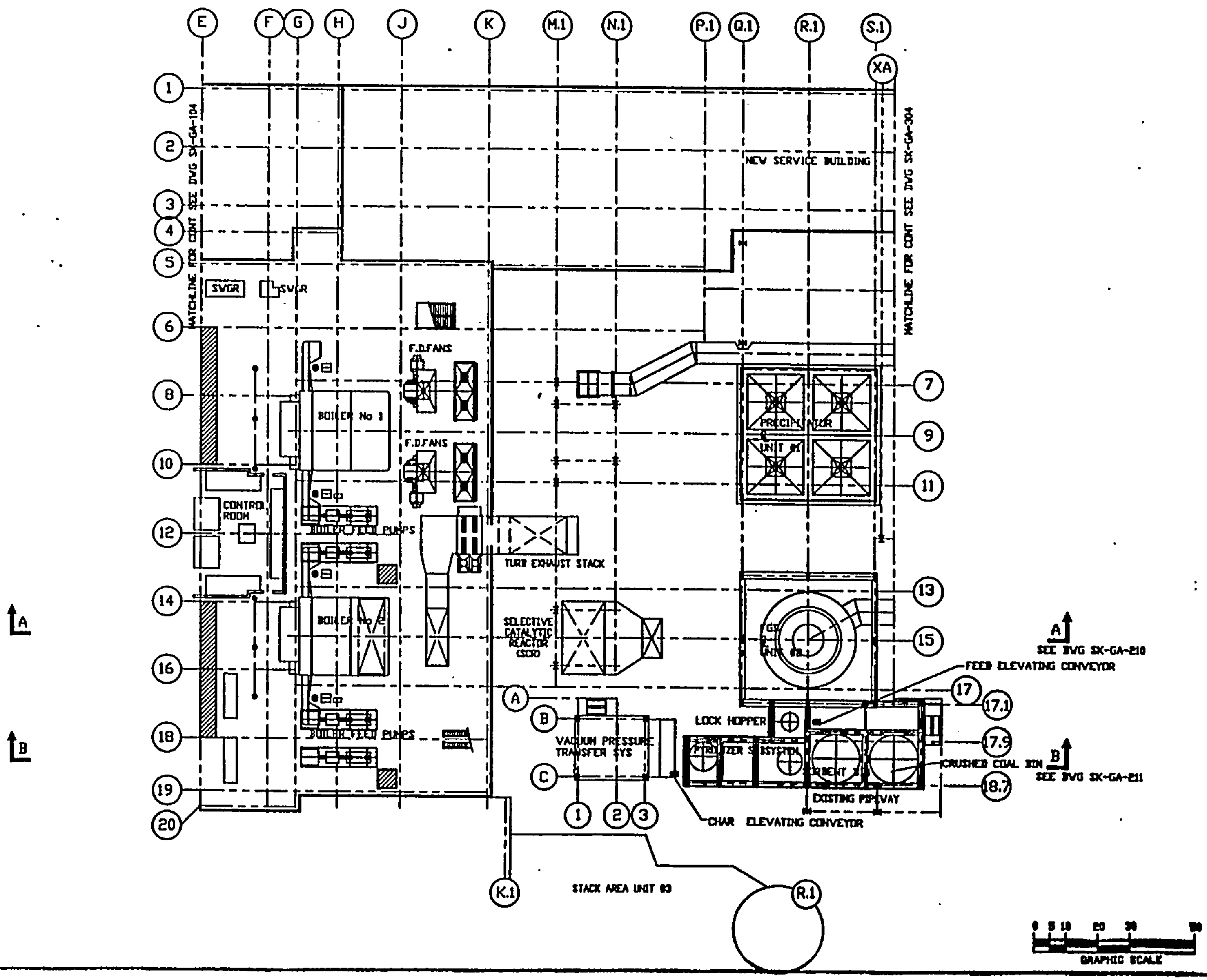
Bechtel

San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BLDG PRECIPITATOR
PLAN BELOW EL 30'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-201	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

4-1-96	ISSUED FOR INFORMATION
T.NICHOLSON	ACAD

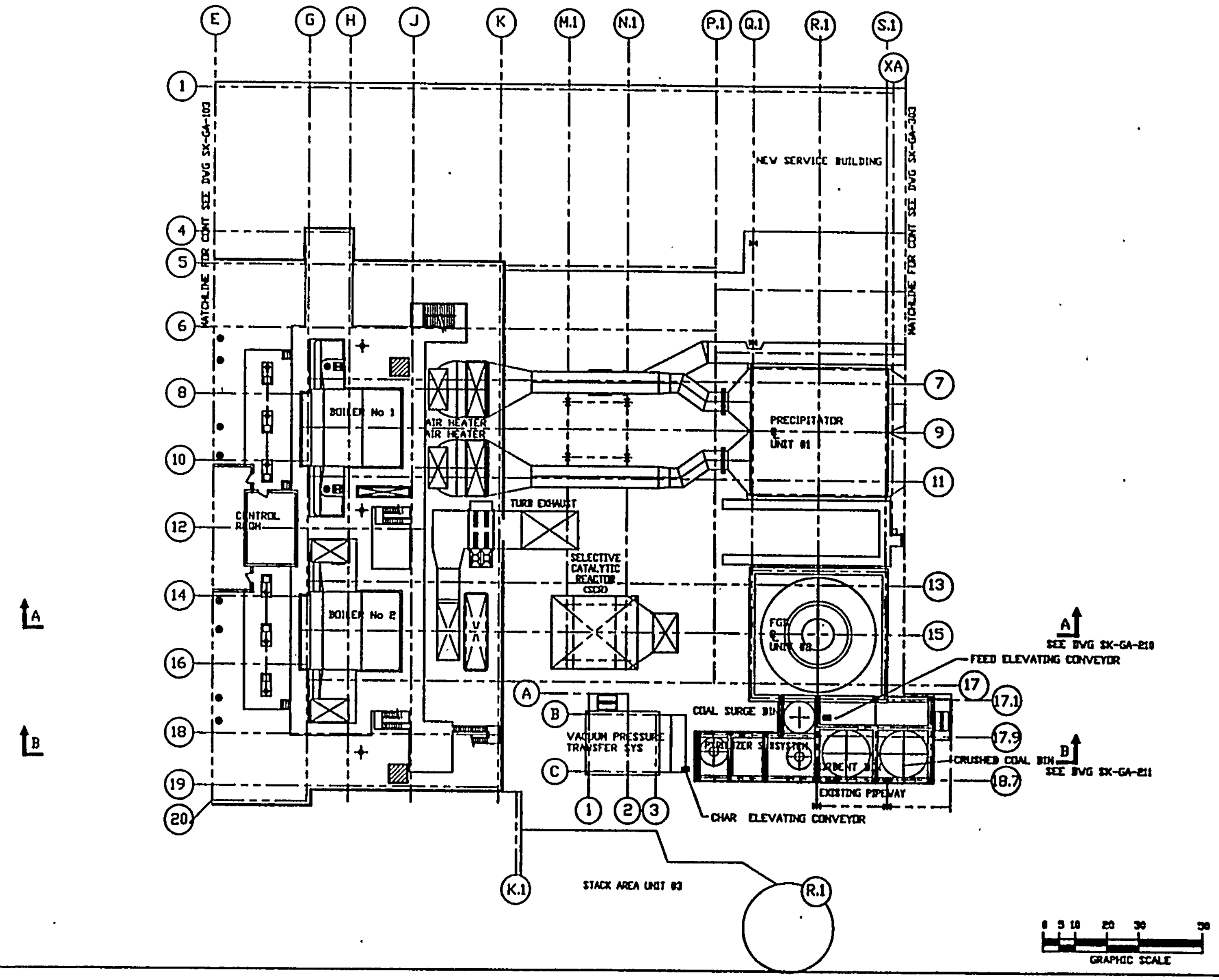
Bechtel

San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BLDG & PRECIPITATOR
PLAN BELOW EL 49'-0"

Job No.	Drawing No.	Rev.
21940	SK-GA-202	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

ISSUED FOR INFORMATION

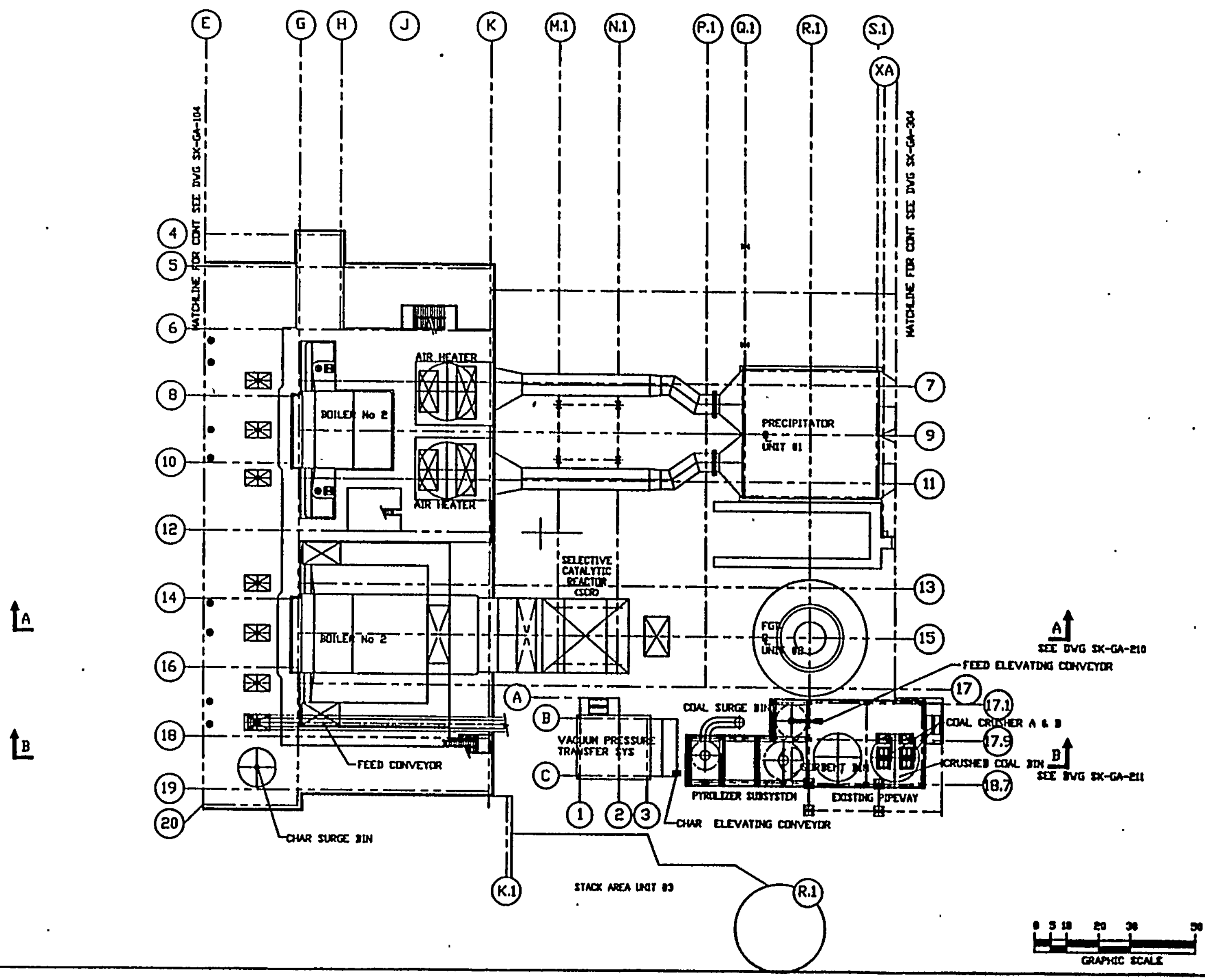
Bechtel

San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BUILDING & PRECIPITATOR
PLAN BELOW EL 60'-0"

21840	SK-GA-203	A



NOTES

1.FOR NOTES AND REFERENCES SEE DRAWING SX-GA-200

A	4-1-96	ISSUED FOR INFORMATION

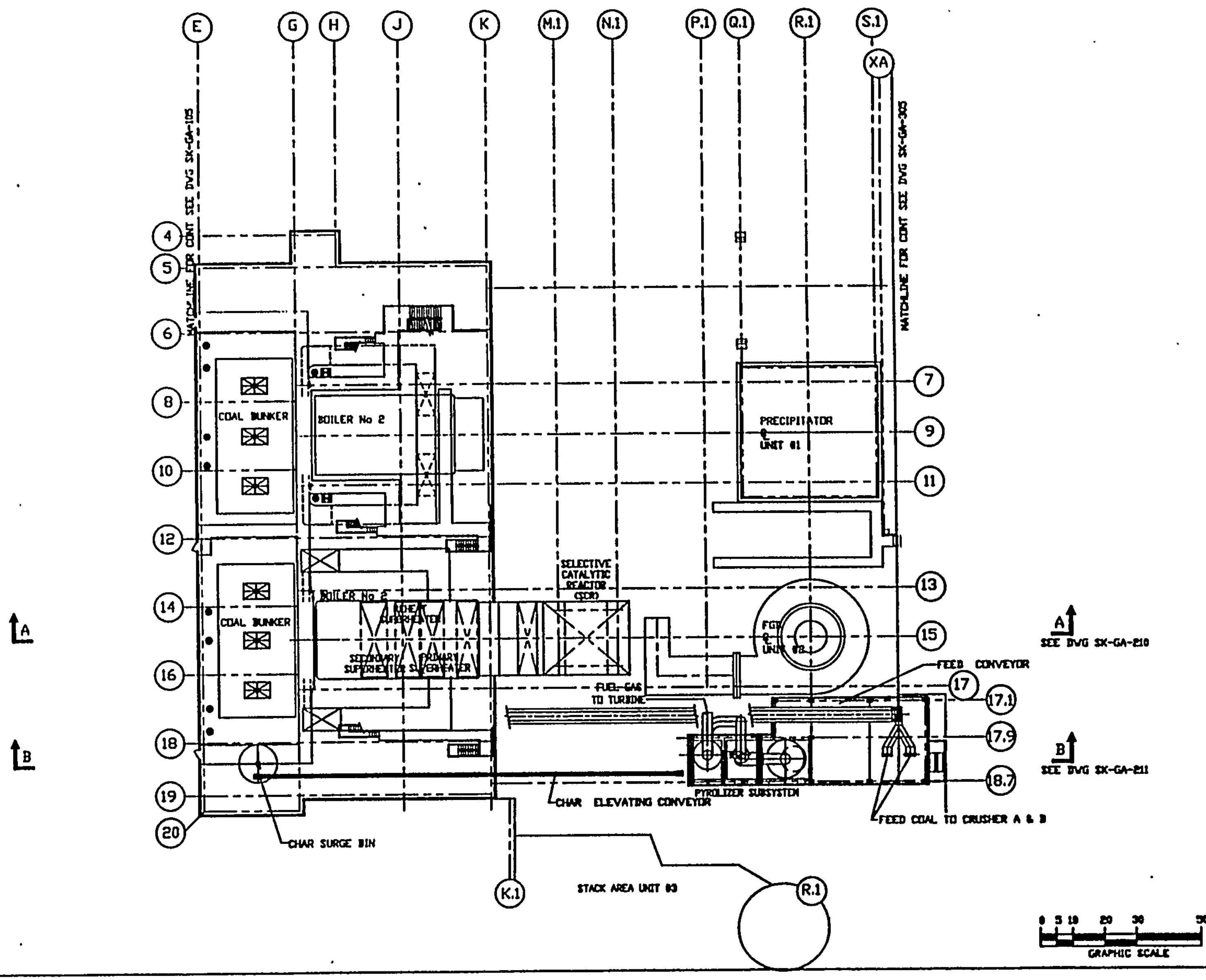
Bechtel

San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT BOILER BLDG & PRECIPITATOR PLAN BELOW EL 82'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-204	A



