Table 9
PIPING & INSTRUMENTATION DIAGRAMS

NUMBER	DESCRIPTION
115007 B	STEAM TURBINE SYSTEM
115007 C	EXTRACTION STEAM SYSTEM
115007 D	SURFACE CONDUCTOR - HOTWELL
115007 E	SURFACE CONDENSER - CONDENSATE RETURN
115007 F	VACUUM DEAERATOR & MISC. CONDENSATE
115007 G	CONDENSATE SYSTEM
115007 H	LP FEEDWATER HEATERS - VENTS AND DRAINS
115007 J	BLOWDOWN SYSTEM
115007 K	PROCESS STEAM TO DISTRIBUTION
160007 A	CIRCULATING WATER SYSTEM

I) Metallurgical Diagrams

A materials study was undertaken as described below to make recommendations for materials of construction for those areas of the plant that are not standard industry applications. The results of this study were used to mark up a set of the AFD PFD's. This was done to specify the piping materials and to identify special materials for the gasifier island equipment. The marked up PFD's were formalized into Metallurgical Flow Diagrams and a piping specification was developed which was used in the P&ID development.

J) Equipment Data Sheets

An equipment list was identified from the AFD PFD's. Equipment data sheets were generated for each piece of equipment identified. The equipment data sheets include design data such as maximum temperatures, pressures, flows, required operating performance, and materials of construction. The data sheets were used to produce requisitions for quotations for each piece of equipment for the cost estimate. Table 10 lists the equipment data sheets generated for this project.

Table 10
EQUIPMENT DATA SHEETS

NUMBER	EQUIPMENT
FR 20 11	PC STREAM SPLITTER
GB 20 11	MILL FAN
GB 20 21	MILL ID FAN
JD 20 11	PC TRANSPORT CONVEYOR
PA 20 11	PC KINETIC EXTRUDER
PS 30 11	GASIFIER SLAG GRINDER
PW 20 11	PC COAL MILL
FA 45 11	SLAG LOCKHOPPER
FA 30 21	GASIFIER SLAG TANK
FA 35 11	CHAR SEAL HOPPER
FC 35 11	CHAR PRIMARY CYCLONE
FD 35 11	CHAR REMOVAL BAGHOUSE
FH 35 21	CHAR TRANSPORT SCREW

Table 10
EQUIPMENT DATA SHEETS

NUMBER	EQUIPMENT
FH 35 31	CHAR ROTARY VALVES
FH 35 61	PRIMARY CYCLONE CHAR CONTROL VALVE
BH 40 11	WARM-UP BYPASS DESUPERHEATER
EC 40 11	CHAR SPRAY COOLER
EG 40 21	CHAR RECEIVING BIN VENT EDUCTOR
FA 40 11	CHAR FEED BIN
FA 40 21	CHAR LOCKHOPPERS
FA 40 31	CHAR RECEIVING BIN
FH 40 31	CHAR FLOW CONTROL VALVE ELEVATION
FR 40 11	CHAR STREAM SPLITTER ELEVATION
FR 40 21	CHAR PICK-UP "T" ELEVATION
EA 45 11	SLAG WATER COOLER
GA 20 21	COAL MILL HEATER CONDENSATE PUMP
EC 20 31	COAL MILL HEATER #2
EG 20 21	PC COAL KINETIC EXTRUDER VENT EDUCTOR
EC 20 21	COAL MILL HEATER #1
FA 20 11	PULVERIZED COAL FEED BIN
FA 20 21	PULVERIZED COAL LOCKHOPPERS
FA 20 31	COAL MILL HEATER #2 CONDENSATE POT
FA 20 51	OVERSIZE COAL COLLECTION TANK
FA 20 61	COAL EXTRUDER BIN
FC 20 11	PULVERIZED COAL CYCLONE
FD 20 21	PULVERIZED COAL BAGHOUSE
FE 20 11	PULVERIZED COAL RECEIVING BIN
FE 20 21	PULVERIZER COAL KINETIC EXTRUDER FEED
FH 20 41	PC TRANSPORT CONVEYOR FEEDER
FH 20 51	PC CYCLONE DISCHARGE VALVE
FH 20 71	PC SCREEN FEEDER
FH 20 81	PC FLOW CONTROL VALVE
FH 20 91	RAW COAL GRAVIMETRIC FEEDER
GA 45 31	SLAG BATH CIRCULATION PUMPS
FL 20 11	PC SCREEN
FR 20 12	PC STREAM SPLITTER
FR 20 21	PC PICK-UP "T"

K) Gasifier and Heat Exchanger

The gasifier and its heat exchanger are utilized to produce a pressurized product gas stream containing char and H2S. Pulverized coal is delivered and combusted in a deficiency of air. Gasification occurs in an entrained reactor. Sensible energy is removed from the gas in a heat exchanger called a Syngas Cooler (SGC). The gas exits the system for char removal and desulfurization. Coal ash is fused and tapped from the bottom of the gasifier as molten slag. All streams to the gasifier are delivered pressurized.

Product gas leaves the gasifier and passes through a crossover and enters the SGC. The bounding walls of the gasifier, crossover, and SGC are water cooled. Located in the SGC is convection superheat surface. The gasifier and SGC are vertically orientated while the crossover is horizontal. The heat transfer surface arrangement is of a configuration that will yield an outlet gas temperature over the operating load range which will satisfy the requirements of the hot desulfurization system. The steam flow generated and the superheating of steam is integrated into the steam cycle.

In the gasifier a stream of molten slag continually flows through a slag tap into a slag tank. Quenched slag is periodically let down from this tank. The slag tank is located just below the gasifier.

The gas pass from the slag floor to the SGC outlet is gas tight and is bounded almost completely by waterwalls. The slag tank and gas pass are contained in pressure vessels. The annulus area between the gas pass and ID of the pressure vessel is pressurized with steam at a pressure slightly higher than the gas pass. With this system the pressure vessels are only exposed to inert non-corrosive gases. A water seal accommodates the differential movements and provides for a gas tight seal between the annulus area and the gas pass. It allows for pressure equalization between the gas pass and annular area during transients. This seal is sized so that during pressure differentials caused by either process effects or mechanical failures the design pressure differential across the waterwalls will not be exceeded.

The heat exchange surfaces are integrated into the cycle and are evaporative and superheat. A separate steam drum is provided for the gasifier island. Preheated water is received from an economizer located in the HRSG. This feedwater is introduced into the steam drum and steam at matching HRSG conditions is produced in the SGC.

The gasifier incorporates several elevations of coal introduction and char introduction. The lowest elevation contains both coal and char. At this level all air and start-up natural gas is introduced. Four elevations of future diagnostic water injection, one elevation of emergency water and one elevation of process steam introduction are provided. All injection nozzles are water cooled. This water cooling is not part of the boiler water circulation system and is connected to a manifold system external to the gasifier and SGC. Instrumentation for control and process evaluation is provided.

A circulation system is used for the generation of steam. Steam is generated in the gasifier, SGC, and a heat exchanger in the HGCU system. Steam is used in the coal feed system by an air heater and a coal heater. The steam drum separates the two phase mixture into high purity steam and water. The high purity steam is provided to the superheat system. The separated water is recirculated to the steam generating circuits.

i) Syngas Cooler Performance Studies

One of the major components in the steam cycle is the Syngas Cooler (SGC). The design of this component is not as straight forward as some of the other more typical steam cycle components included in this cycle. The complexity of the SGC design is partially due to the relative uncertainty for some of the design parameters of this component. Another complexity is due to the highly integrated design of this plant. With this high degree of integration, changes to the performance of one component may effect the performance or design requirements of other components. Because of this component to component dependency, an individual component cannot be designed rigorously without integrating the design with the remainder of the cycle.

A performance sensitivity study was done for the SGC component in order to study the effect of varying some of the key SGC design parameters over the likely ranges for these parameters. The five variables shown in Table 11 were changed over the indicated ranges to quantify the potential impacts to plant performance.

TABLE 11
Syngas Cooler Performance Sensitivity Study

Sensitivity Variable	Units	Variable Range
Fouling Factor	(hr ft F/Btu)	50% - 150%
Gasifier WW Heat Abs.	(MM-Btu/hr)	50% - 200%
HGCU Evap. Heat Abs.	(MM-Btu/hr)	0 - 200%
Sootblower Steam Flow	(lbm/hr)	0 -15000 #/hr
Superheater Surface Effectiveness Factor	(fraction)	71% - 95%

The STMCYC program was used for this SGC sensitivity study in order to properly account for the effects on other plant components. The sensitivity study base case operating condition used base gas turbine load and 59°F ambient temperature (this was defined as the "maximum design" case). A total of 12 runs were made for this study using the STMCYC program.

The basic result of this study was the selection of design point values for all the SGC sensitivity study parameters as well as other parameters required to design the SGC. Another result of this study was a set of curves which show primarily the SGC performance and secondarily the other steam cycle components performance over the ranges of the sensitivity study variables. In general these results show maximum variations to SGC outlet temperature of about 50°F. SGC outlet steam flow varies by about 10% as compared to the base case. The desuperheating spray water flow varied from 0 to about 18% as compared to about 10% for the base case. Outlet steam temperature was maintained at the 950°F set point in all but one case (200% of base case gasifier waterwall heat absorption) where it fell to about 900°F.

These results indicate that over the range of potential uncertainty of key variables, the performance of the SGC is acceptable. The current design is flexible enough to be able to handle the design requirements even if some of the design assumptions are not exactly as expected.

ii) Initial Mechanical Design

This effort established a base design from which final engineering would begin. Sufficient system layout work was completed to establish a definite schedule and cost. The schedule was for both engineering and shop fabrication. This schedule determined the best fit for the resources of both the shop and the engineering departments involved. In addition, a schedule for LCI's interface requirements was established. These requirements include information exchange, scope split, physical geometry definition, performance requirements, and their construction schedules. The location and types of instrumentation required were determined.

Numerous trade-off studies were performed to resolve technical issues for the base design. With this type of a first generation design the quality and number of support drawings were developed in more detail than those required to initiate a typical pulverized boiler final design.

A final engineering schedule was established to meet the on-site delivery dates. This schedule established the critical path items, manpower requirements and internal deliverables. This schedule identified the following types of releases: engineering, data, material and fabrication for all components.

A package of engineering data was assembled for pricing. Representatives of the CE shops were advised on cost reduction concepts as they reviewed the package. This information with feedback from a construction group was factored into the design.

Co-ordination with LCI was achieved through data sheets, exchange of engineering personnel and drawings. A package was prepared which included drawings and supporting information. The supporting information included performance requirements and physical location data for the gasifier and heat exchanger. The appropriate codes were reviewed to determine the scope split for power piping and for hydro testing. This established the scope split between CE and LCI for all interfaces.

iii) Arrangement Drawings

The general arrangement in side view is shown in Figure 14, DWG 16990-1E001. The major components shown are the gasifier, crossover, heat exchanger, steam drum, support system and slag lock hopper.

The gasifier has several levels of coal injection and several levels of char injection. Each level consists of four injection locations. The lowest level of coal and the lowest level of char are at the same elevation. At this elevation air is admitted to both the coal and char nozzles in a primary and secondary stream. Incorporated at this level are the natural gas burners for start-up.

The gasifier and heat exchanger vessels are connected together with a horizontal crossover vessel. This assembly is supported by a trunion and U hanger rod system. The trunions are located on each vessel and are supported by U rods. Vessel guides at three gasifier elevations and two heat exchanger elevations and a compensating strut maintain the vessels in alignment.