NOTES

FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

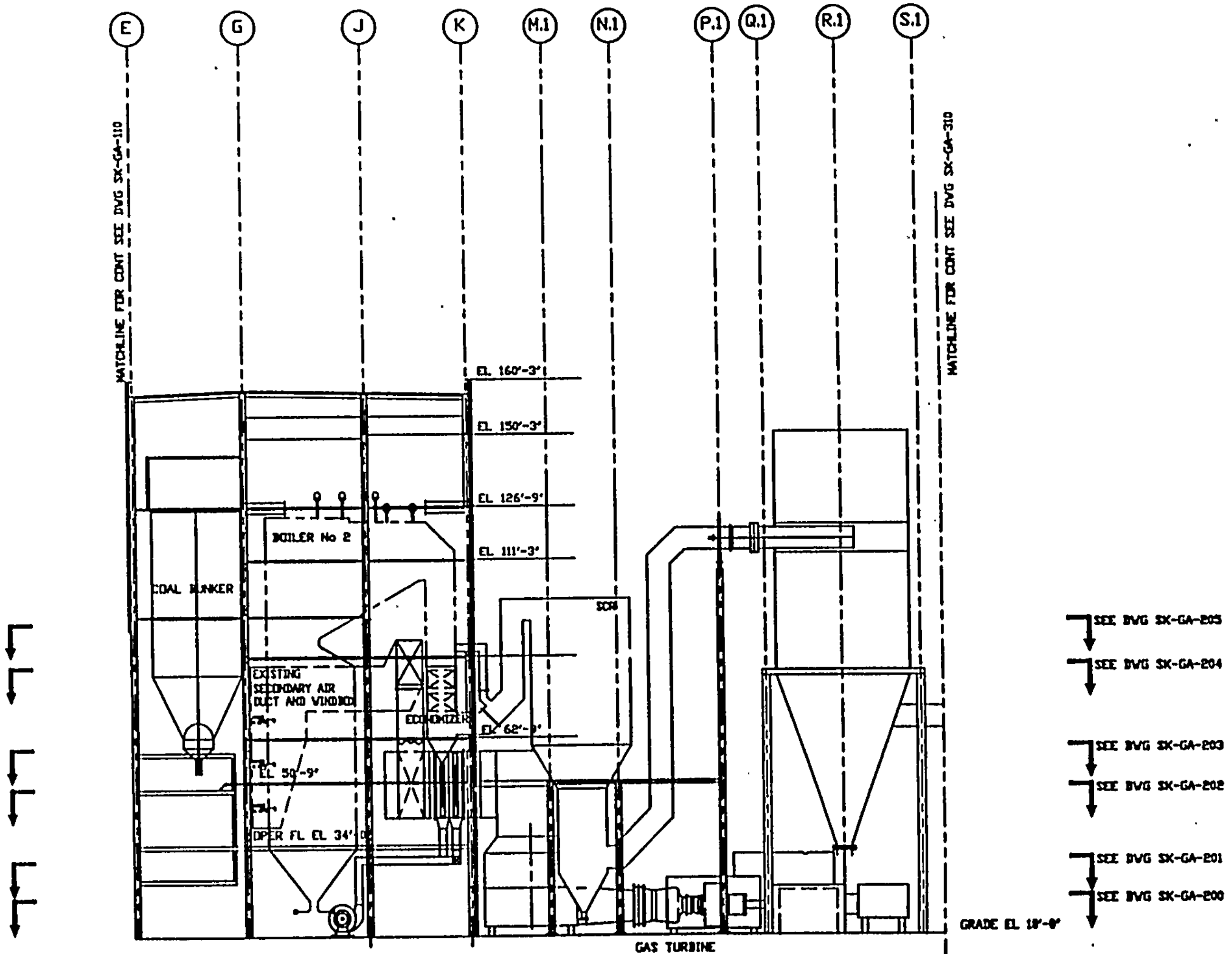
4-1-96	ISSUED FOR INFORMATION	
SCALE 1/16"=1'-0"	TALCARLSON	ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BLDG & PRECIPITATOR
PLAN BELOW EL 94'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-205	A



SECTION A-A

NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

0 5 10 20 30 50

GRAPHIC SCALE

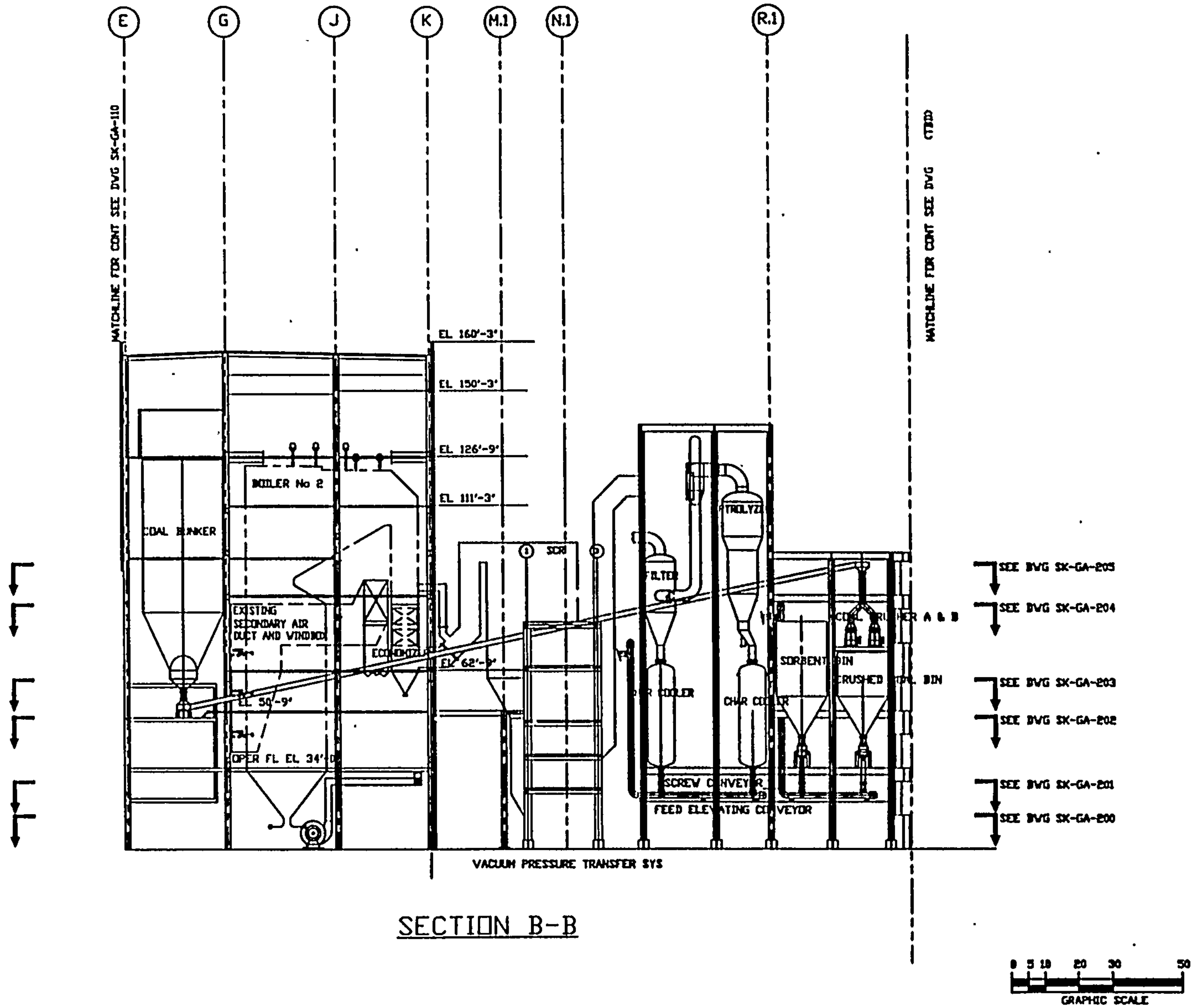
4-1-96	ISSUED FOR INFORMATION
1/16"=1'-0"	T.ALCARLSON
	ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
BOILER BLDG & PRECIPITATOR
SECTION A-A

Job No.	Drawing No.	Rev.
21840	SK-GA-210	A



SECTION B-B

NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-200

A	ISSUED FOR INFORMATION

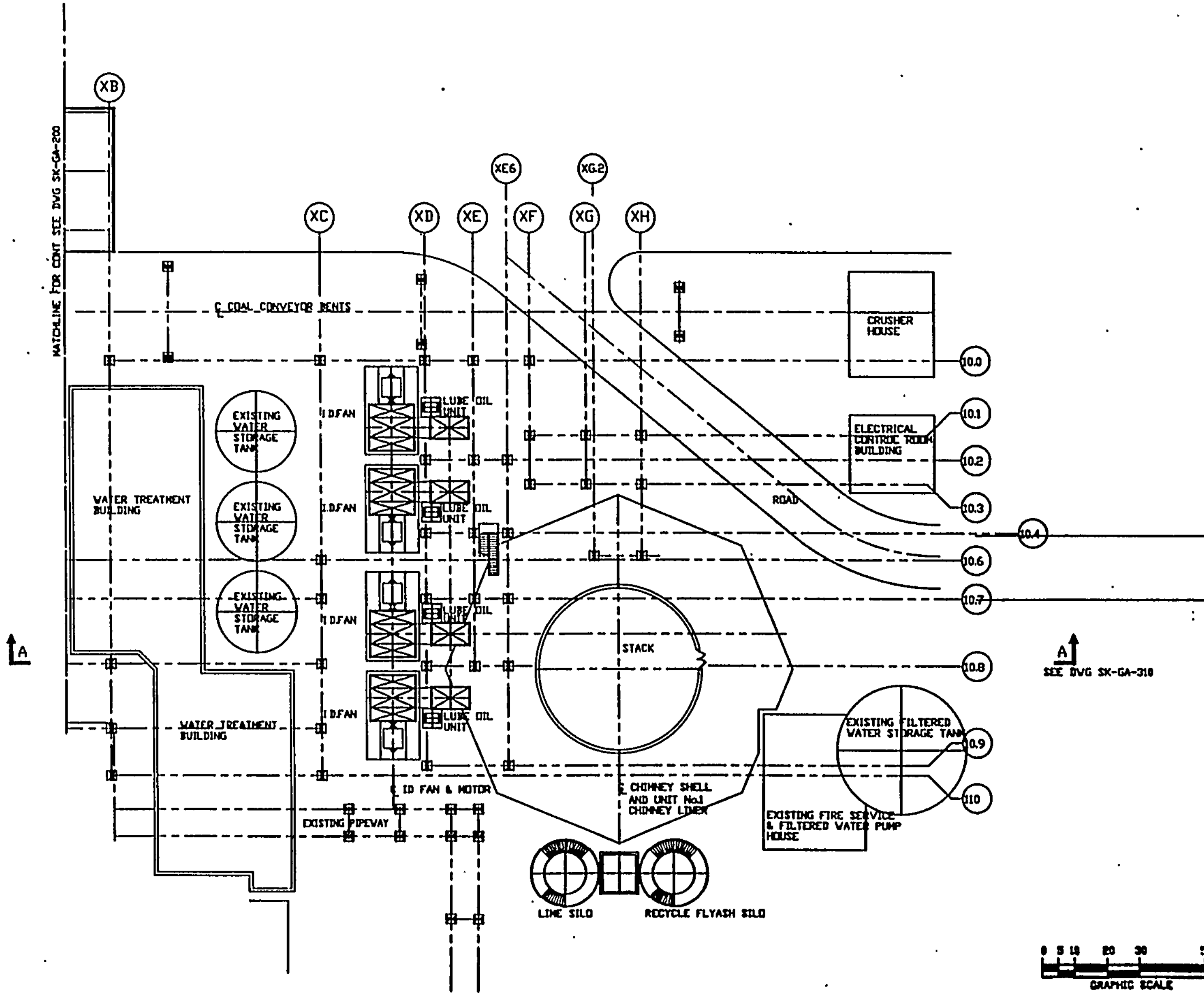
Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT BOILER BLDG & PRECIPITATOR SECTION B-B

JOB No.	DRAWING No.	REV
21840	SK-GA-211	A

REFERENCES	
SK-GA-301	GENERAL ARRANGEMENT WATER TREATMENT/ STACK PLAN BELOW EL 30'-0"
SK-GA-302	PLAN BELOW EL 49'-0"
SK-GA-303	PLAN BELOW EL 60'-0"
SK-GA-304	PLAN BELOW EL 82'-0"
SK-GA-310	SECTION A-A
SK-0A-075	OVERALL ARRANGEMENT UNITS 1,2&3 PLAN BELOW EL20'-0"
SK-GA-100	GENERAL ARRANGEMENT TURBINE BUILDINGS PLAN BELOW EL20'-0"
SK-GA-200	GENERAL ARRANGEMENT BOILER BLDG/PRECIPITOR PLAN BELOW EL20'-0"



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

4-1-96	ISSUED FOR INFORMATION
	TALCARLSON ACAD

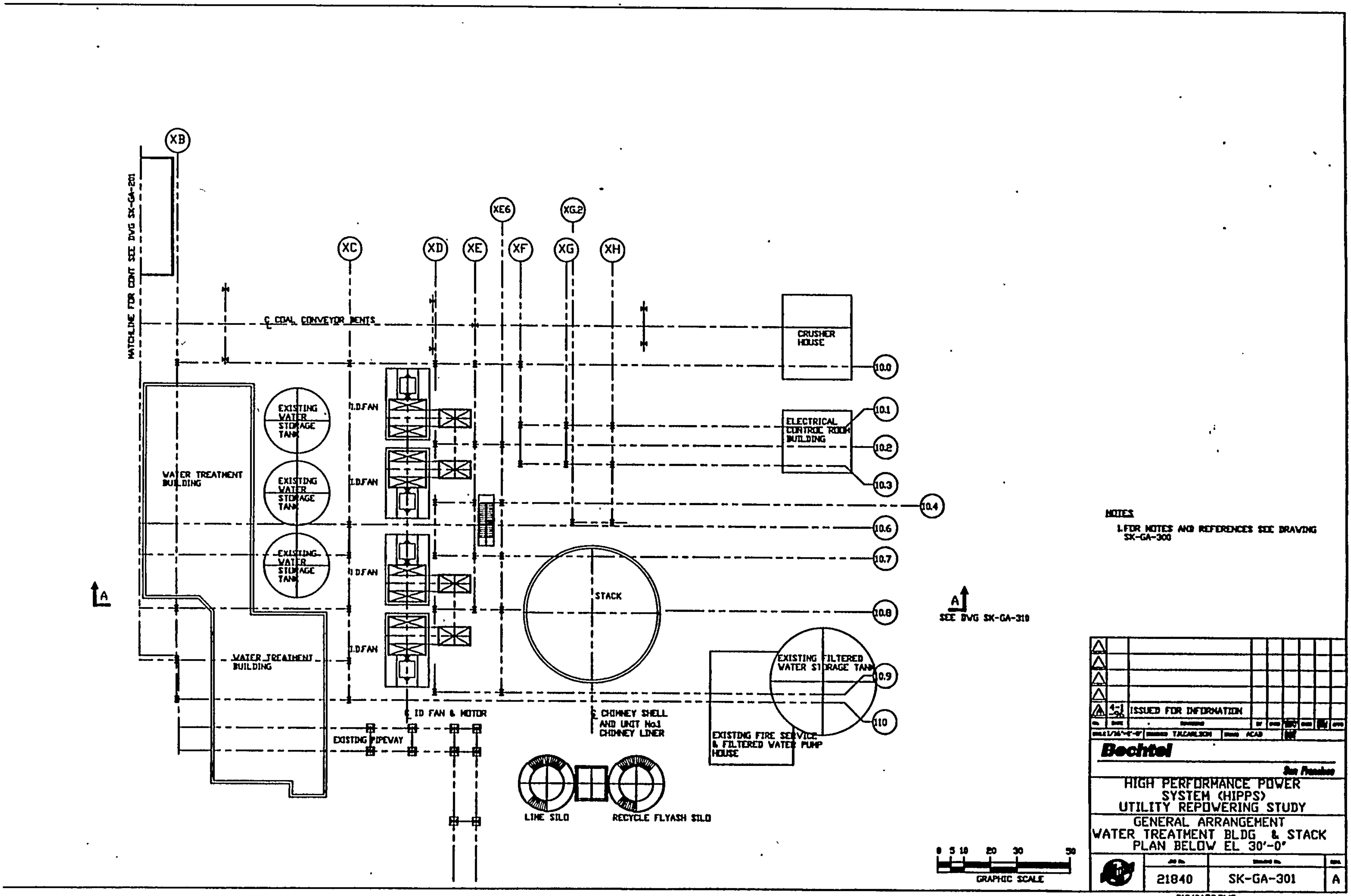
Bechtel

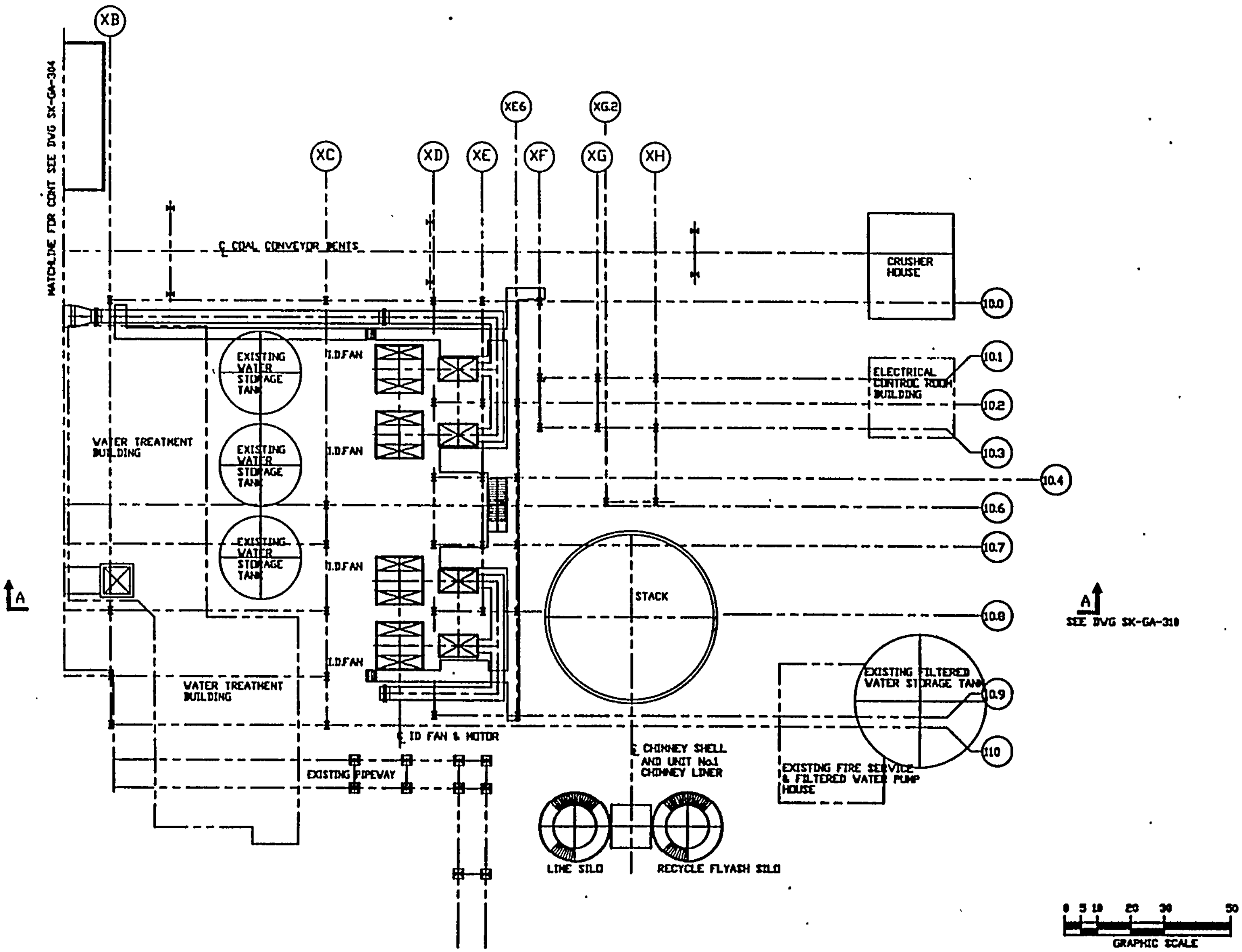
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT WATER TREATMENT & STACK PLAN BELOW EL 20'-0"