FIGURE 14

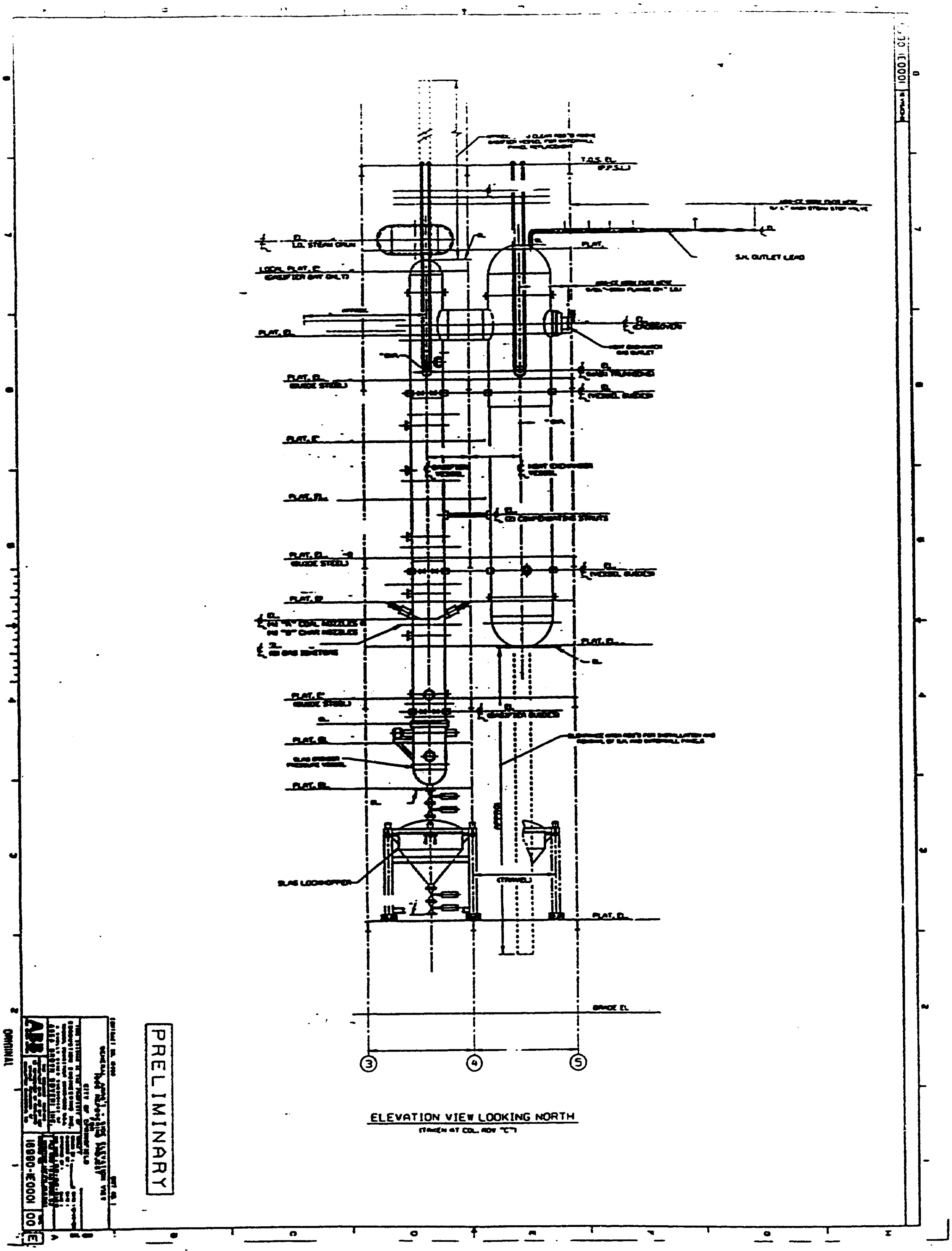

S.H. OUTLET LEAD
SLAG LOCKHOPPER
(TRAVEL)
GRADE EL
3
4
5
ELEVATION VIEW LOOKING NORTH
PRELIMINARY
ORIGINAL

FIGURE 15

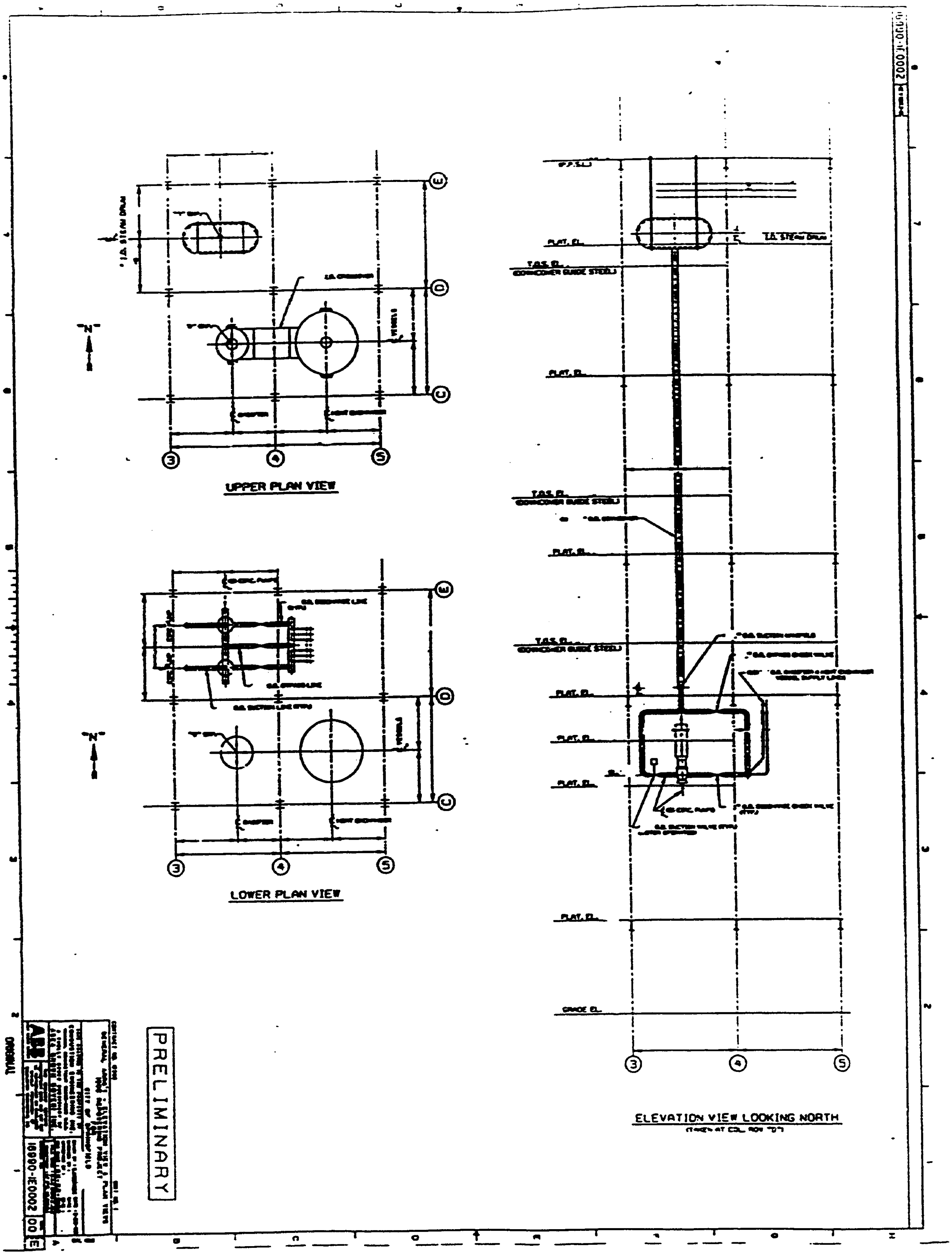
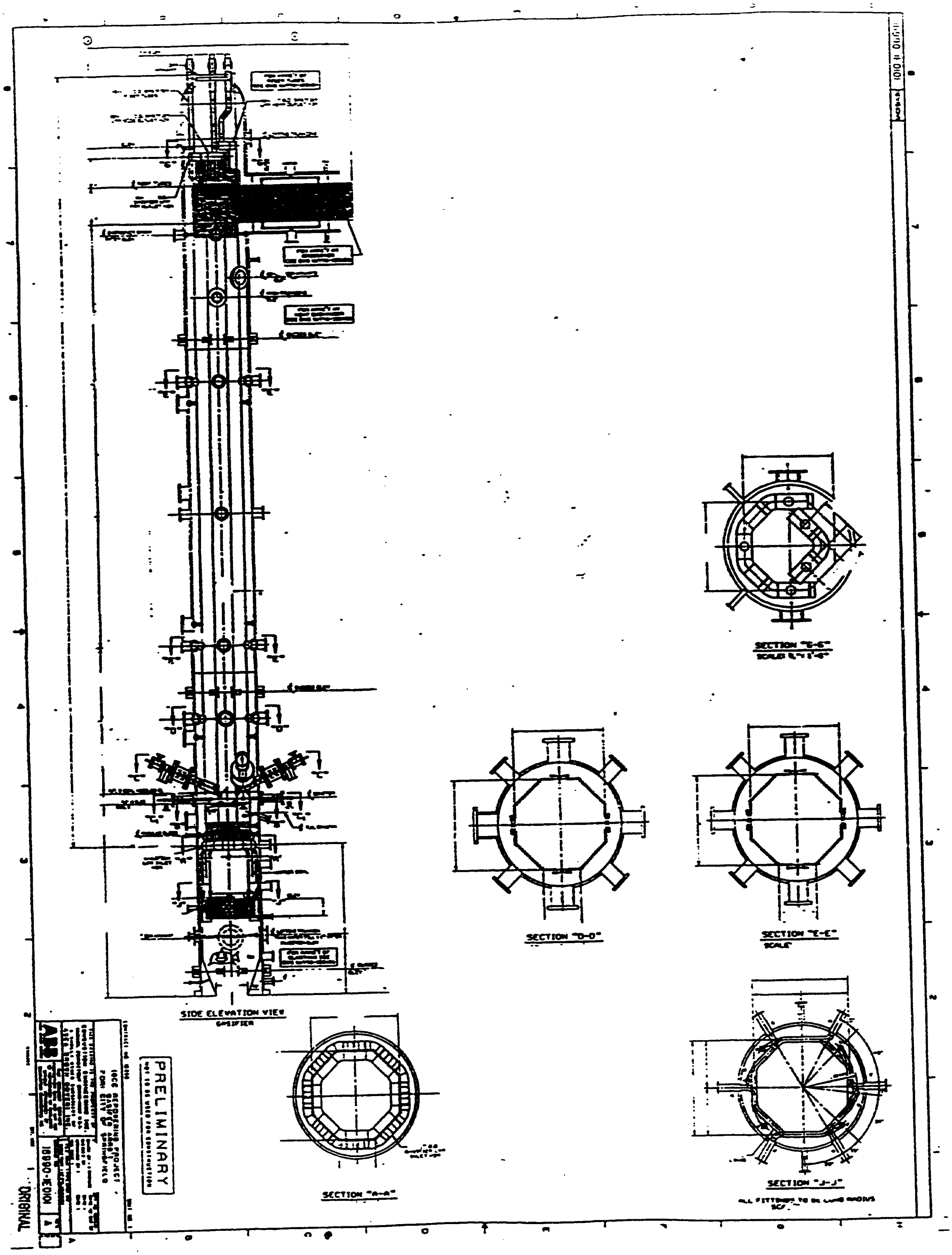

UPPER PLAN VIEW
LOWER PLAN VIEW
ELEVATION VIEW LOOKING NORTH
PRELIMINARY
PLAT. EL.
T.O.S. EL.
GRADE EL.
10000-IE0002

FIGURE 16


SIDE ELEVATION VIEW
GASIFIER
SECTION "A-A"
SECTION "D-D"
SECTION "E-E"
SECTION "G-G"
SECTION "J-J"
PRELIMINARY
ORIGINAL

Located beneath the gasifier is the slag lock hopper with its inlet and outlet double valving. A slag grinder housing pressure vessel follows with an external hydraulic motor. Next comes the coal and char elevations. The SGC shows the steam outlet lead with its valving and the gas outlet to which the product gas fuel pipe is connected. On this drawing access removal areas are shown for pressure part removal for the gasifier and heat exchanger. Also shown is a removal area for a possible future crossover soot blower installation.

The general arrangement Figure 15, DWG 16990-1E0002 shows the plan relationship of the steam drum. An elevation section shows the components of a controlled circulation system. These components are a downcomer, suction manifold, two circulation pumps with their suction and discharge valves, a pump bypass system, and the discharge manifold.

The cross sectional view of the gasifier is shown in Figure 16, DWG 16990- 1E0101. The pressure vessel has a lower flange to which the slag grinder housing attaches to, a head and a horizonal flange to which the crossover is welded to. A portion of the crossover pressure vessel is shown. Enclosed in the pressure vessel are the following: slag tank, enclosure for the waterwall supply tubing, water seal, lower inlet header, vertical waterwalls, the crossover waterwalls, upper outlet headers and riser tubes. Penetrating the pressure vessel are: waterwall feed and relief lines, cooling inlet and outlet lines, coal and char burner assemblies, diagnostic and instrumentation connections.

A slag tank is located at the bottom of the vessel. An inner cylindrical and conical shroud is used to funnel the slag to the grinder. The slag tank water temperature is maintained by an auxiliary heat exchanger. Inlet water is introduced at two locations. The first is tangentially just above the shroud and the second is into the water seal. The cooling water outlet is located behind the shroud at a low point. A water jet system is used to ensure that slag build up does not occur on the conical section.

A water tight expansion loop tubing enclosure is provided in an annular area which is approximately at slag tank water level. The supply tubing for the lower waterwall header is introduced into this enclosure. Within this enclosure supply tubing expansion loops are provided to allow for the differential movement which will exist in transients between the waterwalls and the pressure shell. Each of these feed tubes makes a 300 degree arc before rising vertically for introduction to the lower ring header.

Located above the expansion loop tubing enclosure is the water seal. The water in the seal can either flow over into the slag tank or into an annular cavity between the seal and the pressure vessel wall. This cavity is connected to the slag tank water by drain lines located in the expansion loop tubing enclosure. Located in this cavity are pipe sleeve extensions of the expansion loop enclosure. The supply tubing for the lower waterwall ring header passes through these sleeves. This sleeving minimizes any liquid water which could enter the expansion loop tubing enclosure. The secondary feed of cooling water to the slag tank is introduced into the water seal. The annulus is maintained at a pressure above the gas pass and therefore the water level in the water seal exposed to the gas pass is at the rim and continually overflowing into the slag tank.

The area above the water level in the slag tank is vented to ensure that any gases generated will not pass upward to chill the slag tap. This vent is provided by a nozzle in the pressure shell. In the upper part of the expansion loop enclosure a horizontal passage way is provided which connects the nozzle to a vertical passage way which rises up through the gas side of the water seal. This design minimizes the amount of liquid water which could enter the vent line. Additionally another pressure vessel nozzle and horizontal passageway through the upper part of the expansion loop enclosure is provided for a camera to view the surface of the water to ensure successful removal of slag.

Separate stand pipes are used to monitor the level of the water in the slag tank and to ensure that water is not present in the annulus area. These are located adjacent to the pressure vessel and are connected by passage ways and pressure vessel nozzles. The system which monitors the annulus has one connection to the bottom of the water seal. This connection is part of purge system to ensure the water seal stays free of solids.

Additionally located in this area on the pressure vessel is a manway for access and two trunions which will be used for vessel erection. A pressure vessel nozzle is provided for instrumentation which will measure the vertical differential movement between the pressure shell and the pressure parts.

The gas pass walls between the water seal and the slag tap are bounded by the waterwall lower ring header and the waterwalls. Located in this area is a camera which views the slag tap. These waterwalls rise vertically and form the gas tight bounding walls of the gasifier. At the elevation of this header is a nozzle in the pressure vessel which is used to bleed the annulus area.

A separately cooled water cooled floor is provided. Located in this floor is a opening used as a slag tap and as an access manway. The connecting inlet and outlet lines are routed to pressure vessel nozzles.

All surfaces exposed to gas from the slag floor to the outlet of the crossover are studded and covered with refractory. This includes the slag tap, waterwalls and all water cooled nozzles which penetrate into the gas pass. The waterwalls are of membrane type construction. The penetrations into the gasifier gas pass are three elevations of coal, two elevations of char, four elevations of diagnostic water spray, one elevation of emergency water spray, one elevation of process steam, and one elevation of start-up natural gas burners.

The lowest level of coal and the lowest level of char, are at the same elevation. Primary and secondary air are introduced with both coal and char at this elevation. A water cooled rectangular shaped nozzle is attached in an opening in the waterwalls using a seal box design. This provides for a gas tight design. A burner assembly has been specifically designed for this application. This assembly is attached to the pressure vessel and to the water cooled nozzle.

Natural gas burners are located just below the char nozzles. Provisions for future burners are provided just below the coal nozzles. The natural gas burner assemblies are attached to the water cooled nozzles and to their own pressure vessel nozzles.

The pressure vessel has numerous nozzles for instrumentation connection and access. Nozzles which are multi-function are located on the front of the pressure vessel. A total of five of these flange nozzles are located: just below the slag tap, just below the second elevation of char, just above the second elevation of coal, just above the mid point of the upper two coal elevations, and just under the highest coal elevation. These multi-function nozzles may contain some or all of the following: Ircon for gas temperature measurement, gas sample probe and thermocouple, heat flux measurement, annulus pressure measurement, and gas pressure measurement. Additionally provided is instrumentation for measurement of annulus gas temperature in the vicinity of waterwall penetrations.

At the horizontal gasifier outlet plane gas temperature is measured and pressure vessel nozzles are provided. Pressure vessel nozzles are located in the upper head for measurement of upper head annulus temperature.

At the horizontal exit plane of the gasifier some of the waterwall tubing is diverted to provide coverage for the crossover. The crossover is fully enveloped in waterwall tubing. Tubing is supplied from the rear and the front walls of the gasifier. The tubing which originates from the rear wall serpentine in three loops to cover the floor and sides. Tubing which originates from the front wall makes one loop and provides coverage for the roof. All waterwall tubing exits to upper headers. Links connect these headers to the steam drum. A bellows is used to provide a seal between the link and the pressure vessel. The gasifier internals are supported by lugs at the roof of the waterwalls. Rods transfer this loading into the upper head of the gasifier pressure vessel.

The crossover contains provisions for future sootblowing. These provisions are plenums located on the annulus side of the waterwall panels. The plenums are connected using flexible lines to nozzles on the pressure vessels which are capped. By perforating the fins or installing nozzles in the fins of the waterwall panels a sootblowing system can be field installed. Additionally, the crossover pressure vessel has nozzles to connect instrumentation to measure product gas temperature and annulus temperature. The crossover pressure parts and pressure vessel are mated to the SGC.

The cross sectional view of the SGC is shown in Figure 17, DWG. 16990-1E0102. The SGC is comprised of a pressure vessel and an internal water cooled gas pass which includes convective heat exchange surface.

The arrangement has two vertical passes. Gas enters horizontally from the crossover and is directed into a downward channel then is redirected into an upflow channel where convective surface is installed. The downflow gas pass and the upflow gas pass share a common division wall. Gas then enters a horizontal transition section which is coupled to a removable pressure vessel nozzle.

The supply for the bounding walls of the gas pass is a ring header which is located in the lower head of the heat exchanger pressure vessel. Headers outboard of the side walls are the supply for the division walls. These inlet headers are fed by supply tubes from the discharge manifold of the circulation system.

The front, side, and rear walls exit directly into an upper ring header. The division wall tubes form a water cooled roof section for both passes before exiting into the upper ring header. This ring header is relieved to the steam drum by riser tubes. The riser tubes are connected to the pressure shell by bellows. These bellows accommodate differential movement and tubing expansion loops are not required.

The SGC internals are supported by lugs at the roof of the waterwalls. Rods transfer this loading into a support level. This support level transfers the loads into the pressure shell at the same support elevation as the gasifier.

Where the crossover and heat exchanger pressure parts meet a bellows joint is provided to accommodate differential movements.