JOB No.	DRAWING No.	REV.
21840	SK-GA-300	A


MATCHLINE FOR CONT SEE DWG SK-GA-201
XB
XC
XD
XE
XE6
XF
XG
XG.2
XH
C COAL CONVEYOR BENTS
CRUSHER HOUSE
ELECTRICAL CONTROL ROOM BUILDING
10.0
10.1
10.2
10.3
10.4
10.6
10.7
10.8
10.9
110
WATER TREATMENT BUILDING
EXISTING WATER STORAGE TANK
EXISTING WATER STORAGE TANK
EXISTING WATER STORAGE TANK
I.D.FAN
I.D.FAN
I.D.FAN
I.D.FAN
STACK
WATER TREATMENT BUILDING
C ID FAN & MOTOR
EXISTING PIPEWAY
C CHIMNEY SHELL AND UNIT No.1 CHIMNEY LINER
EXISTING FILTERED WATER STORAGE TANK
EXISTING FIRE SERVICE & FILTERED WATER PUMP HOUSE
LIME SILO
RECYCLE FLYASH SILO
A
A
SEE DWG SK-GA-310
NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-300
0 5 10 20 30 50
GRAPHIC SCALE
4-1-96 ISSUED FOR INFORMATION
TALARLSON
ACAD
Bechtel
San Francisco
HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY
GENERAL ARRANGEMENT WATER TREATMENT BLDG & STACK PLAN BELOW EL 30'-0"
21840
SK-GA-301
A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-300

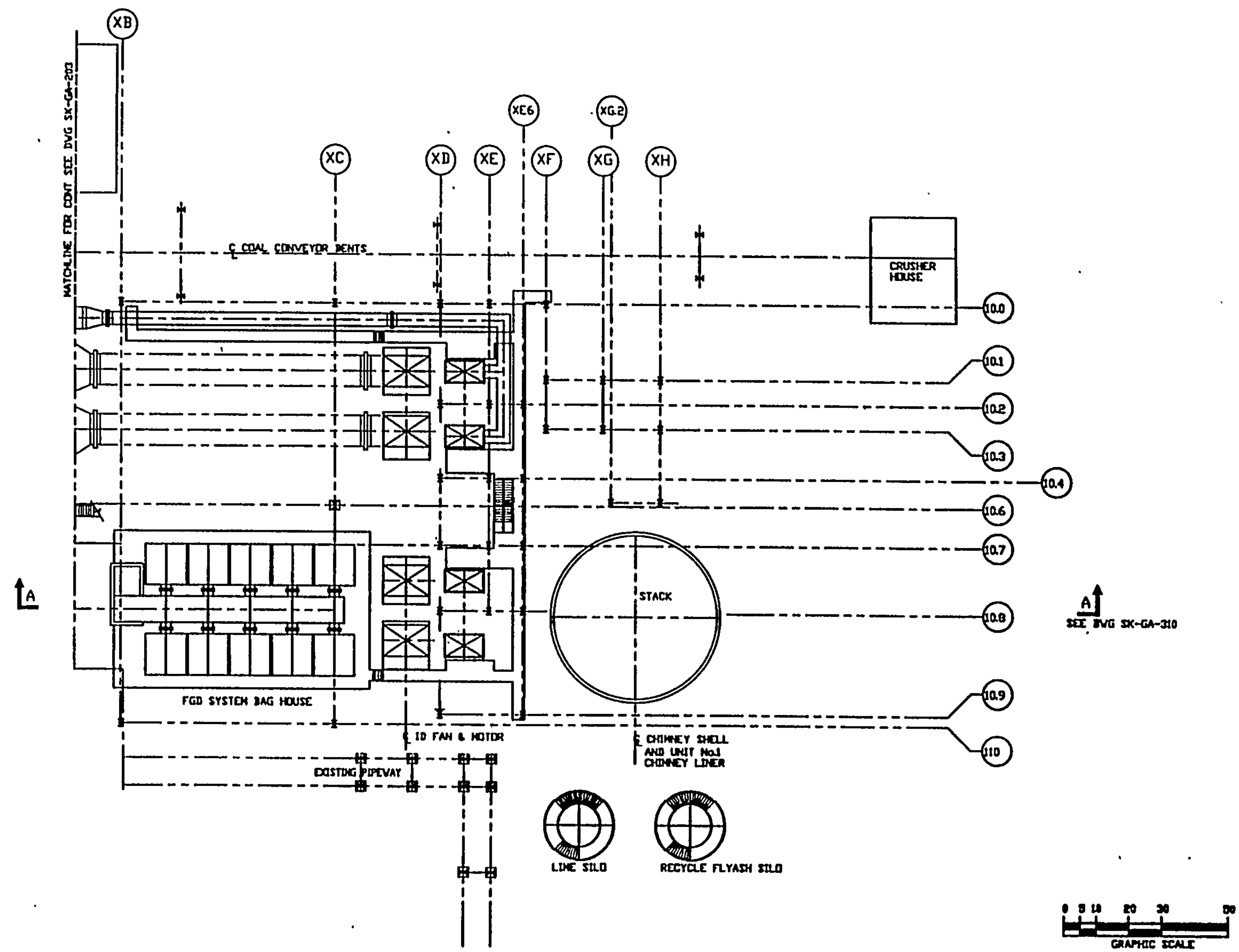
4-1-96	ISSUED FOR INFORMATION
TACARLSON	ACAB

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
WATER TREATMENT BLDG & STACK
PLAN BELOW EL 49'-0"

JOB No.	DRAWING No.	REV
21840	SK-GA-302	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-300

	ISSUED FOR INFORMATION

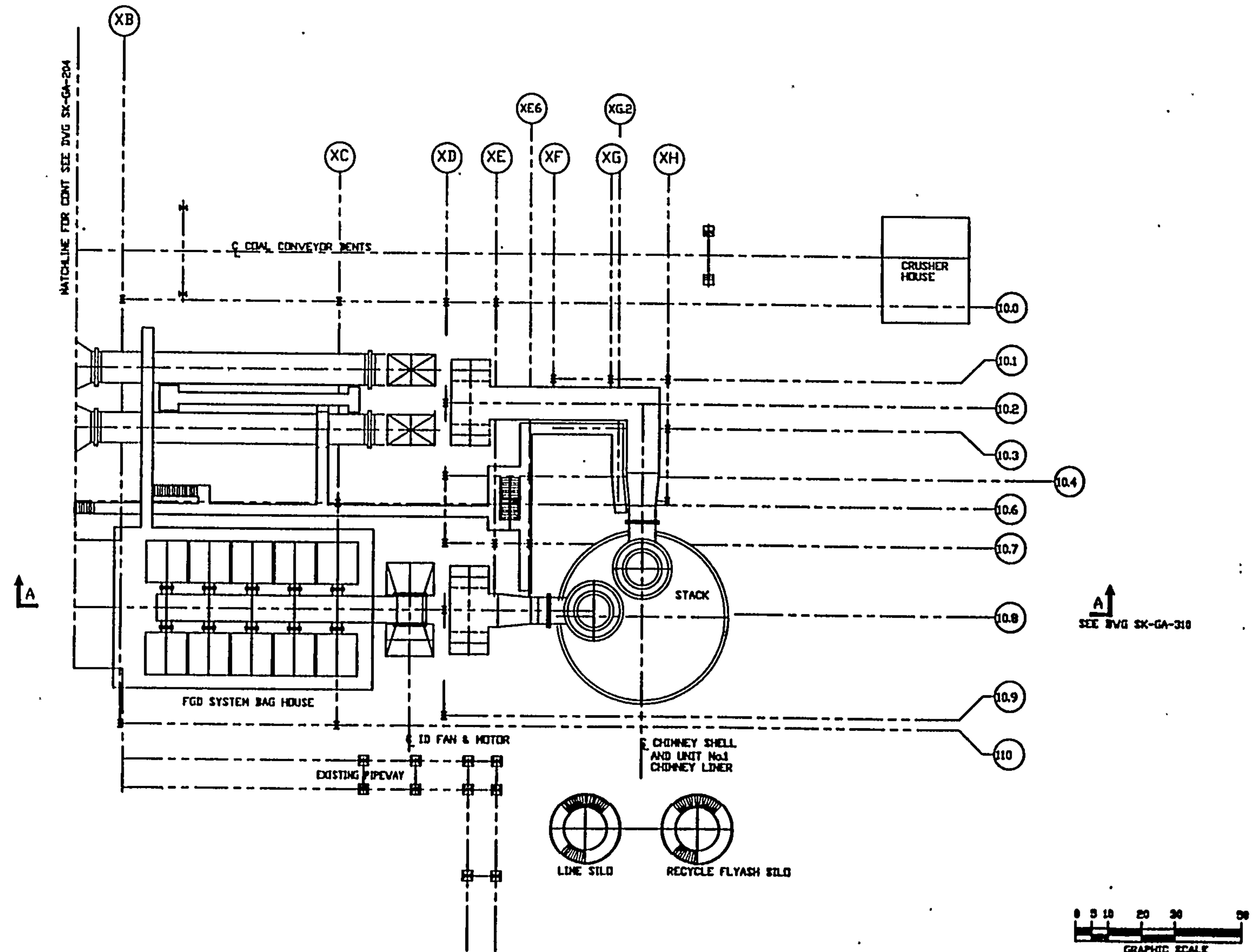
T.ACARLSON ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
WATER TREATMENT BLDG & STACK
PLAN BELOW EL 60'-0"

Job No.	Drawing No.	Rev.
21840	SK-GA-303	A



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-300

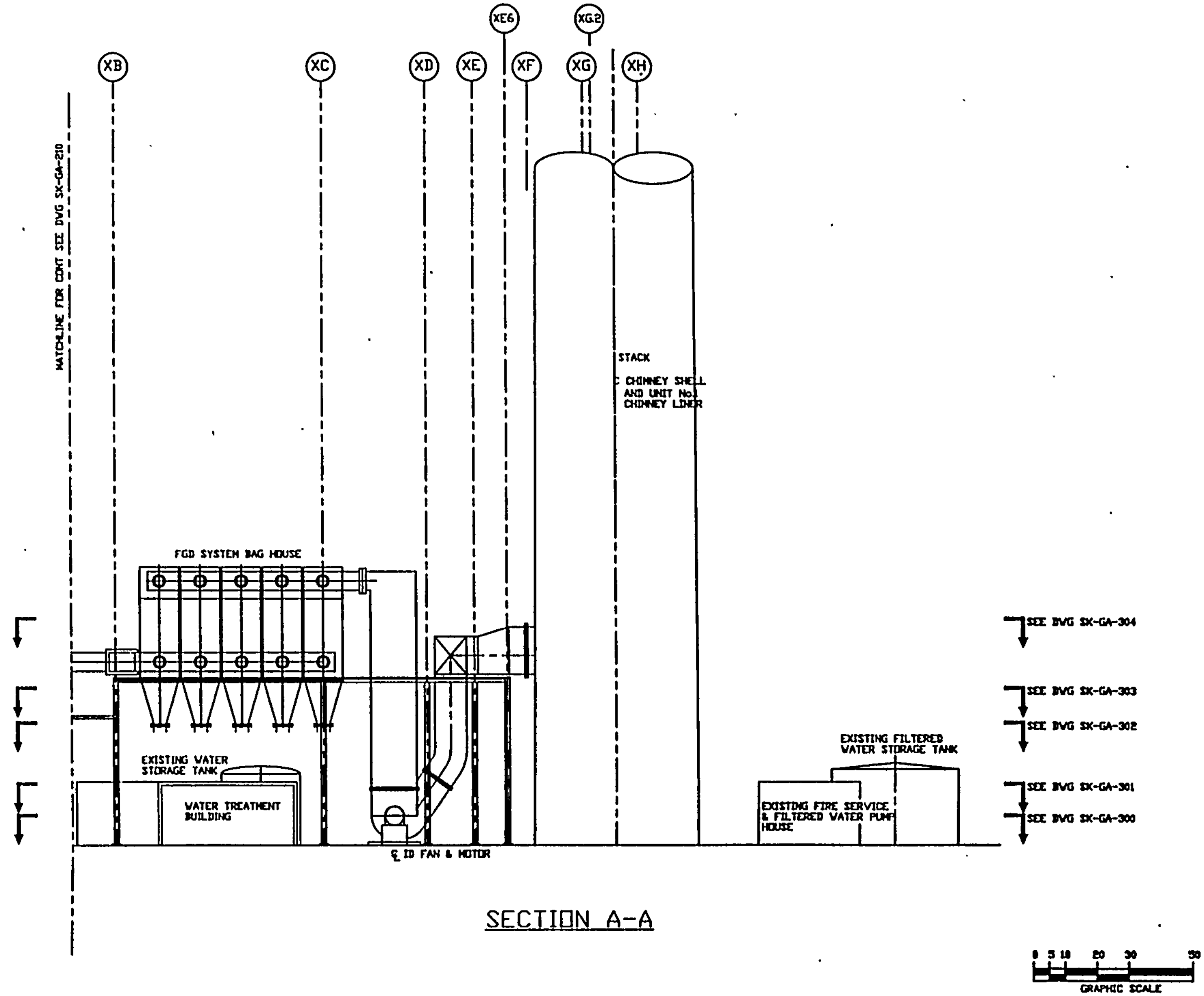
A	4-1-96	ISSUED FOR INFORMATION	
SCALE 1/16"=1'-0"	DRAWN T.McCARLSON	CHKD ACAD	

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS)
UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT
WATER TRETMENT BUILDING & STACK
PLAN BELOW EL 82'-0"

JOB No.	DRAWING No.	REV.
21840	SK-GA-304	A



SECTION A-A

NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-300

A	4-1-96	ISSUED FOR INFORMATION

Bechtel

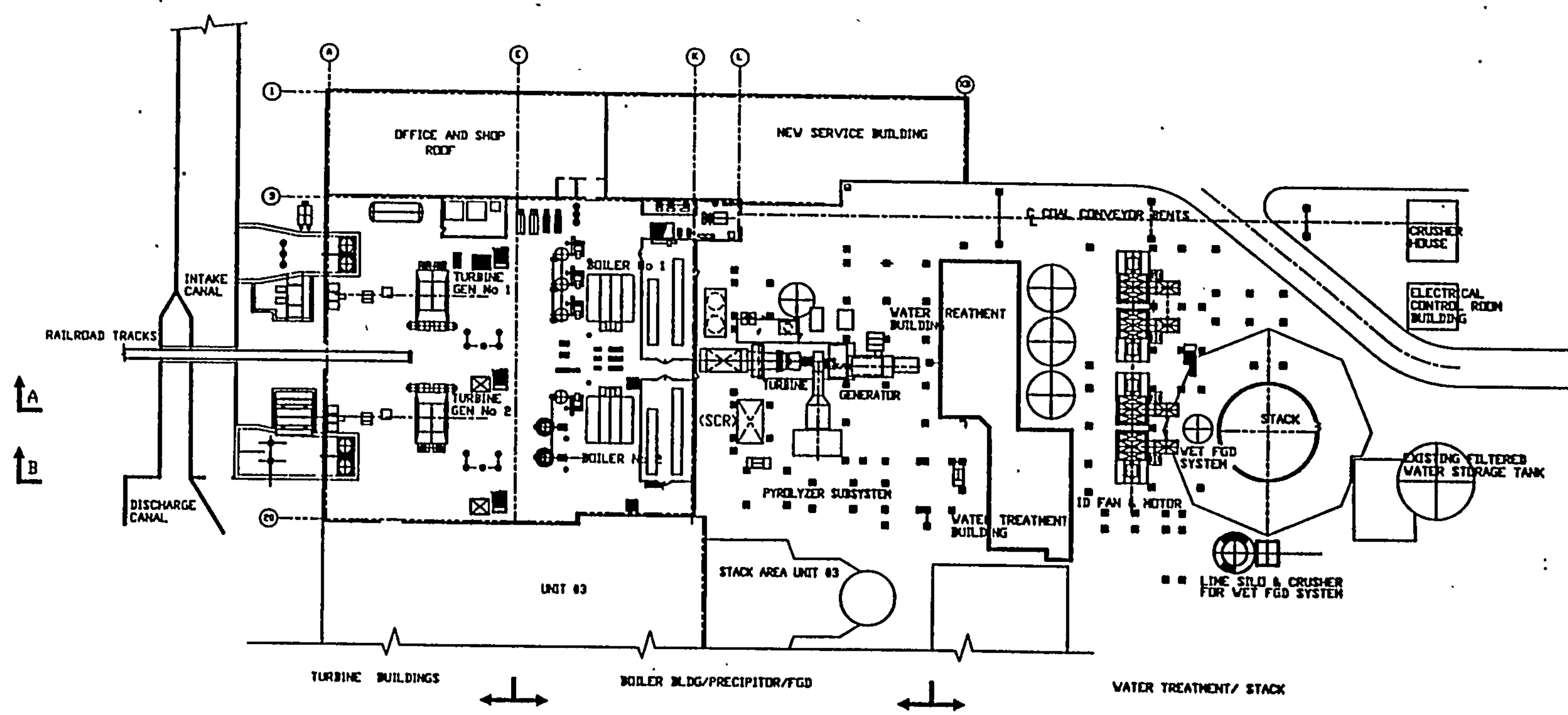
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