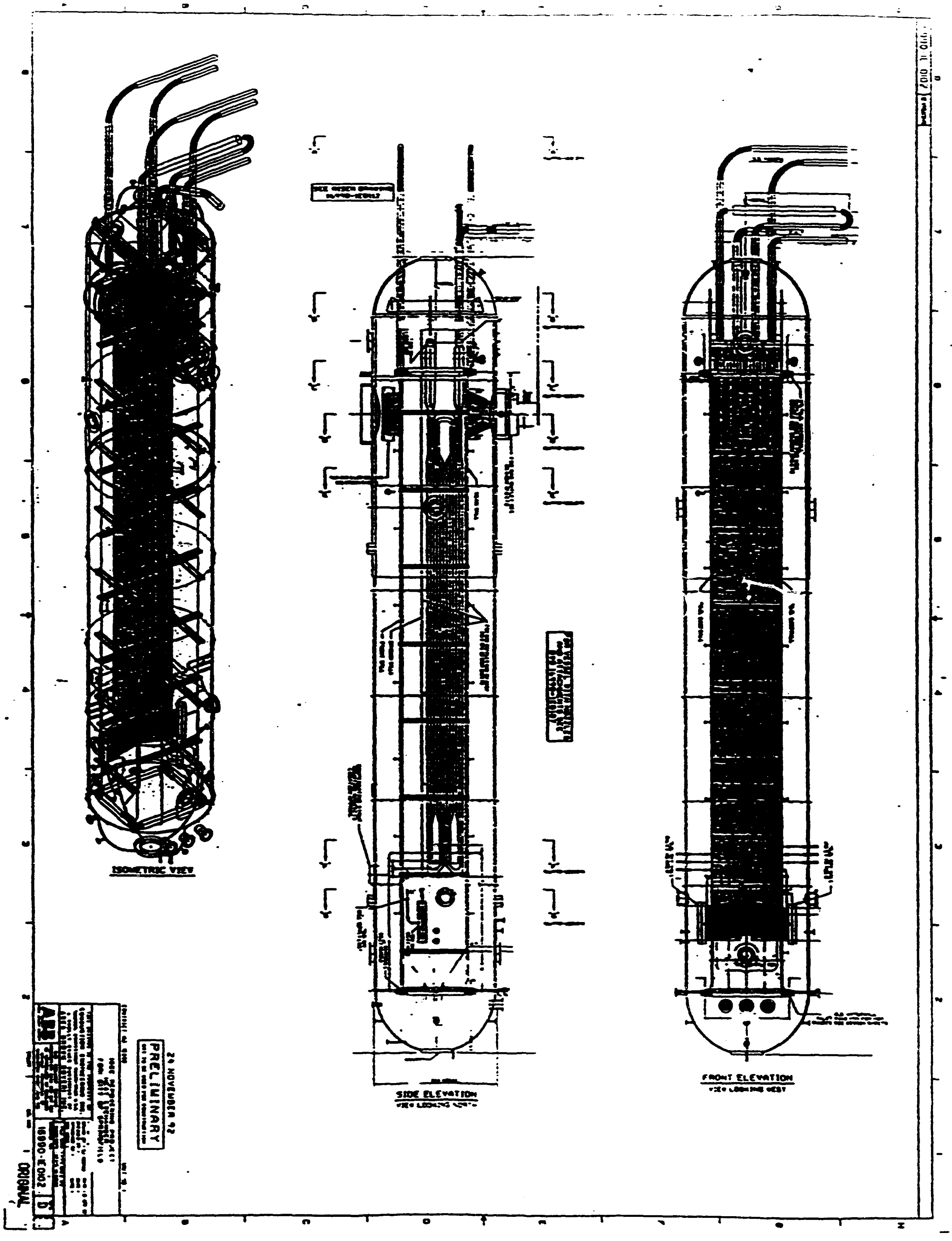
At the gas outlet a bellows is used to connect the pressure part opening to the product gas outlet nozzle. A separate nozzle housing is employed to provide maintenance for the latter bellows. This nozzle is bolted to the SGC pressure vessel and the product gas outlet pipe is bolted to it. The detail of this bellows and nozzle is not shown in the drawing.

Superheat pendants are suspended in the upflow or second pass. The pendants are of three intermesh and double loop design. The inlet and outlet headers for the superheat assemblies are single headers which have internal sectioning so as to create a series of four stages. The header closest to the division wall has no link connections to it. It contains one sectioning plate. The header closest to the gas outlet has an inlet link, link to a desuperheat station, link from a desuperheat station and superheat outlet link. It contains three sectioning plates. All links connecting to the superheat penetrating the pressure shell have bellows joints for sealing at the pressure shell. The superheat terminals tubes are sealed to the waterwall tubes with a conventional sealing arrangement where they pass through the gas pass roof.

Gas baffles are used in the second pass to prevent gas channeling at the walls. Around the perimeter of the waterwalls there are five elevations of waterwall reinforcing.

The pressure vessel has additional nozzles which have not been described. The lower head contains a manway, a vessel drain, nozzles to incorporate a future eductor system to be used if the gas pass return bend requires solids removal, annulus

FIGURE 17



pressurizing injection, annulus temperature measurement and nozzles which provide instrumentation to measure relative expansion movements. The cylindrical portion contains nozzles for future sootblower installation, instrumentation for gas temperature measurement and annulus pressure measurement. The upper head contains nozzles for annulus temperature measurement and for superheat instrumentation connection. The gas outlet housing contains a nozzle for gas temperature measurement.

The pressure vessel contains two elevations of guides, two elevations of trunions used for erection, and the main support trunions.

iv) Transportation Study

This study was done for rail shipment from the CE shop in Chattanooga, Tennessee to the site. It identified the orientation of the vessels for shipping and components which could be shipped with the vessel. Small interferences were identified and these will be addressed during the final design.

v) Construction Studies

This task involved studies for both construction and maintenance of the pressure parts and the pressure vessel. The gasifier and SGC would be assembled in the shop and would be delivered to the site with their internals. Both vessels would have hydrostatic testing performed in the shop. The vessels would be field erected using erection trunions which are located 90 degrees from the permanent trunions. U rods would support both vessels from structural steel when the vessels are in their final location. At this time the crossover pressure parts would be installed. The boiler tubing would be hydro tested. The crossover pressure shell will be provided in half sections. Measurements will be taken and appropriate corrections will be made to ensure the required fit up. Both half sections will be field welded to the gasifier and heat exchanger pressure vessels and inspected.

The pressure parts of the gasifier and SGC are designed to be serviced without cutting of the pressure shells. The gasifier and crossover are designed with a minimum gap between the waterwalls and the pressure vessel. This does not allow for access to the backside of the waterwall tubing for welding. The SGC, however has a minimal amount of space on the backside of the waterwalls to do welding.

The gasifier vessel has a manway in its upper head and a full diameter flange for the slag grinder attachment at the bottom. The wall tubing does not have any buckstay system for wall reinforcement on the back side. The tubing connections to the upper and lower headers are made for orbital welding guidelines. Therefore, individual panels from the octagon can be removed either from above or in half length sections from below. The concept of using window welds for single tube replacement was found to be industrially acceptable. With this concept individual sections of tubing can be removed without requiring access to the backside of the tube.

The crossover waterwall arrangement is such that it is formed in three major sections and can be assembled and disassembled from within the pressure shell. The assembly of crossover tubing is fed by tubes from the rear wall and front wall of the gasifier. For tubing which originates from the front wall two manways are provided for back to access the backside of the tubes. Tubing which originates from the front wall and tubing which returns from the crossover can be serviced on both sides of the waterwall roof of the gasifier.

The waterwalls of the SGC are generally accessible from both sides. The superheat pendants are designed to be removed individually or in an assembly. The superheat terminal tubes above the roof are detailed for conventional welding procedures. Assemblies can be cut loose and can be removed through an opening in the return bend of the gas pass and through a manway in the bottom of the pressure vessel. If required, portions of the division wall can be removed and the downflow pass used for service. If the lower pressure vessel head and some of the lower waterwalls are removed the entire superheat module can be removed.

vi) Heat Exchanger Computer Program.

An existing syngas design and performance computer program was initially used. This program was continually updated and improved. Provisions for in-line surface, parallel surface arrangements, improved gas properties and modified iteration techniques were added. In addition the program was independently verified with hand calculations. It was integrated with a computer program used for HRSG performance predictions to allow for complete steam side analysis.

vii) Transient Studies

The differential movement between pressure parts and the pressure shell during operating transients at locations where those components are attached is required for design. To accommodate these differentials either expansion loops, toggles, flexible piping or bellows are required.

To establish a temperature schedule for the pressure parts as a function of time, preliminary start-up and shutdown performance predictions were made. The cylindrical sections of the pressure shell exchanges heat with only waterwalls. The upper head of the SGC exchanges heat with superheat terminal tubing, headers and links and with waterwall headers and riser lines. The lower head of the SGC exchanges heat with waterwall surface and an insulated access door into the gas pass.

In the gasifier, design movements are required for the feed lines which supply the lower ring header and at each elevation of fuel firing. In the SGC, design movements are required for the supply lines which feed the lower waterwall headers. A computer program was developed using numerical techniques to establish a pressure shell temperature profile using a waterwall temperature profile as input.

For the design temperature of the SGC pressure vessel upper and lower heads a computer program was developed which used the surface temperature, area and orientation of surfaces which would exchange heat with the head as input.

Both a performance and structural analysis was performed for the crossover pressure parts. A computer program was developed which predicted circumferential metal temperatures in the pressure shell during heat up and cool down. This used a waterwall temperature profile and considered annular heating of horizontal cylinders. A top to bottom temperature pressure shell differential versus time was generated and used as an input for the structural analysis. The results of this preliminary work indicated that a more complete analysis would be required during the design phase.

The performance of the water seal during transients controls the pressure differential across the waterwalls. The water seal received a cursory design and this established a design pressure differential for the waterwalls. The boundary conditions for a more complete analysis were established and this work will be done during the design phase.

Wherever lines that penetrate the pressure shells have a substantially different temperature than the pressure vessel, the design of the pressure vessel nozzle requires special consideration. The temperature differential can occur during transients or steady state. The special consideration is a design using a thermal sleeve construction. Design pressure vessel nozzle differentials were determined. The SGC product gas outlet nozzle was considered the most unconventional. For this nozzle a finite element model was developed for the design of this nozzle.

viii) Circulation System

A circulation system analysis was performed. The waterwall system was designed to ensure that sufficient mass flow exist at all times in the tubing to prevent overheating. Design heat absorption rates and where applicable horizontal differential rates were established. Waterwall metal temperatures were predicted and fin widths between tubes were established. Flow rates for the high heat absorption of the gasifier combustor and horizontal circuits were established. A tube diameter of 1 1/4 inch was selected. This small diameter tube was selected to provide an overall reduced quantity of recirculated water and a tube size which would be easily manipulated during field modification. The reduced quantity of recirculated flow results in a minimum number and size of supply and relief lines. The supply tubing is used to bias the flow as required to circuits.

A mechanical shaft seal circulation pump was selected. A circulation pump by-pass system was incorporated. The by-pass system would be automatically used during loss of circulation pump power events. A preliminary investigation into natural circulation was performed with optimistic results.

ix) Superheater

The superheat sections are placed last in the SGC gas pass. The high temperature of this surface ensures that the outlet gas temperature over the load range will be maintained high to meet the requirements of the HGCU system. In addition desuperheat spray is used as a method to further increase the quantity of superheat surface. This surface is located in a gas temperature environment were tight spacing can be used and tightly spaced vertical surface was selected. This type of surface operates relatively clean and there is no requirement for sootblowing.

The superheat is in a pendant arrangement. The metal temperature in superheat tubing is the sum of the steam temperature plus the rise due to heat transfer. Because of this the leg temperatures of the pendants are different. With this characteristic, the expansion growth of different legs makes the entire assembly distort and arc. A swing or horizontal movement of the bottom results. Each leg of the assembly grows a different amount. The legs are attached together and each leg forms an arc about a common center point. The gap between legs along with the differential vertical movement determines the horizontal movement. The geometry of the assembly selected was of an intermesh of three and a double loop. A center cavity in each return loop is maximized to reduce the swing. In addition each leg is made of materials with different expansion characteristics in an effort to make the growths of all legs equal. Using these two techniques the horizontal movement at the bottom of the assembly is kept to a minimum. The gap that results is still larger than acceptable and gas baffles are installed along the walls to divert the gas toward the middle of the assembly.

The SGC is designed to operate relatively free of fouling. A fouling factor consistent with this condition was used for performance design. Performance was calculated for a range of fouling to ensure that performance can be met and that the proper metals were installed.

The superheat assemblies are arranged in four series stages. This is accomplished by sectioning of the headers. For the gas pass plan selected this arrangement provides the required steam mass flows, tube OD, assembly length, tube spacing and steam side pressure drop. Desuperheat spray injection is provided interstage between the first two stages and the last two stages.

x) Burner Development

The design of the coal burners at elevation A and the char burners at elevation D required development. Both coal and char use the same concept. This burner provides for the introduction or either coal or char, primary air and secondary air into the gasifier gas pass. The burner assembly consists of components which are rigidly connected to the waterwalls of the gasifier and components which are rigidly connected to the pressure vessel. During transient conditions there is vertical differential expansion between the pressure parts and pressure vessel. A design capable of accommodating this differential is required.

Natural gas ignitors are located just below the fuel nozzle assemblies. The ignitor heads share the same waterwall opening as the fuel nozzles. Separate pressure vessel nozzles are provided for the ignitor assemblies just below the fuel burners. The ignitor assembly includes air and natural gas connections. This assembly is allowed to pivot as it is connected to the pressure vessel nozzle with a bellows.

A mock-up was built to demonstrate the fuel nozzle design concept. Construction representatives found that all parts of the assembly were accessible for maintenance. A differential movement test was performed. During this test a movement equal to the maximum predicted was applied for the number of cold start-ups that were expected.

xi) Slag Tap

The slag tap is the opening in the floor of the gasifier combustor. This floor is water cooled and has inlet and outlet lines which penetrate the pressure shell. It slopes from the octagonal waterwalls at an angle and has a opening for slag flow. This opening also serves for access. The tubing is arranged in a number of circular hairpin return bends. It is of loose construction with minimum gaps between the tubing. It is supported from beneath by brackets cantilevered off the waterwalls at three locations. An uncooled stainless steel drip edge is located at the ID of the opening. The tubing facing the combustor is studded and covered with refractory. The refractory on the sloping floor is a continuation of the refractory on the vertical waterwalls.

xii) Slag Grinder

The slag grinder is enclosed in a separate housing and has an external hydraulic motor drive. This housing has the outside dimensions of the gasifier and is bolted directly to the bottom of the gasifier pressure vessel. The full diameter flange offers many advantages in gasifier initial assembly and maintenance.

A slag quench tank is located in the gasifier pressure vessel. A transitional shut section of the gasifier slag tank directs slag into the grinder. The grinder is a ABB/CE Single Roll Clinker Grinder. The slag grinder is located in the top of the vessel and is supported by brackets welded to the pressure vessel walls. The vessel has a manway for inspection. The bottom end of the vessel has a head which terminates in a flange to which the slag lock hopper inlet valves connect. A discharge cone is welded to the inside of the vessel in the hemispherical region to allow free flow of slag into the lock hopper. Clean out nozzles are provided above the cone.

The supports for the slag grinder are equipped with adapters to allow three directional movement of the grinder so that the shaft alignment can be fine tuned with the vessel wall penetration and the hydraulic motor. The hydraulic motor shaft penetrates the vessel wall to connect the grinder shaft with a split coupling. The wall penetration is sealed with a stack of Grafoil packing rings. The shaft sealing concept simulating actual design conditions will be tested at ABB/CE.

The hydraulic motor has an auxiliary power unit and controls.

xiii) Gasifier and Syngas Cooler Cost Estimate

The cost estimate for the gasifier and SGC was assembled with pricing provided by the CE shop in Chattanooga, Tennessee, CE in Windsor and Lummus Crest. A comprehensive package was prepared for the CE shop. Included were sixteen drawings, eight sketches, and fourteen documents. This package defined the pressure shells, pressure parts and most of the internal components. The pressure parts include tubing, headers, piping, and the steam drum. Typical components priced in Windsor included: controls, slag grinder, firing system, support guides and struts, circulation pumps, and expansion joints. Typical Components priced by Lummus Crest include: auxiliary piping, valves, support steel, insulation and lagging, and field erection.

L) Balance of Plant

i) Coal Handling

Coal Delivery and Handling System PFDs were developed by ABB Lummus Crest and issued for client approval in June. Client approval was received in November, and the PFDs were subsequently issued in November as Approved For Design (AFD) documents.

Following issue of the AFD PFDs, work commenced on the development of equipment data sheets for the coal handling equipment. The procurement strategy for this equipment is to have one vendor supply all of the equipment as a package system.

The plan for 1993 was to complete the equipment data sheets to AFD status and develop and issue a requisition to obtain competitive bids for this equipment. After receipt of the bids, ABB Lummus Crest would perform a technical and commercial evaluation and the successful vendor's pricing will be used in the updated cost estimate.

One area of concern was the increased cost of the current coal handling system versus the original concept. The current system includes a common coal pile area for both the gasifier and Lakeside II boilers 7 & 8, as well as a coal stacker. As the plot plan developed, it made sense from a space utilization standpoint to provide a common coal pile. As far as the addition of a coal stacker, this was a requirement that surfaced during the approval process of the conceptual plot plan. CWL&P required the coal stacker on the basis of their experiences at the Dallman Station. It significantly improves the operability of the coal handling system to include a stacker, and from this standpoint ABB Lummus Crest concurred with CWL&P.

ii) Slag Removal and Handling

The flowsheet and layout basis for slag collection and in-plant storage was the result of various comparison studies by ABB Lummus Crest, ABB Combustion Engineering, and CWL&P during Budget Period 1. It is important to note that the original project basis assumed that gasifier bottom slag would be sluiced to existing ash holding ponds on CWL&P property. This concept was rejected during Budget Period 1 due to future permitting concerns. Two alternates were then evaluated; 1) a hydraulic system and 2) a scraper conveyor concept utilizing an on site slag pile with frequent front end loading to trucks. Both alternatives required the gasifier slag to be trucked to an unidentified off-site location for landfill. As the lowest cost alternative, the scraper conveyor option was selected as the basis for Budget Period 2 cost estimates, layouts and basic engineering.