GENERAL ARRANGEMENT WATER TREATMENT BUILDING & STACK SECTION A-A

JOB No.	DRAWING No.	REV.
21840	SK-GA-310	A

REFERENCES	
SK-OA-176	ALT OVERALL ARRANGEMENT UNIT 2 W/WET FGD SYSTEM PLAN BELOW EL 60'-0"
SK-OA-180	SECTION A-A
SK-OA-181	SECTION B-B
SK-PP-050	FACILITY PLOT PLAN UNITS 1, 2 & 3



NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-100

A — SEE DWG SK-OA-180

B — SEE DWG SK-OA-181

0 10 20 40 60 100
GRAPHIC SCALE

A	4-1-93	ISSUED FOR INFORMATION

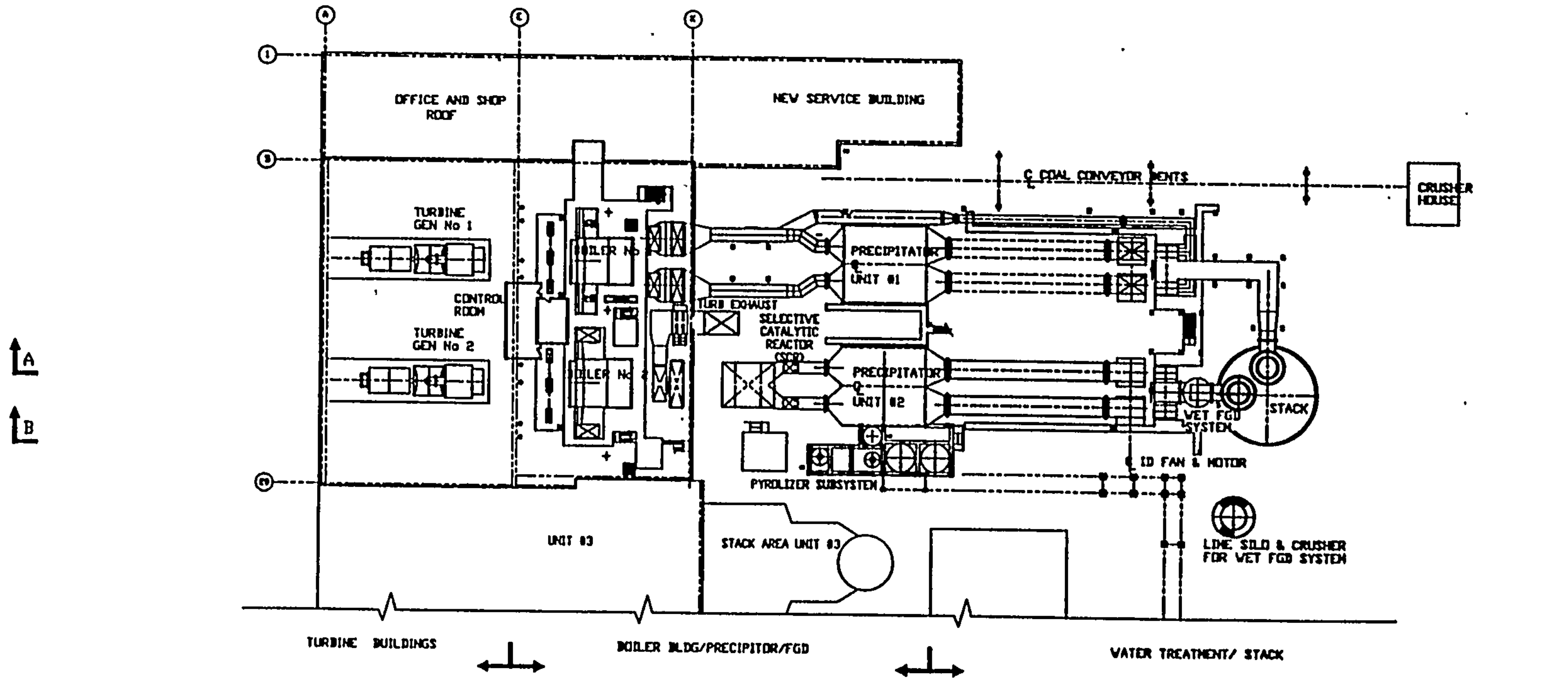
SCALE 1/32"=1'-0" DRAWN TACARLSON ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

ALT OVERALL ARRANGEMENT UNIT 2 W/WET FGD SYSTEM PLAN BELOW EL 20'-0"

JOB No.	DRAWING No.	REV
21840	SK-OA-175	A

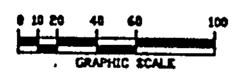


NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-OA-175

A SEE DWG SK-OA-180

B SEE DWG SK-OA-181



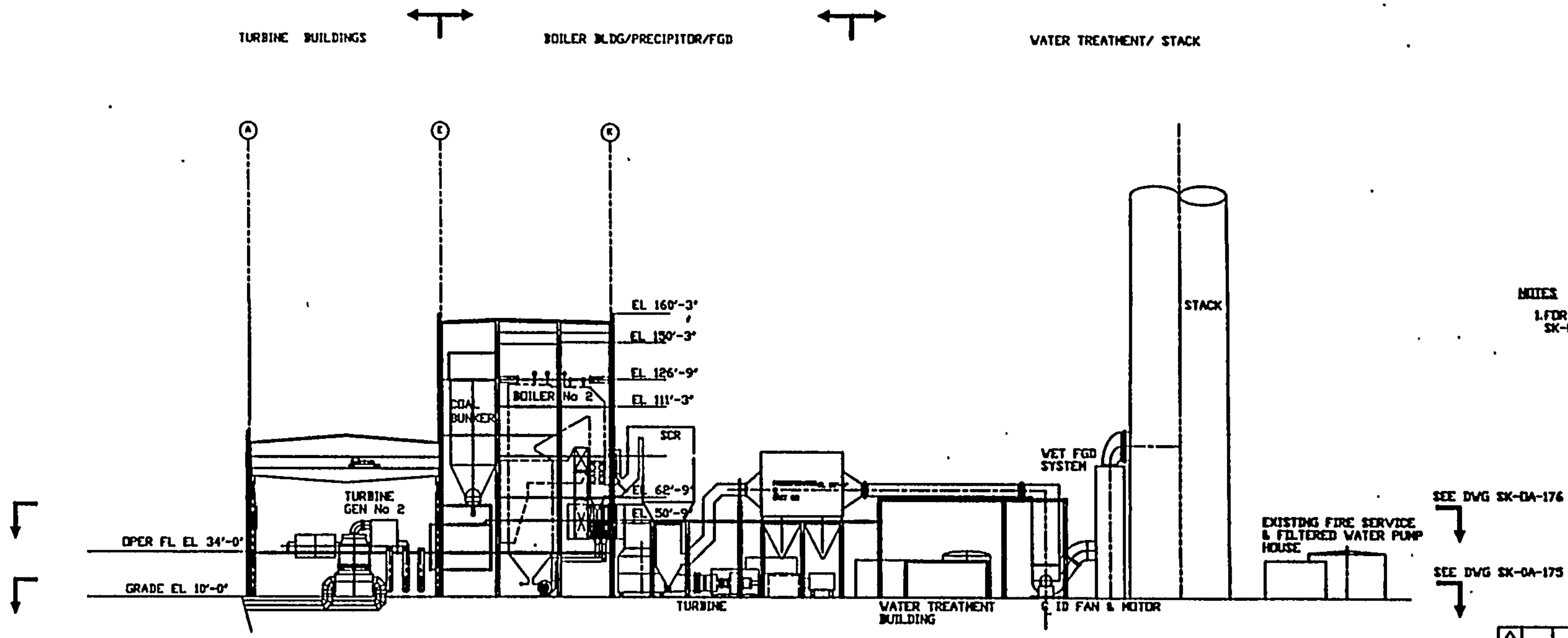
4-1-96	ISSUED FOR INFORMATION	
SCALE 1/32"=1'-0"	T.ACARLSON	ACAD

Bechtel San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

ALT OVERALL ARRANGEMENT UNITS 2 W/WET FGD SYSTEM PLAN BELOW EL 60'-0"

Job No.	Drawing No.	Rev.
21840	SK-OA-176	A



SECTION A-A

NOTES

1. FOR NOTES AND REFERENCES SEE DRAWING SK-DA-175

0 10 20 40 60 100
GRAPHIC SCALE

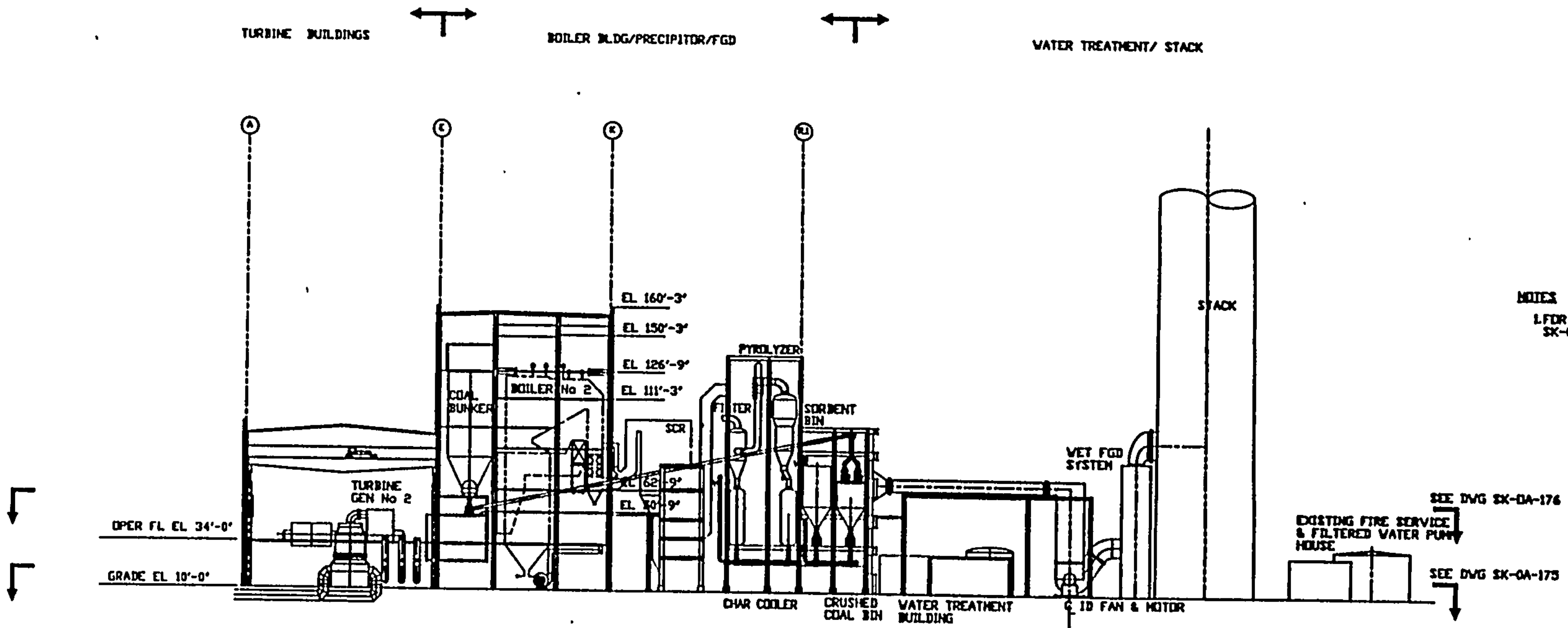
4-1-96	ISSUED FOR INFORMATION	
1/32"=1'-0"	T.ACARLSON	ACAD

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

ALT OVERALL ARRANGEMENT UNITS 2 W/WET FGD SYSTEM SECTION A-A

Job No.	Drawing No.	Rev.
21840	SK-DA-180	A



SECTION B-B

NOTES
1. FOR NOTES AND REFERENCES SEE DRAWING SK-GA-175

0 10 20 40 60 100
GRAPHIC SCALE

4-1-92	ISSUED FOR INFORMATION	
TACARLSON	ACAD	

Bechtel
San Francisco

HIGH PERFORMANCE POWER SYSTEM (HIPPS) UTILITY REPOWERING STUDY

ALT OVERALL ARRANGEMENT UNITS 2 W/WET FGD SYSTEM SECTION B-B

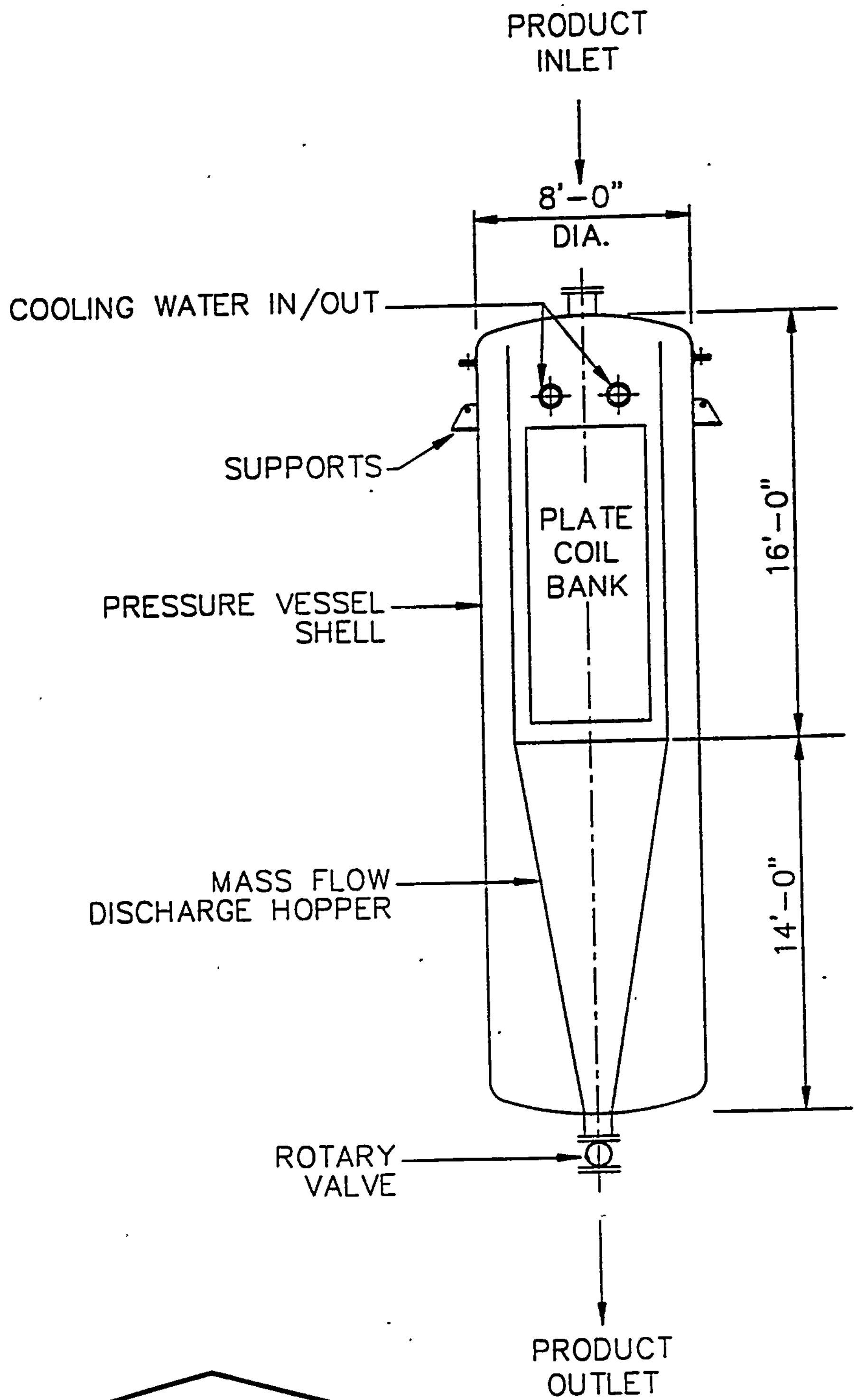
21840	SK-OA-181	A

G.10 BOILER MODIFICATIONS AND PYROLYZER SUBSYSTEM DRAWINGS

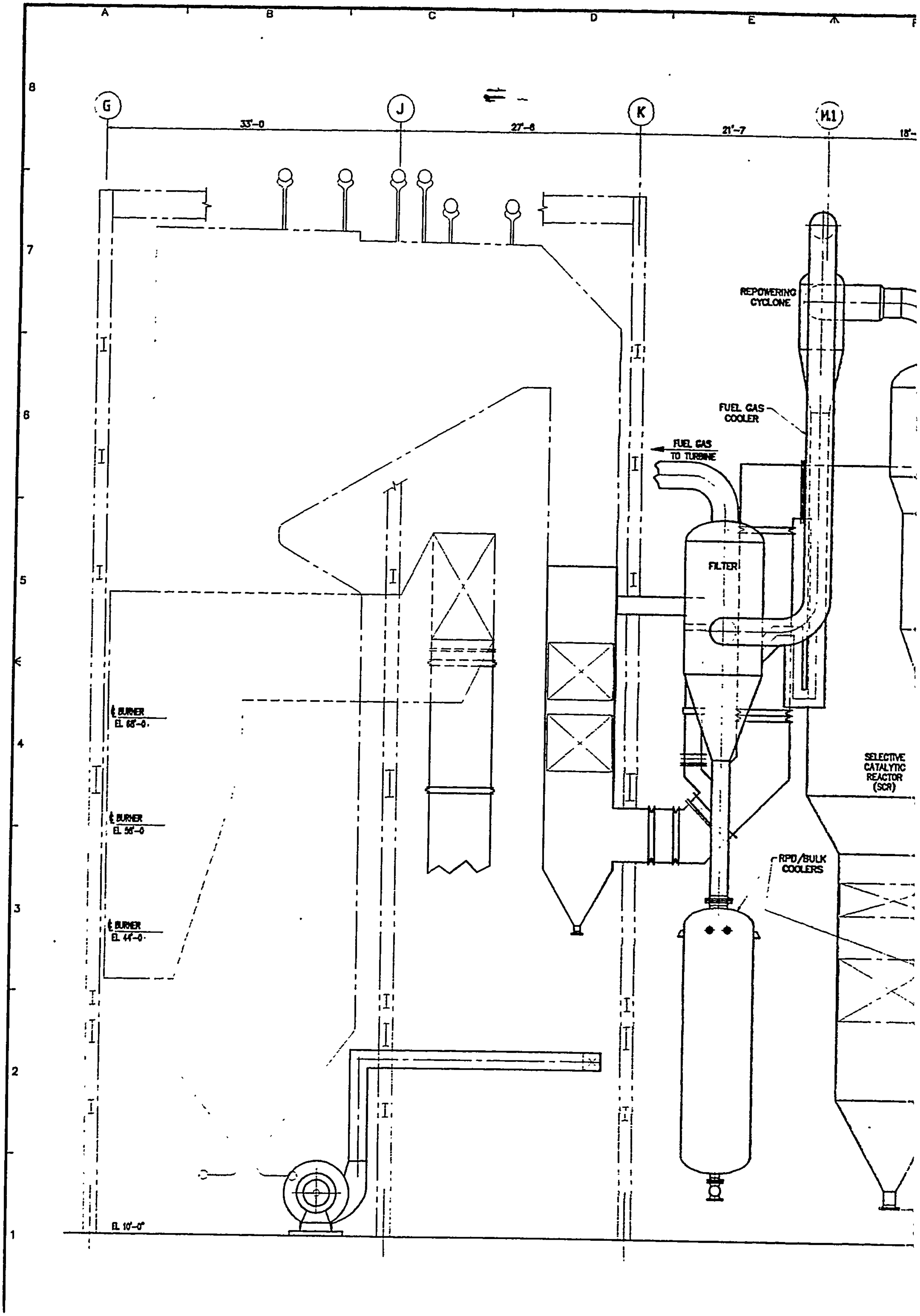
Following drawings are included in this section:

- RD950-3, General Arrangement, Side Elevation
- RD950-4, General Arrangement, Cross Section
- RD950-5, General Arrangement, Plan
- RD950-10, HIPPS Repowering, Cyclone
- RD950-21, HIPPS Repowering, Pyrolyzer
- RD950-25, HIPPS Repowering, Fuel Gas Spray Cooler
- RD950-27, HIPPS Repowering, "J" Valve
- RD950-28, HIPPS Repowering, Sections & Details
- FWD-001, Char Cooler Preliminary General Arrangement

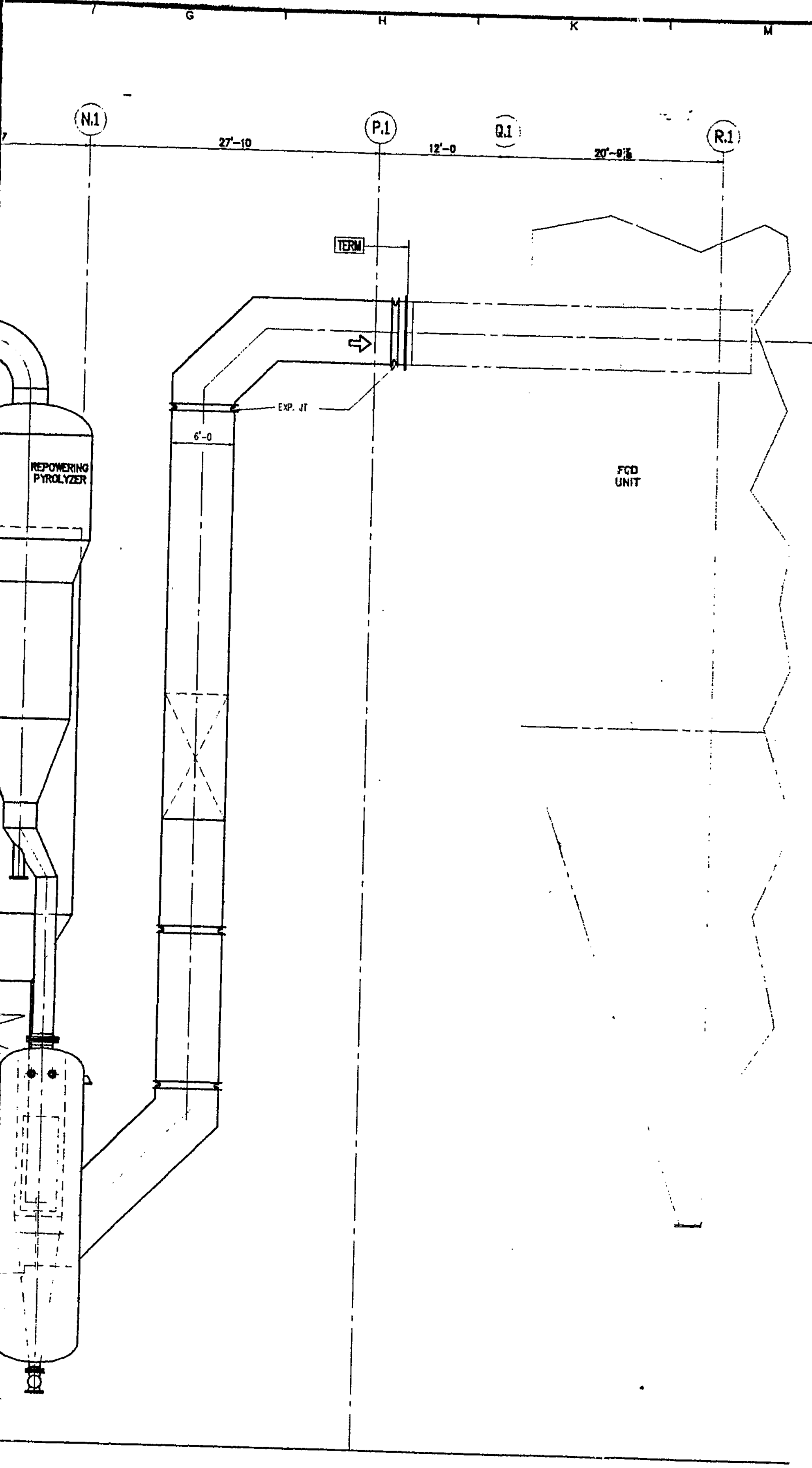
CESL BULK FLOW HEAT EXCHANGERS Cominco Engineering Services Ltd.	Title FOSTER WHEELER DEVELOPMENT CORP. CHAR COOLER PRELIMINARY GENERAL ARRANGEMENT	Drawing No. FWD-001 Date: 95/06/01 Design: NPJ	Rev A Scale: NTS App'd



PRELIMINARY



A
B
C
D
E
F
8
7
6
5
4
3
2
1
G
J
K
M.1
33'-0
27'-6
21'-7
REPOWERING CYCLONE
FUEL GAS COOLER
FUEL GAS TO TURBINE
FILTER
SELECTIVE CATALYTIC REACTOR (SCR)
RPD/BULK COOLERS
℄ BURNER EL 68'-0
℄ BURNER EL 56'-0
℄ BURNER EL 44'-0
EL 10'-0"



REV	DATE	DR BY	DESCRIPTION
A	2/22/95	DK	GENERAL REVISION

NOTES:

1. DO NOT SCALE THIS DRAWING. USE FIGURE DIMENSIONS ONLY.
2. ABBREVIATIONS USED ON THIS DRAWING ARE IN ACCORDANCE WITH AMERICAN STANDARD "ABBREVIATIONS FOR USE ON DRAWING".

ITEM NO	AMT REQ'D	DESCRIPTION/MATERIAL	SIZE

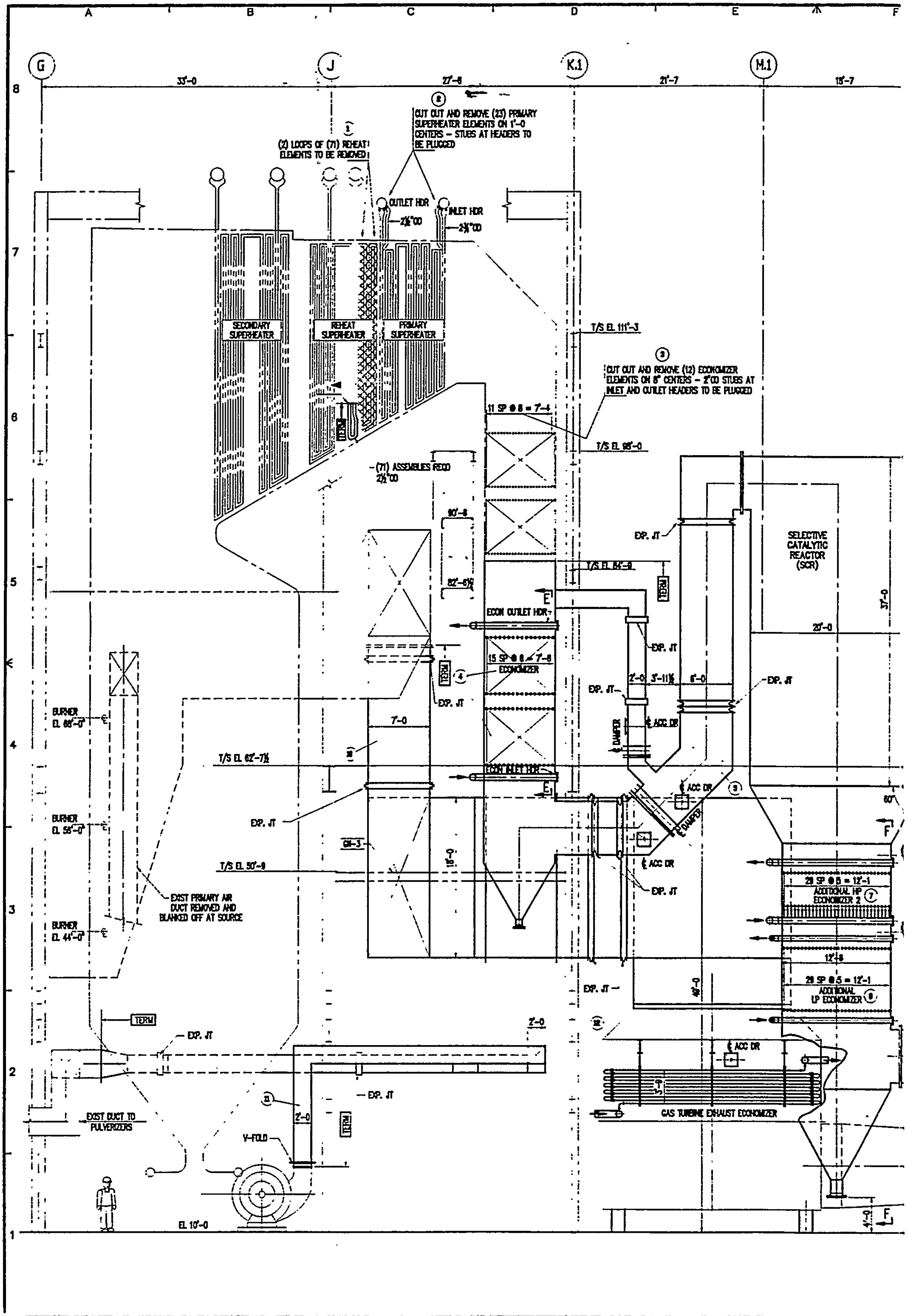
APPROVAL	NAME	DATE
DESIGN		

GENERAL ARRANGEMENT SIDE ELEVATION

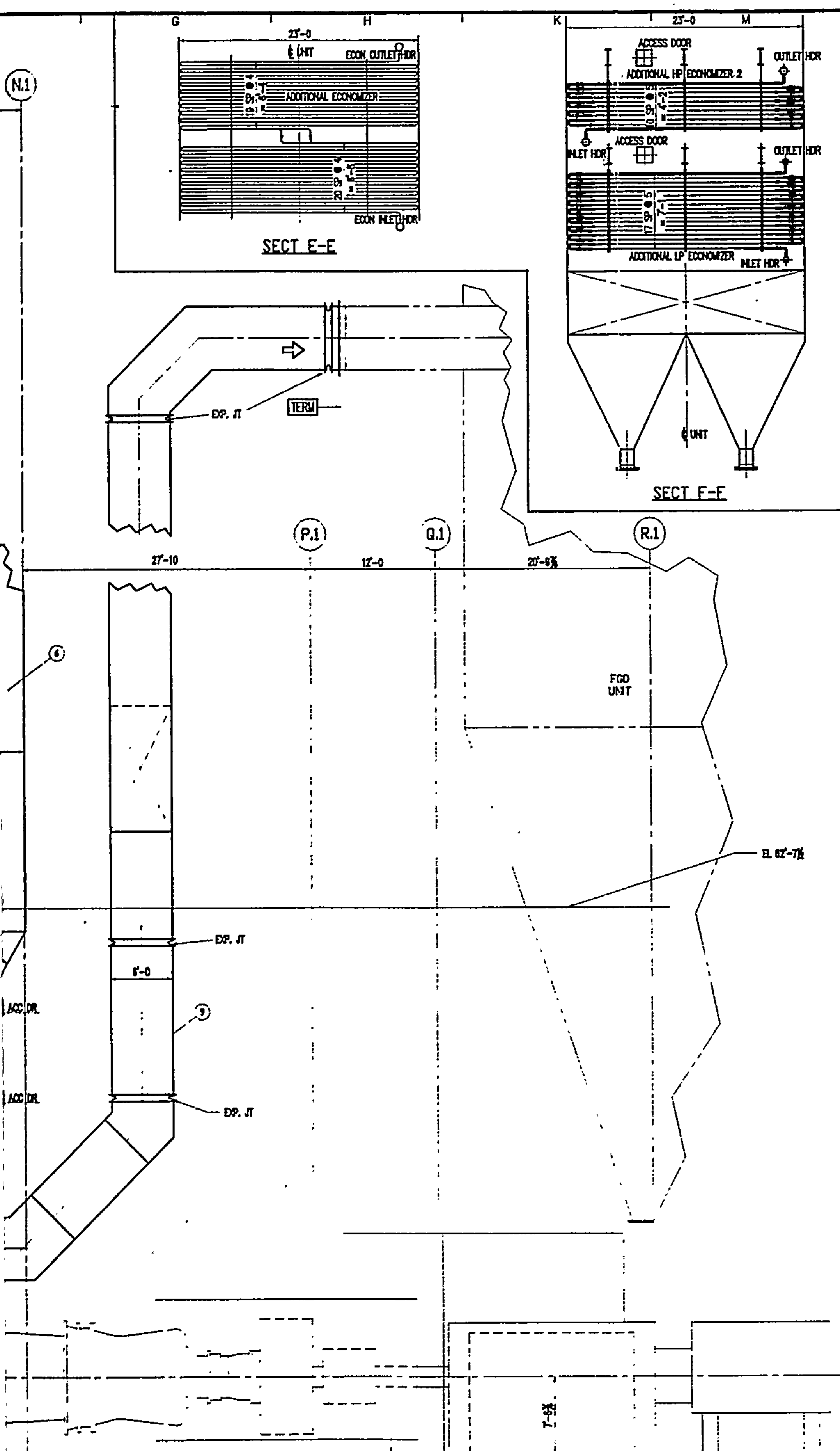
HIGH PERFORMANCE POWER SYSTEM HIPPS UTILITY REPOWERING STUDY

DRAWING NUMBER	SCALE 3/16" = 1'-0	
RD960-3		REVISION A
DRAWN BY	D. FULCSAR	1-16/95
CHECKED BY		
APPROVED BY		

THIS DRAWING IS THE PROPERTY OF THE FOSTER WHEELER DEVELOPMENT CORPORATION
12 PEACH TREE HILL RD
LIVINGSTON, N.J. 07039



CUT OUT AND REMOVE (23) PRIMARY SUPERHEATER ELEMENTS ON 1'-0 CENTERS - STUBS AT HEADERS TO BE PLUGGED
(2) LOOPS OF (71) REHEAT ELEMENTS TO BE REMOVED
OUTLET HDR
INLET HDR
SECONDARY SUPERHEATER
REHEAT SUPERHEATER
PRIMARY SUPERHEATER
T/S EL 111'-3
CUT OUT AND REMOVE (12) ECONOMIZER ELEMENTS ON 8" CENTERS - 2"OD STUBS AT INLET AND OUTLET HEADERS TO BE PLUGGED
11 SP @ 8 = 7'-4
T/S EL 98'-0
(71) ASSEMBLIES REQD
EXP. JT
SELECTIVE CATALYTIC REACTOR (SCR)
ECON OUTLET HDR
ECONOMIZER
ECON INLET HDR
ACC DR
DAMPER
BURNER EL 66'-0"
BURNER EL 55'-0"
BURNER EL 44'-0"
T/S EL 62'-7½
T/S EL 50'-9
EXIST PRIMARY AIR DUCT REMOVED AND BLANKED OFF AT SOURCE
ADDITIONAL HP ECONOMIZER 2
ADDITIONAL LP ECONOMIZER
TERM
EXIST DUCT TO PULVERIZERS
V-FOLD
GAS TURBINE EXHAUST ECONOMIZER
EL 10'-0



REVISIONS

GENERAL REVISION

NOTES:

1. DO NOT SCALE THIS DRAWING. USE FIGURE DIMENSIONS ONLY.
2. ABBREVIATIONS USED ON THIS DRAWING ARE IN ACCORDANCE WITH AMERICAN STANDARD "ABBREVIATIONS FOR USE ON DRAWING".
3. STRUCTURAL STEEL TO BE MODIFIED / RELOCATED / DELETED TO CLEAR NEW EQUIPMENT.
4. ADDITIONAL STRUTURAL STEEL & BRACING MAY HAVE TO BE MODIFIED / RELOCATED / ADDED / DELETED UPON RECEIPT OF ALL STEEL DRAWINGS FOR OUR REVIEW / COMMENTS FROM CUSTOMER.
5. TERM DENOTES FWEC WORK STOPS HERE.