Gasifier slag is quenched in an water filled vessel internal to the gasifier pressure vessel then periodically removed using a single slag lockhopper system. In October 1992, the vessel capacity was increased in size to allow 4 hours holdup. The equipment arrangement and layout for the lower section of the gasifier and lockhopper was also revised. The lockhopper support system was changed by CE so that the vessel could be supported independently of the gasifier and be moved on rails from under the gasifier structure to permit inspection, and replacement of the gasifier water walls and other equipment tied to the gasifier.

ABB Lummus Crest developed the Piping and Instrument Diagram for the slag lockhopper system. The equipment specification covering the slag lockhopper was issued by ABB Lummus Crest for competitive bids in November 1992 and quotations received in December from 4 potential suppliers.

The Process Flow Diagram for the Slag Handling System was issued in November 1992. In December the Piping and Instrument Diagram was initiated. Process data sheets for the Slag Handling System were also completed in November.

iii) Sulfur Recovery

During Budget Period 2 sulfur recovery systems for the CE-IGCC Repowering Project consisted of hot gas desulfurization followed by conversion of sulfur rich regeneration off-gas to a marketable sulfuric acid.

Previously during Budget Period 1, ABB Lummus Crest evaluated several alternative combinations of process technology to determine the best fit for the CE-IGCC project in terms of capital and operating costs, technical maturity and viability and environmental performance. This evaluation, issued to Combustion Engineering and City Water, Light and Power in October 1991, recommended sulfuric acid production as the best fit to meet the project requirements. At that time both the hot gas desulfurization process (provided by General Electric Environmental System Inc.) and more conventional desulfurization technology (COS hydrolysis and ammonia removal followed by MDEA absorption of H_2S) were included in the plant basis of design with the latter as 'back-up contingency' in the event the former 'emerging' technology experienced operational problems. Sulfuric acid production not only was identified by ABB Lummus Crest as the best fit in combination with the two alternate sulfur removal systems but in particular was advantageous if considered only in combination with the hot gas desulfurization process.

As follow-up to the report in January 1992, ABB Lummus Crest provided marketing studies for sulfuric acid production which indicated favorable local midwestern outlets. Local sulfuric acid suppliers/distributors were also contacted to solicit possible business arrangements for the collection and resale of the byproduct sulfuric acid during the CE-IGCC project demonstration period. A promising response was received from G. S. Robbins and Co., Decatur, Illinois.

In March 1992, ABB-CE approved sulfuric acid production as the recommended sulfur recovery option for the project. CWL&P requested more time to make this key design basis decision.

In May 1992, ABB Lummus Crest arranged joint meetings with CE, GEESI and CWL&P at Monsanto Enviro-Chem Inc.'s offices in St. Louis, Missouri. Monsanto presented their background and experience as a leading supplier of sulfuric acid technology and related engineering, procurement and construction capabilities and answered questions and concerns raised by representatives of the project participants. The presentation was followed by a Monsanto arranged plant tour at American Cyanamid's sulfuric acid plant in Hannibal, MO.

In June 1992, CWL&P approved the ABB Lummus Crest recommendation to incorporate the sulfuric acid unit into the project definition.

Following the cost estimate submitted by ABB Combustion Engineering in July, 1992, cost reduction studies resulted in dropping the conventional sulfur removal 'backup' system from the basis of design.

During 1992, ABB Lummus Crest provided a factored cost estimate for conventional sulfur removal systems and coordinated and integrated the hot gas desulfurization process as provided by GEESI into the overall plant design.

With regard to conventional technology, in early 1992 it was decided to limit the scope of work associated with conventional sulfur removal facilities to preparation of a factored cost estimate and to provision of space on plot plans and gasifier structure layouts for "future installation" only. This strategy would minimize up front project capital expenditures while at the same time permit lower future costs should the hot gas desulfurization process require major modifications or replacement during demonstration. Subsequent to this decision ABB Lummus Crest developed equipment data sheets and prepared the factored cost estimate of the conventional sulfur removal facilities.

In August 1992, as part of the Cost Reduction Studies all requirements associated with conventional sulfur removal were deleted from the project scope.

In April 1992, CE completed a contractual agreement with GEESI for Budget Period 1 scope of supply on the Hot Gas Cleanup System. GEESI submitted their completed Budget Period 1 design package in September, 1992.

The GEESI Budget Period 1 package consisted of preliminary process flow diagrams, equipment conceptual data sheets, a suggested equipment layout and piping and instrument diagrams.

An order of magnitude cost estimate for the HGCU was provided by GEESI in June, 1992.

During preparation of the package ABB Lummus Crest and GEESI resolved certain interface issues including overall space requirements, regeneration air supply conditions and source, and off-gas battery limit conditions applicable to the sulfuric acid unit specification.

Major comments still to be resolved with GEESI at year end involved data sheets, equipment mechanical design conditions, P&ID inconsistencies with data sheets, analytical requirements and plant safety and operation details.

Following cost reduction studies in August and September 1992, which established a new plant design coal capacity, ABB Lummus Crest prepared and issued in October a comprehensive Request for Proposal to Monsanto EnviroChem Inc. and Lurgi Corporation to obtain competitive Lump Sum Turnkey Engineering, Procurement and Construction quotations for the sulfuric acid unit.

A proposal was received from Monsanto Enviro-Chem in two parts; 1) a technical definition including preliminary flow sheets, equipment definition, plot plan, operating requirements and basis for air permitting was received in November, 1992, and 2) a commercial proposal was received per request in mid-December 1992. A preliminary technical definition was received from LURGI in December.

As a result Monsanto Enviro-Chem's technical package was used as the basis for Lummus Crest Inc's basic engineering activities at the close of 1992. This included development of the P&ID acid unit interface drawing to coordinate the GEESI and Monsanto units and input into the preparation of BACT and air modeling documents developed by ABB-Environmental Services Inc. The overall plant layouts were also modified based on the Monsanto technical package.

ABB Lummus Crest completed the technical and commercial tabulation for Monsanto Enviro-Chem bid in January, 1993.

iv) Booster Compressor

The AFD data sheets for the booster compressor with the variable speed motor drive were developed by CE and jointly reviewed by ABB CE and ABB Lummus Crest and issued in October, 1992. The AFD data sheets for the booster compressor inlet cooler were issued by ABB Lummus Crest in November, 1992.

A major cost component of this system is the inclusion of a variable speed drive deemed necessary by CE and ABB Lummus Crest to meet goals for efficient operation at gasifier turndown.

The booster compressor PFD showing these pieces of equipment was issued "Approved for Design" in November, 1992.

A requisition for the booster compressor was issued in November, 1992. Bids were received and sent to engineering for bid tabulation on December 17, 1992. Bids were received from Dresser and Allis-Chalmers. Elliott chose not to bid.

A requisition for the booster compressor inlet cooler #1 was issued in November, 1992. Bids were received in January, 1993 from Shell and Tube Inc., Ohmstede Inc. and Hughes-Anderson Inc. Texas Metal Fabricating Co. did not bid. Bid tabulations will be initiated in 1993.

The air booster compressor P&ID was issued for screening in December, 1992. The air booster compressor lube oil system P&ID will be started after supplier drawings were received.

v) Gas Turbine

GE's July, 1991 technical proposal served as the starting point for developing a complete technical package that would serve as the basis for a purchase order from CWL&P to GE. At the time this process started, CWL&P anticipated issuing a purchase order in mid-summer of 1992.

In March 1992, LCI reviewed GE's technical proposal and transmitted those comments and clarifications to GE along with a request to schedule a GE/CWL&P/LCI/CE meeting in April 1992 to resolve the remaining technical issues and assess the commercial impacts of some of the requested changes.

A meeting was held in Springfield on April 9, 1992 with participants from LCI, GE and CWL&P. The meeting resulted in a few additional action items for each of the participants, primarily GE. After receiving the final pricing data from GE, LCI developed a spread-sheet of price adders and deducts and made recommendations to CWL&P regarding items that should or shouldn't be incorporated in the technical package. On May 4, 1992, CWL&P responded to the LCI fax with their final list of adders and deducts that were to be included or excluded from the technical package. This list was transmitted to GE to serve as the basis for an updated GE proposal scheduled to be issued in June 1992.

After issuing the updated proposal, a Design Finalization Meeting was held in Schenectady, New York, with participants from GE, LCI, CWL&P and CE. In GE terminology, the Design Finalization Meeting normally initiates the kickoff of a recently signed purchase order. Since this project had not progressed to the stage of issuing a purchase order, this meeting resulted in the identification of a GE project team and in addressing further technical clarifications. GE also committed to a preliminary drawing schedule which would support LCI cost estimate activities.