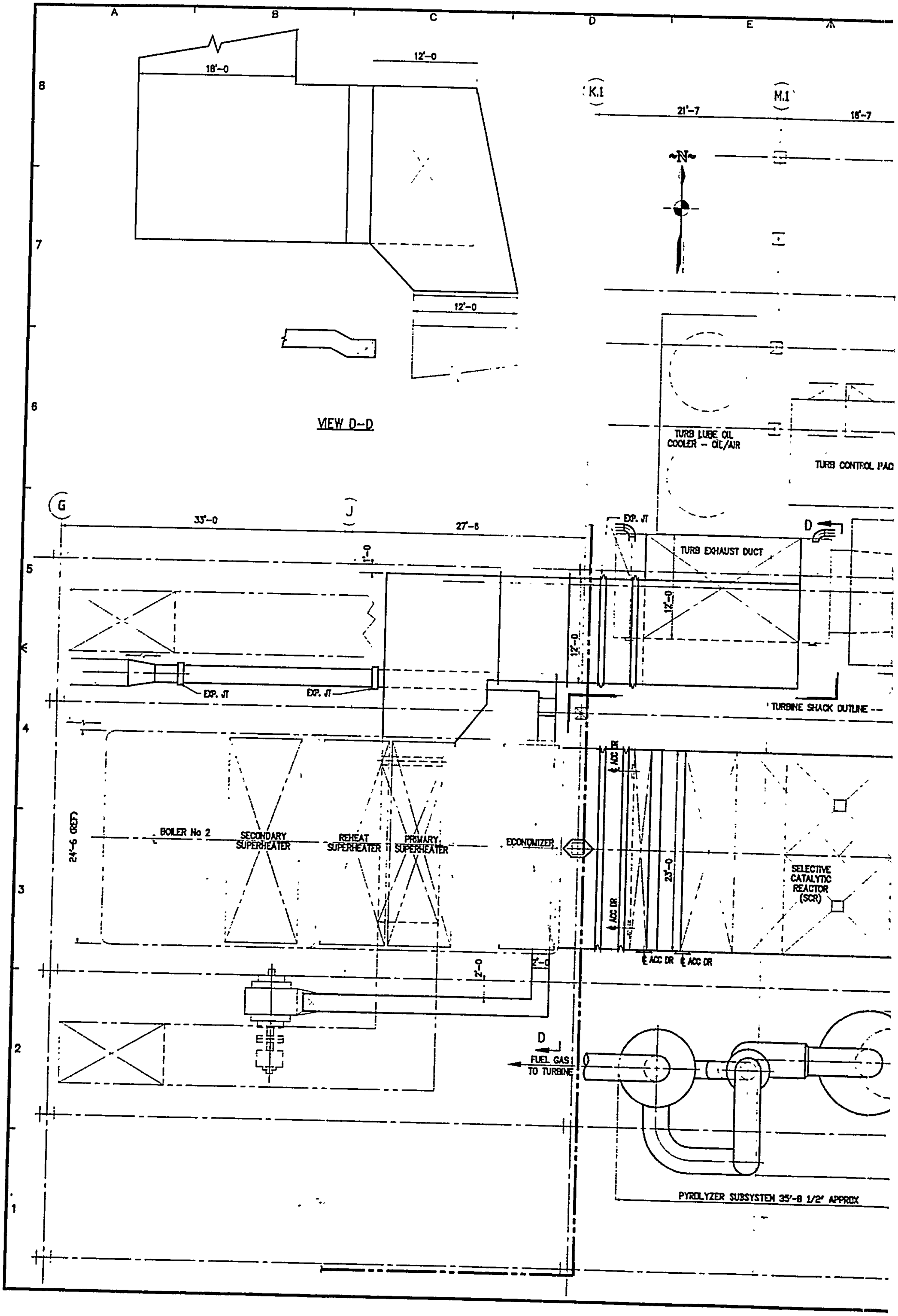
APPROVAL	NAME	DATE
DESIGN		

GENERAL ARRANGEMENT
CROSS SECTION

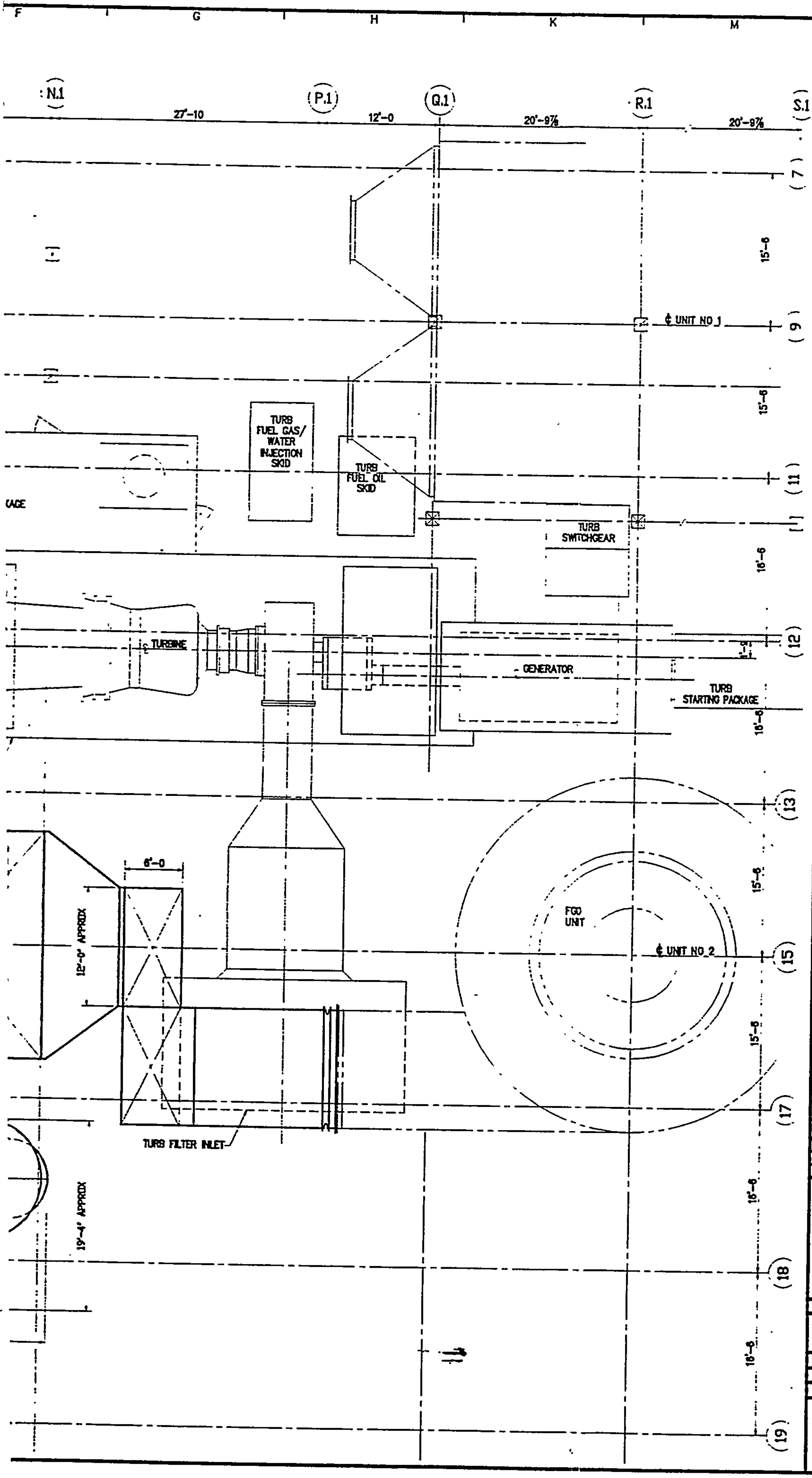
HIGH PERFORMANCE POWER SYSTEM
HIPPS
UTILITY REPOWERING STUDY

RD960-4 A

FOSTER WHEELER DEVELOPMENT CORPORATION



A
B
C
D
E
8
7
6
5
4
3
2
1
18'-0
12'-0
K.1
M.1
21'-7
15'-7
N
12'-0
VIEW D-D
TURB LUBE OIL COOLER - OIL/AIR
TURB CONTROL PAD
G
J
33'-0
27'-6
EXP. JT
D
TURB EXHAUST DUCT
1'-0
12'-0
12'-0
EXP. JT
EXP. JT
TURBINE SHACK OUTLINE
ACC DR
24'-6 (REF)
BOILER No 2
SECONDARY SUPERHEATER
REHEAT SUPERHEATER
PRIMARY SUPERHEATER
ECONOMIZER
23'-0
SELECTIVE CATALYTIC REACTOR (SCR)
ACC DR
ACC DR
ACC DR
2'-0
2'-0
D
FUEL GAS TO TURBINE
PYROLYZER SUBSYSTEM 35'-8 1/2" APPROX



REVISIONS

REV	DATE	BY	DESCRIPTION
A	2/22/96		GENERAL REVISION

NOTES:

1. DO NOT SCALE THIS DRAWING. USE FIGURE DIMENSIONS ONLY.
2. ABBREVIATIONS USED ON THIS DRAWING ARE IN ACCORDANCE WITH AMERICAN STANDARD "ABBREVIATIONS FOR USE ON DRAWING".

ITEM NO.	AMT REQD.	DESCRIPTION/MATERIAL	SIZE

APPROVAL	NAME	DATE
DESIGN		

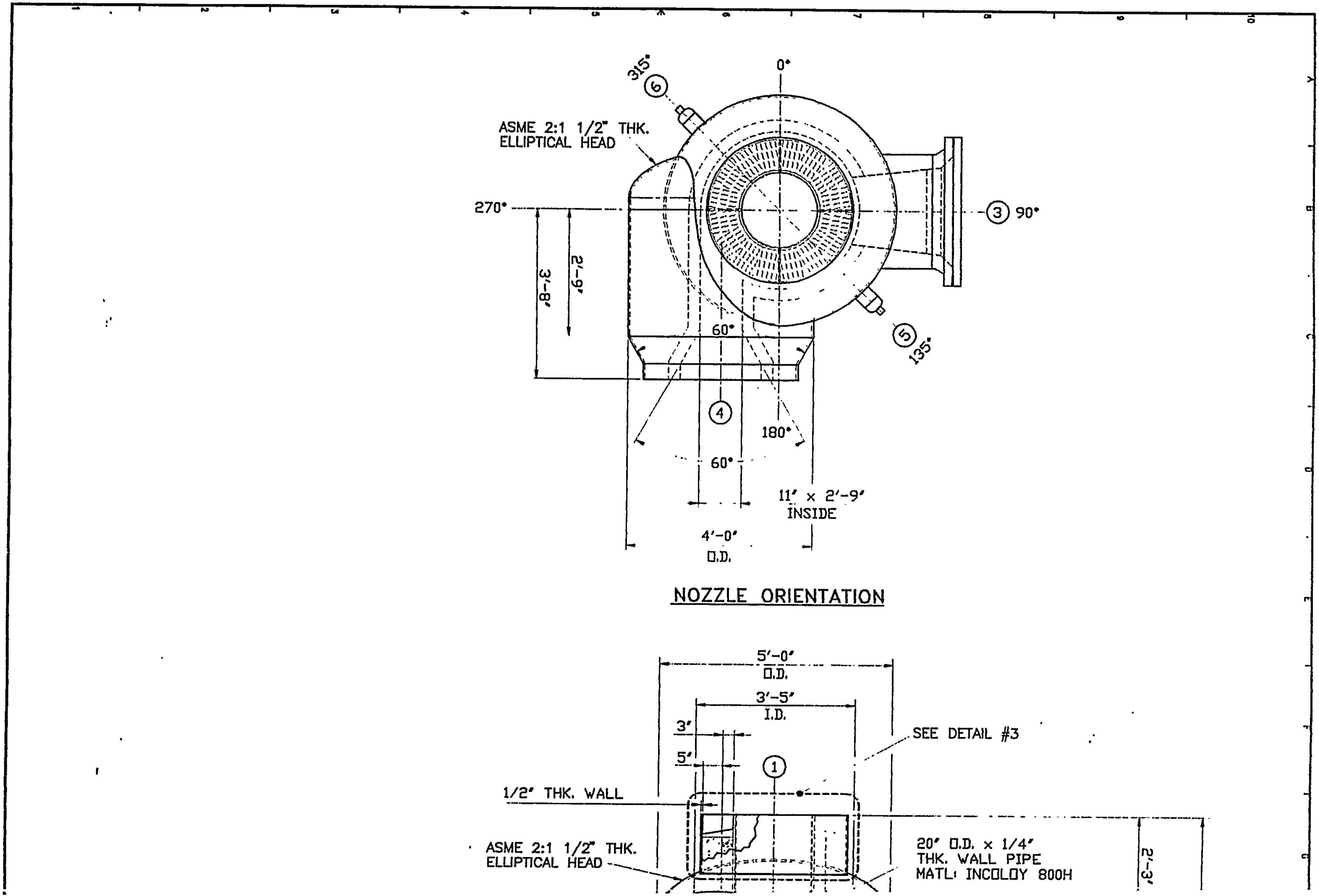
GENERAL ARRANGEMENT PLAN

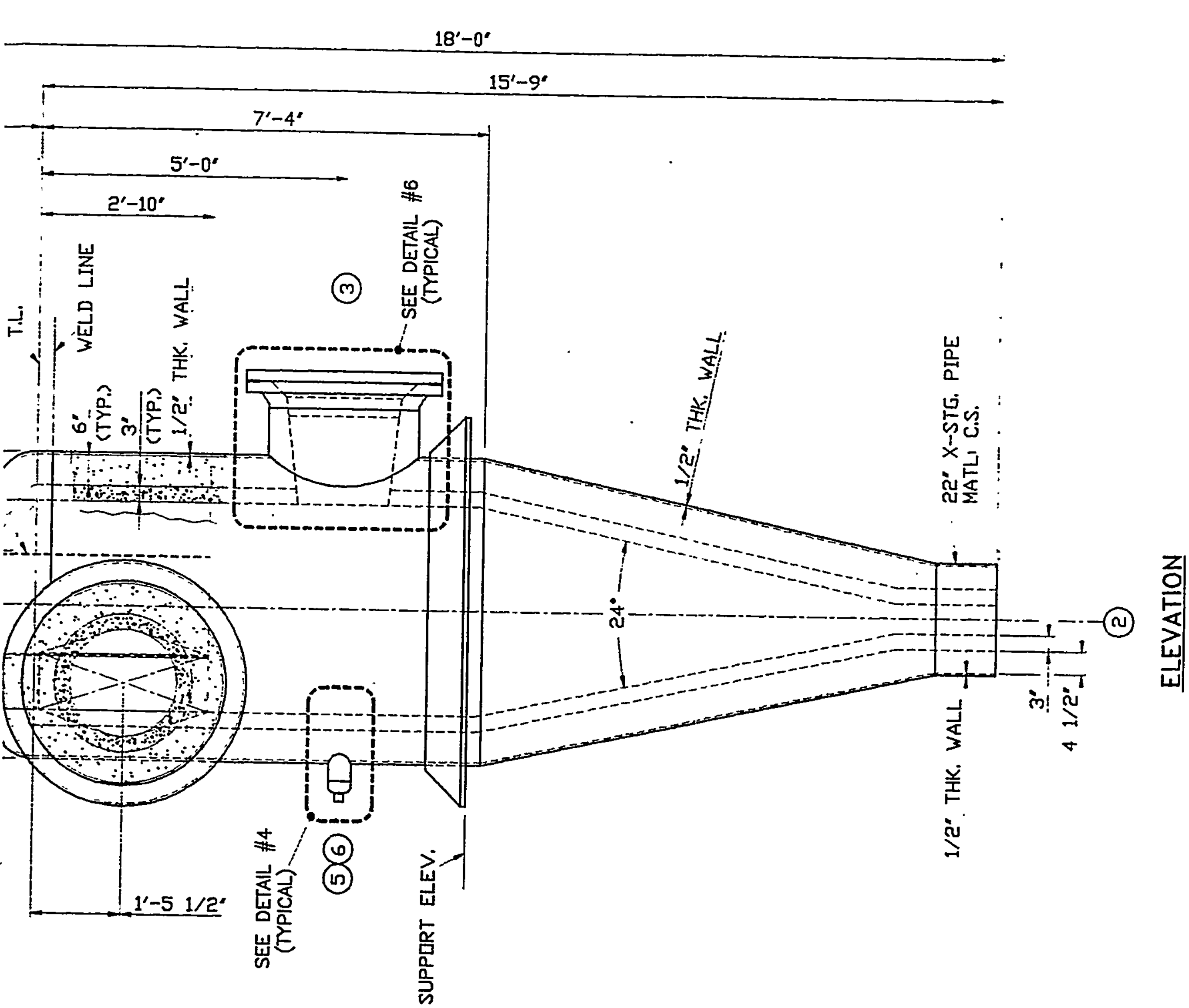
HIGH PERFORMANCE POWER SYSTEM
HIPPS
UTILITY REPOWERING STUDY

DRAWING NUMBER — SCALE: 3/16" = 1'-0"

RD960-5 — REVISION A

DRAWN BY	D. KULCSAR	1/16/95	
CHECKED BY			
APPROVED BY			


0°
315°
6
ASME 2:1 1/2" THK.
ELLIPTICAL HEAD
270°
3
90°
2'-9'
3'-8'
60°
5
135°
4
180°
60°
11' x 2'-9'
INSIDE
4'-0'
O.D.
NOZZLE ORIENTATION
5'-0'
O.D.
3'-5'
I.D.
3'
5'
SEE DETAIL #3
1
1/2' THK. WALL
ASME 2:1 1/2" THK.
ELLIPTICAL HEAD
20' O.D. x 1/4'
THK. WALL PIPE
MATL: INCOLOY 800H
2'-3'



VESSEL DATA

1	ITEM NO.	NO. REQ'D [illegible]		
2	SERVICE SECONDARY CYCLONE			
3				
4	OPER. PRESSURE ABOVE LIQUID LEVEL	NORM:	[illegible]	PSIG.
5		MAX:	[illegible]	PSIG.
6	DESIGN PRESSURE	INT.	[illegible]	PSIG.
7		EXT:		PSIG.
8	OPER. LIQUID HOLD UP PRESS:			PSIG.
9	OPER. PRESS. DROP THRU VESSEL:		[illegible]	PSIG.
10	MAX. RELIEVING PRESS. AT TOP HD.		[illegible]	PSIG.
11	MAX. OPER. TEMPERATURE 1700F (INTERNAL)			
12	DESIGN TEMPERATURE 650F (METAL)			
13	SPECIFIC GRAVITY (PROCESS FLUID): 0.6 (DUST			
14	MIN. DESIGN METAL TEMP. 0F			
15	WIND DATA: ASCE 7-88. 70 MPH, EXP. "C"			
16	EARTHQUAKE DATA: ASCE 7-88, ZONE 1			
17	CODE: ASME VIII DIV 1 STAMPED: YES			
18	P.W.H.T. FOR CODE: NO FOR PROCESS: NO			
19	RADIOGRAPHED: SPOT MATL. ID.: YES			
20	JOINT EFFICIENCY: 85%			
21	CORROSION ALLOW./CLAD TK. [illegible]			
22	MATL. SHELL: SA-516-70			
23	MATL. HEADS: SA-516-70			
24	MATL. SUPPORTS: SA-516-70			
25	MATL. FLANGES: SA-105			
26	MATL. NOZZLES: SA-106-B/SA-234-WPB			
27	EXTERNAL BOLTING: SA-193-B7/SA-194-2H			
28	MATL. CONE:			
29	GASKETS: SPIRAL WOUND 316 S.S. GRAPHOIL F[illegible]			
30	TYPE OF HEADS: 2:1 ELLIPTICAL			
31	INSULATION: HW 22 TL. WT & PS [illegible]			
32	PAINT/PREPERATION: SSPC SP-[illegible]			
33	PRIMER: BCS-38/P-101			
34				
35				
36	SHIPMENT: ONE PIECE			
37	VOLUME:			
38	EMPTY WGT. (METAL ONLY)			LBS.
39	WATER (ONLY) WGT:			LBS.
40				
41				
42				
43	REFRACTORY WGT.			LBS.
44				
45				

NOTES:

1. FOR SECTIONS AND DETAILS NOT SHOWN SEE DWG. RD940-176.

NOZZLE CHART

CONN. No.	SIZE	ANSI RATING	SERVICE	No. REQ'D	I.D. LINING
1	[illegible]	WELD END	OUTLET	1	1'-4 3/4"
2	[illegible]	WELD END	DRAIN	1	6"
3	[illegible]	[illegible] 300# R.F.	MANWAY W/DAVIT	1	20" & 18"
4	[illegible]	[illegible] 300# R.F.	INLET	1	21"
5	[illegible]	3000# CPLG	INSTR. CONN.	1	–
6					

HIPPS REPOWERING CYCLONE

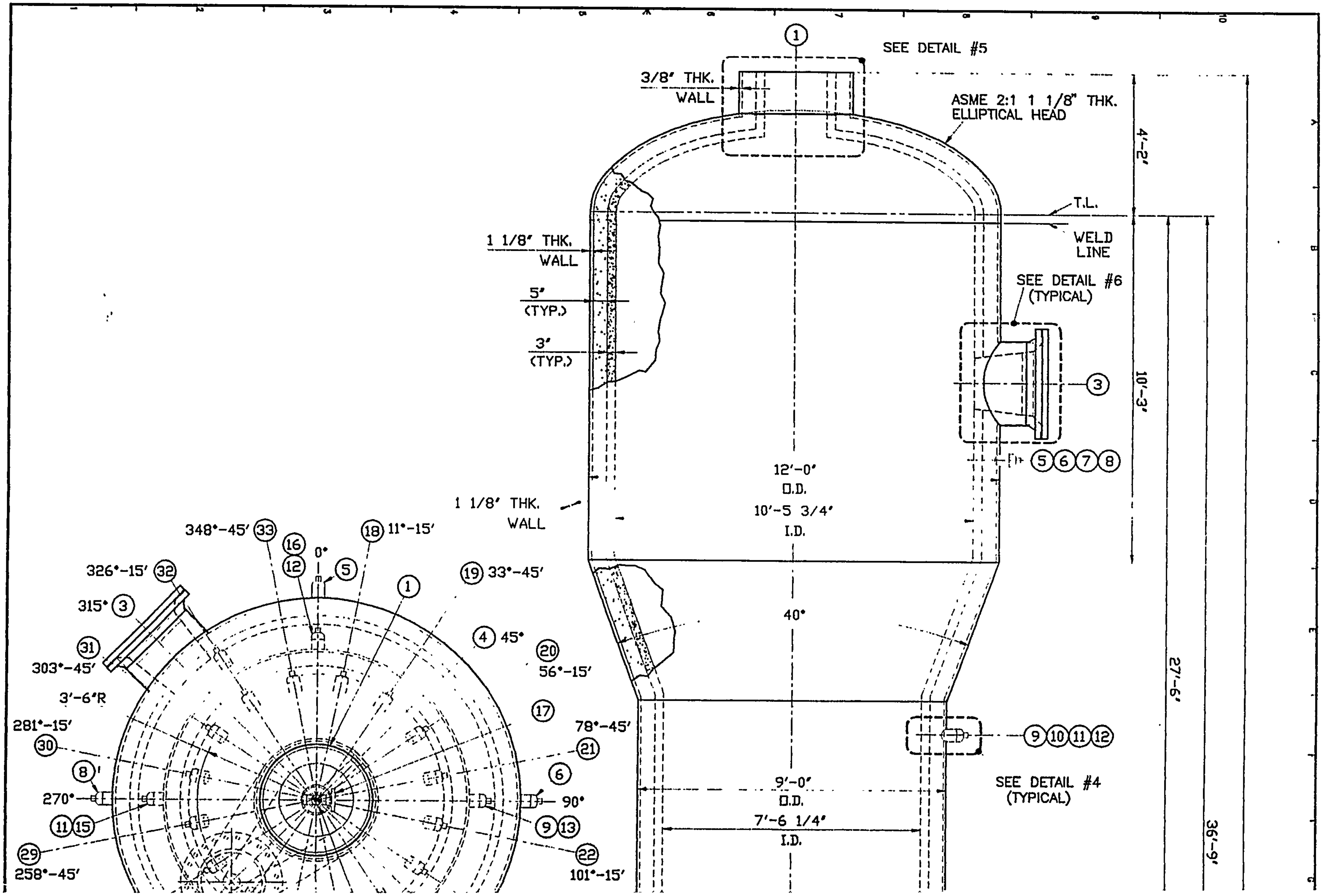
RD950-10

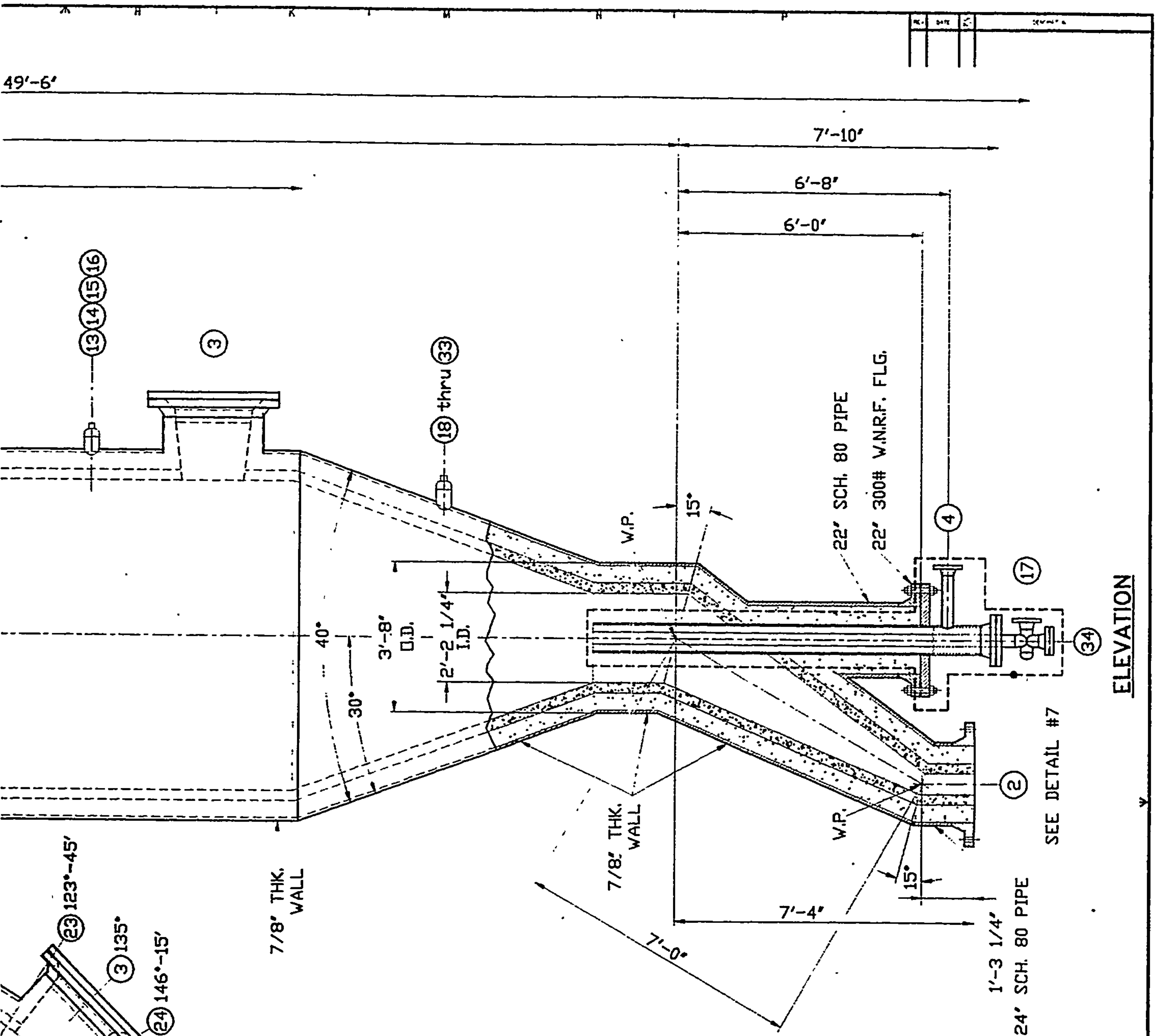
DRAWN BY J.N. 5/1/95

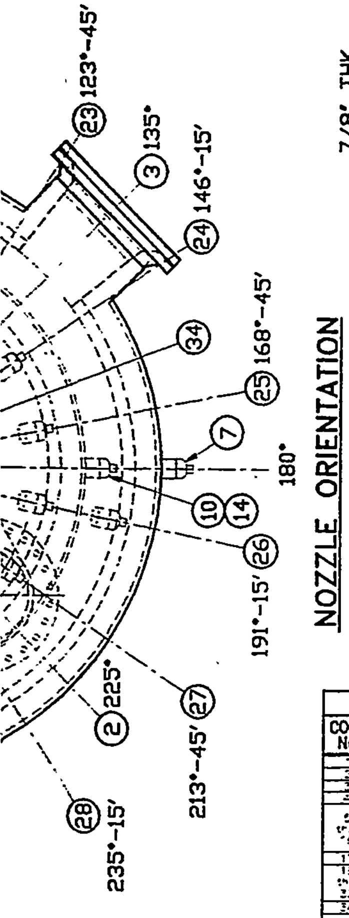
CHECKED BY

APPROVED BY

FW


SEE DETAIL #5
3/8" THK. WALL
ASME 2:1 1 1/8" THK. ELLIPTICAL HEAD
4'-2"
T.L.
WELD LINE
1 1/8" THK. WALL
5" (TYP.)
3" (TYP.)
SEE DETAIL #6 (TYPICAL)
10'-3"
12'-0" O.D.
10'-5 3/4" I.D.
1 1/8" THK. WALL
40°
27'-6"
9'-0" O.D.
7'-6 1/4" I.D.
SEE DETAIL #4 (TYPICAL)
36'-9"
348°-45'
11°-15'
0°
326°-15'
33°-45'
315°
45°
56°-15'
303°-45'
3'-6"R
281°-15'
78°-45'
270°
90°
258°-45'
101°-15'





NOZZLE CHART

CONN. No.	SIZE	ANSI RATING	SERVICE	No. REQ'D	I.D. LINING
1	40"	WELD END	GAS OUTLET	1	1'-10 3/4"
2	24"	CL 300# R.F.	CHAR OUTLET	1	7"
3	32"	CL 300# R.F.	MANWAY [illegible]	2	20" & 15"
4	3"	CL 300# R.F.	AIR INLET	1	–
5 thru 16	1"	3000# CPLG.	INSTR. CONN.		–
17	3"	CL 300# R.F.	COAL INLET	1	–
18 thru 33	1"	3000# CPLG.	AIR INJECTION	1	–
34	3"	CL 300# R.F.	CLEANOUT	1	–

VESSEL DATA

1	ITEM NO.	NO. REQ'D ONE (1)		
2	SERVICE PYROLYZER			
3				
4	OPER. PRESSURE ABOVE	NORM:	169	PSIG.
5	LIQUID LEVEL	MAX:	180	PSIG.
6	DESIGN PRESSURE	INT.	206	PSIG.
7		EXT:		PSIG.
8	OPER. LIQUID HOLD UP PRESS:			PSIG.
9	OPER. PRESS. DROP THRU VESSEL:		2	PSIG.
10	MAX. RELIEVING PRESS. AT TOP HD.		180	PSIG.
11	MAX. OPER. TEMPERATURE 1700°F (INTERNAL)			
12	DESIGN TEMPERATURE 650°F (METAL)			
13	SPECIFIC GRAVITY (PROCESS FLUID): 0.6 (DUST)			
14	MIN. DESIGN METAL TEMP. 0°F			
15	WIND DATA: ASCE 7-88, 70 MPH, EXP. "C"			
16	EARTHQUAKE DATA: ASCE 7-88, ZONE 1			
17	CODE: ASME VIII DIV. 1 STAMPED: YES			
18	P.W.H.T. FOR CODE: NO FOR PROCESS: NO			
19	RADIOGRAPHED: SPOT MATL. REQ.: YES			
20	JOINT EFFICIENCY: 85%			
21	CORROSION ALLOW./CLAD TK. 1/16"			
22	MATL. SHELL: SA-516-70			
23	MATL. HEADS: SA-516-70			
24	MATL. SUPPORTS: SA-516-70			
25	MATL. FLANGES: SA-105			
26	MATL. NOZZLES: SA-106-B/SA-234-WPB			
27	EXTERNAL BOLTING: SA-193-B7/SA-194-2H			
28	MATL. COND			
29	GASKETS: SPIRAL WOUND 316 S.S. GRAPHOIL FILL			
30	TYPE OF HEADS: 2:1 ELLIPTICAL			
31	INSULATION: HW 22 TL. WT. & RS 17E			
32	PAINT/PREPARATION: SSPC SP-5			
33	PRIMER: BCS-38/P-101			
34				
35				
36	SHIPMENT: ONE PIECE			
37	VOLUME:			
38	EMPTY WGT. (METAL ONLY)			LBS.
39	WATER (ONLY) WGT:			LBS.
40				
41				
42				
43	REFRACTORY WGT.			LBS.
44				
45				

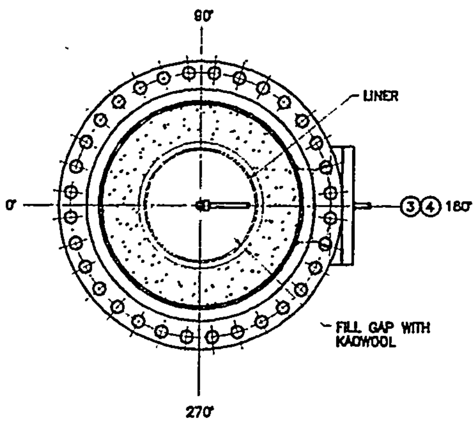
NOTES:

1. FOR SECTIONS AND DETAILS NOT SHOWN SEE DWG. RD940-176.

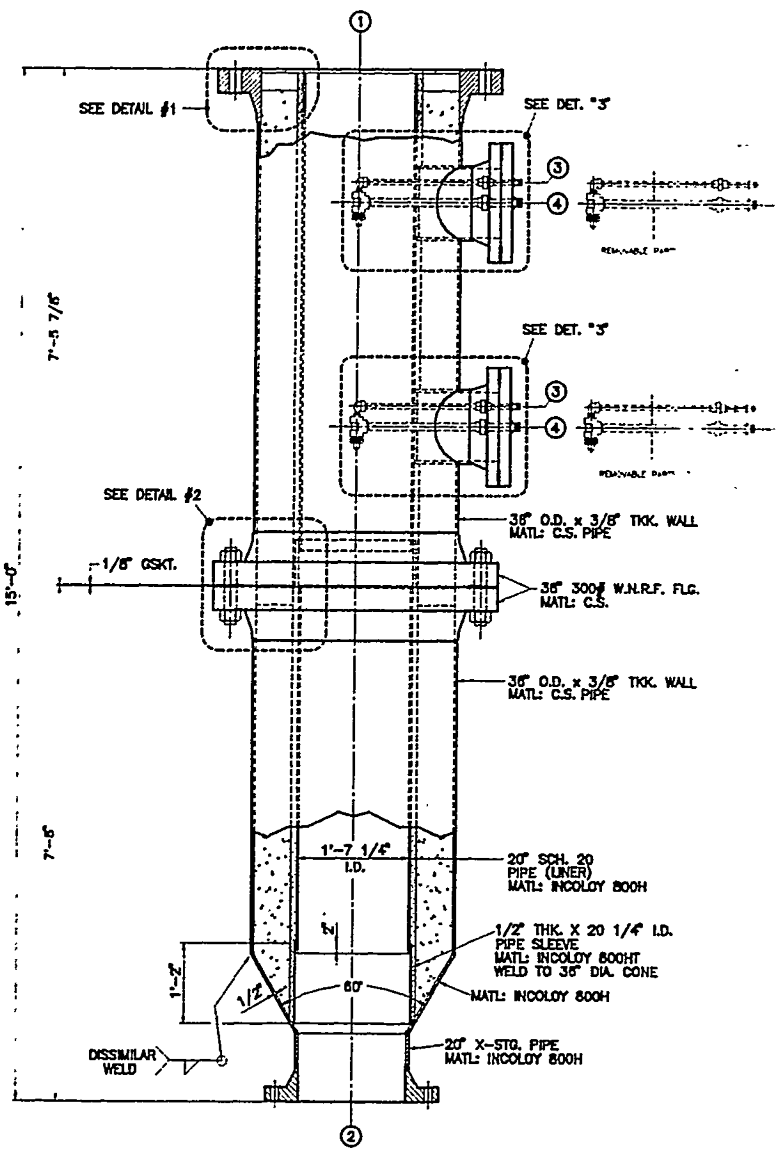
HIPPS REPOWERING PYROLYZER

DRAWING NUMBER	SCALE 3/4" = 1'-0"
RD950-21	REVISION
DRAWN BY	J.N. 4/17/95
CHECKED BY	
APPROVED BY	

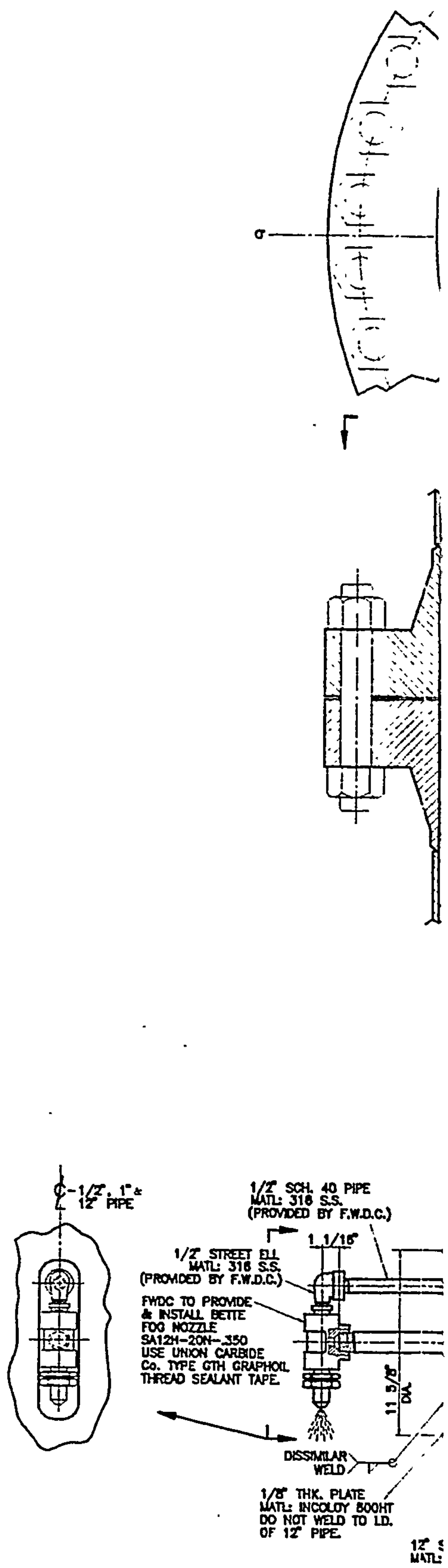
THIS DRAWING IS THE PROPERTY OF THE FOSTER WHEELER DEVELOPMENT CORPORATION

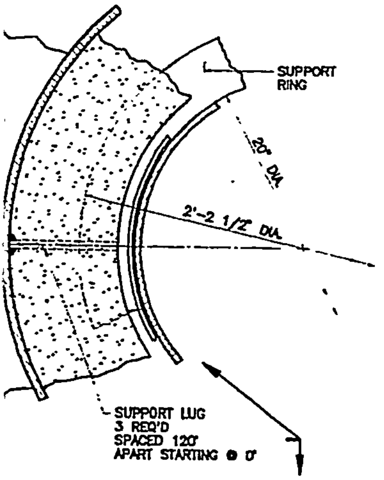


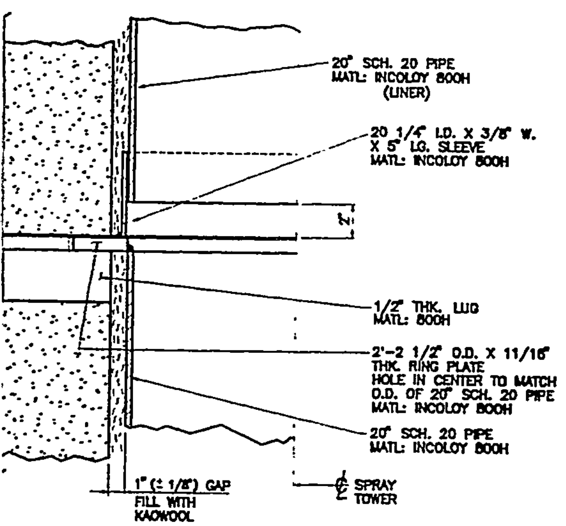
NOZZLE ORIENTATION



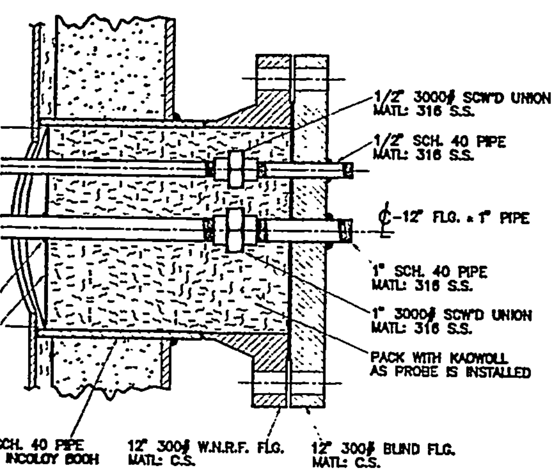
ELEVATION







DETAIL #1 (SINGLE FLG. @ INLET)
DETAIL #2 (DOUBLE FLANGES)
SCALE: 3"=1'-0"



DETAIL "3"
SPRAY NOZZLE DETAIL
(TYP.) (2) PLACES
SCALE: 3"=1'-0"

NOZZLE CHART

CONN. No.	SIZE	ANSI RATING	SERVICE	No. REQ'D	I.D. LINING
1	36"	CL 300# P.F.	GAS INLET	1	1½ 1/4"
2	20"	CL 300# P.F.	GAS OUTLET	1	19"
3	1/2"	SCH. 40 PIPE	WATER	2	–
4	1"	SCH. 40 PIPE	N2	2	–

VESSEL DATA

1	ITEM NO.	NO. REQ'D ONE (1)		
2	SERVICE: FUEL GAS SPRAY COOLER			
3				
4	OPER. PRESSURE ABOVE LIQUID LEVEL	NORM:	169	PSIG.
5		MAX:	180	PSIG.
6	DESIGN PRESSURE	INT.	206	PSIG.
7		EXT.		PSIG.
8	OPER. LIQUID HOLD UP PRESS:			PSIG.
9	OPER. PRESS. DROP THRU VESSEL:		2	PSIG.
10	MAX. RELIEVING PRESS. AT TOP HD.		180	PSIG.
11	MAX. OPER. TEMPERATURE 1700°F (INTERNAL)			
12	DESIGN TEMPERATURE 650°F (METAL)			
13	SPECIFIC GRAVITY (PROCESS FLUID): 0.6 (DUST)			
14	MIN. DESIGN METAL TEMP. 0°F			
15	WIND DATA: ASCE 7-88, 70 MPH, EXP. "C"			
16	EARTHQUAKE DATA: ASCE 7-88, ZONE 1			
17	CODE: ASME VIII DIV. 1 STAMPED: YES			
18	P.W.H.T. FOR CODE: NO FOR PROCESS: NO			
19	RADIOGRAPHED: SPOT MATL. BOL: YES			
20	JOINT EFFICIENCY: 85%			
21	CORROSION ALLOW./CLAD TK. 1/16"			
22	MATL. SHELL: SA-516-70			
23	MATL. HEADS: SA-516-70			
24	MATL. SUPPORTS: SA-516-70			
25	MATL. FLANGES: SA-105			
26	MATL. NOZZLES: SA-106-B/SA-234-WPB			
27	EXTERNAL BOLTING: SA-193-B7/SA-194-2H			
28	MATL. CONE:			
29	GASKETS: SPIRAL WOUND 316 S.S. GRAPHOIL FILL			
30	TYPE OF HEADS:			
31	INSULATION: HW 22 TL. WT & RS 17E			
32	PAINT/PREPERATION: SSPC SP-5			
33	PRIMER: BCS-38/P-101			
34				
35				
36	SHIPMENT: ONE PIECE			
37	VOLUME:			
38	EMPTY WGT. (METAL ONLY)			LBS.
39	WATER (ONLY) WGT:			LBS.
40				
41				
42				
43	REFRACTORY WGT.			LBS.
44				
45				

NOTES:

1. FOR SECTIONS AND DETAILS NOT SHOWN SEE DWG. RD940-176.

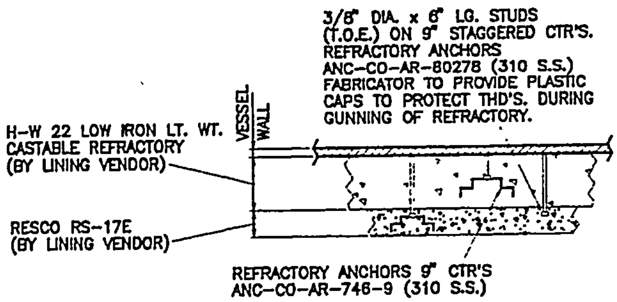
HIPPS REPOWERING
FUEL GAS
SPRAY COOLER

SCALE 1" = 1'-0" OR AS NOTED

RD950-25

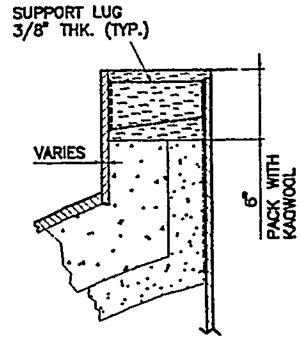
DRAWN BY JN 5/3 95
CHECKED BY
APPROVED BY

THIS DRAWING IS THE PROPERTY OF THE
FOSTER WHEELER DEVELOPMENT CORPORATION
JOHN BLIZZARD RESEARCH CENTER
12 PEACH TREE HILL RD. LIVINGSTON, N.J.



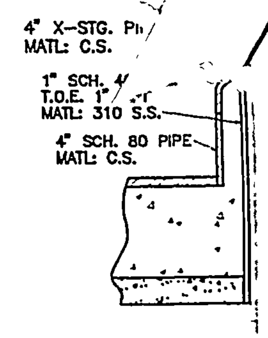
DETAIL #1

(TYPICAL DUAL LAYER REFRACTORY DETAIL)
SEE ELEVATION FOR REFRACTORY AND SHELL THICKNESSES
N.T.S.



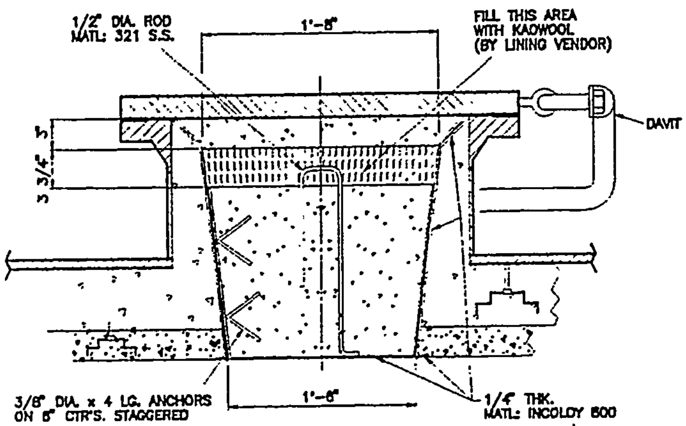
DETAIL #3

N.T.S.



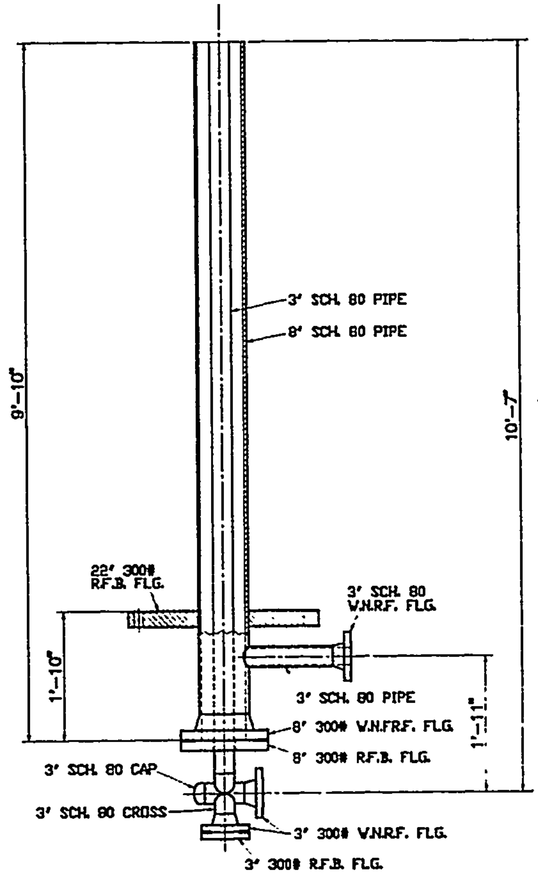
DETAI

N.



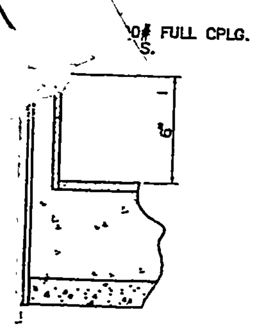
DETAIL #6

(TYPICAL MANWAY DETAIL)
N.T.S.

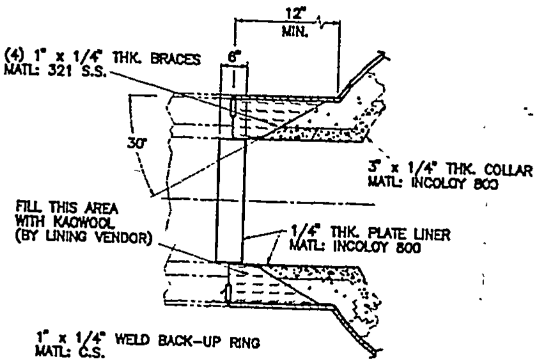


DETAIL #7

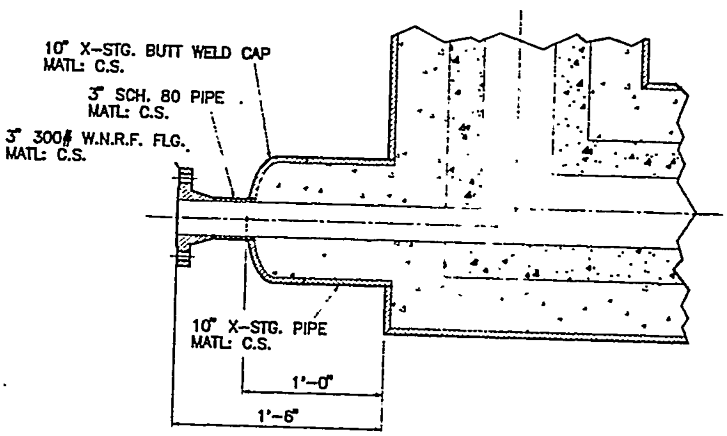
(REMOVABLE PYROLYZER FEED NOZZLE)
N.T.S.



IL #4
r.S.



DETAIL #5
(WELDING DETAIL)
N.T.S.



DETAIL #8
(J-VALVE SPARGER)
N.T.S.

REV	DATE	CK'D	DESCRIPTION

HIPPS REPOWERING
SECTIONS & DETAILS

DRAWING NUMBER	SCALE	
RD950-28		REVISION
DRAWN BY	J.N.	5/8/98
CHECKED BY		
APPROVED BY		