Based on the results of the Design Finalization Meeting and further clarifications from LCI and CWL&P, GE issued an updated technical proposal in July, 1992.

However, subsequent to the preliminary cost review, CWL&P decided to defer issuing a purchase order for the gas turbine.

GE did supply the basic arrangement and layout drawings LCI required to complete the plot plan work.

vi) Steam Turbine

Early in the year much discussion ensued regarding the selection of a cycle configuration to achieve the desired 60 MW net plant output at 95°F ambient conditions. Selection of a cycle configuration was necessary to properly size the steam turbine generator and commence with development of the specification and requisition for the turbine.

In late April 1992, LCI completed a cycle study consisting of 3 different modes of operation and presented it to CWL&P for their approval. On May 1, 1992, CWL&P transmitted their decision on the selection of an operating mode. This operating mode became the design basis for the cycle configuration. To achieve 60 MW net plant output at 95°F ambient conditions, the gas turbine would be base loaded on coal gas and the HRSG would be supplementary fired with natural gas.

This decision was needed to proceed with completion of the Combined Cycle Process Flow Diagram. This PFD was issued in early June and approval from CWL&P was received on June 30, 1992. With an approved PFD LCI commenced on the development of a steam turbine generator specification and requisition.

On July 21, 1992, LCI submitted the steam turbine generator requisition to CWL&P for approval. However, subsequent to the cost review, CWL&P decided to defer the issuing of a purchase order for this equipment.

In October, LCI issued a requisition to six potential suppliers, received bids at the end of October, completed a technical evaluation of the proposals in December and commenced on the commercial evaluation of the bids. The LCI plan for 1993 was to complete the commercial evaluation and utilize the selected supplier's pricing and technical data in the updated cost estimate due in April.

vii) HRSG

The HRSG for this plant is a CE designed unit. Several iterations were carried out in the design of this component. The results of the cycle investigations mentioned earlier were used to come up with the final configuration. After the design basis was established, the arrangement of the HRSG was finalized and a cost estimate was made. The physical dimensions of the HRSG were established on a preliminary basis and this information was used in the plant arrangements generated. At the end of 1992, the detailed physical dimensions were not yet established pending the start of detail design.

viii) Plant Layouts

a) Gasifier Island

In 1992 ABB Lummus Crest Inc. developed conceptual equipment layouts using PASCE computer design software for the following systems included in the Gasifier Island Structure:

- Coal Handling and Feeding
- Gasifier and Heat Exchanger
- Slag Removal
- Char Removal and Recycle
- Hot Gas Desulfurization

Early estimates of the expected shape and possible elevation of the gasifier structure were used primarily as input into preliminary air permit modelling studies conducted by ABB Environmental Services in April 1992.

The early 1992 gasifier island layouts also included space in the structure for future installation of a conventional sulfur removal facility based on equipment data developed by ABB Lummus Crest. These early layouts were upgraded as the following information and revisions were received by ABB Lummus Crest:

August 1992	Deleted requirements for future installation of conventional sulfur removal
September 1992	Received preliminary layouts, equipment data and P&IDs for Hot Gas Desulfurization from GEESI

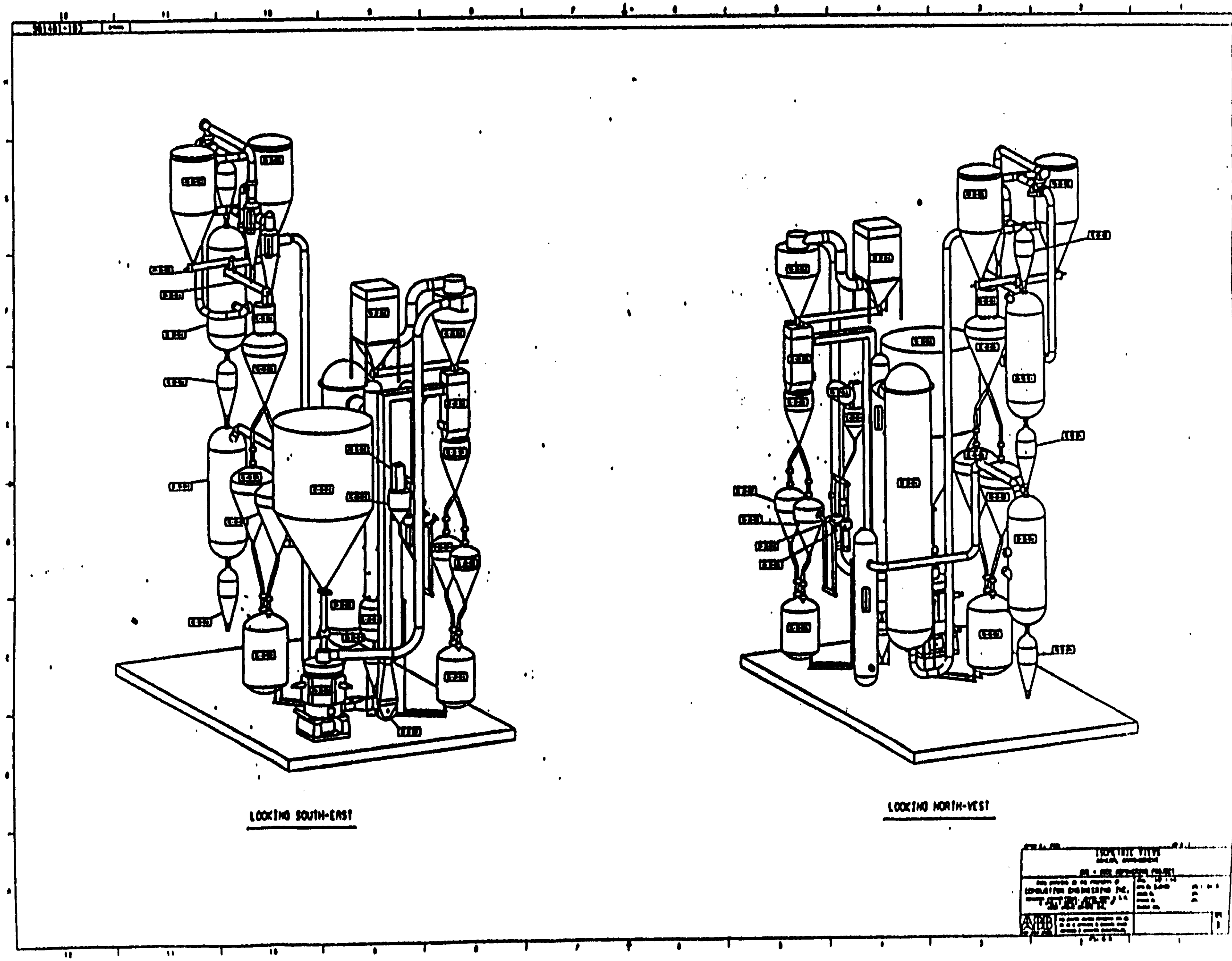


FIGURE 18

October 1992 Received Approved For Design Equipment Data Sheets for coal handling, feeding, char removal and recycle systems from ABB Combustion Engineering

November 1992 Received gasifier/heat exchanger dimensional, layout and maintenance requirements from ABB Combustion Engineering

December 1992 Developed for screening issue of Gasifier Island P&IDs

An important factor which prevented further development in the gasifier island layouts was the lack of size and weight of special equipment which are specifically dependent on supplier engineering and quotations. These include the coal baghouse and pulverizing system and the hot char removal equipment - baghouse, cyclone and hot rotary feeders. Requisitions for these equipment were prepared by ABB Lummus Crest on a priority basis as the process data become available in October 1992. Competitive quotations were received in early December 1992 and technical evaluations initiated to select a single supplier.

At the close of 1992, 22 gasifier island plans and elevations were identified and initiated. These were to be the basis in conjunction with the P&Ids, equipment sizing and steel structural layouts to develop the definitive cost estimate by April 1993. Figure 18 shows an isometric view of one of the early gasifier island arrangement plans.

b) Lakeside Building

At the completion of Budget Period 1 overall layout studies had been completed to optimize the arrangement in the Lakeside Building of the major combined cycle equipment - (Gas Turbine Generator, HRSG, Steam Turbine Generator and Stack). Per CWL&P requirements the various alternative layouts incorporated provisions for a 'future' combined cycle unit of equal capacity to the CE-IGCC Repowering Project basis. Several alternatives were compared in terms of both performance and cost. The results were submitted to ABB Combustion Engineering and CWL&P and one option was selected as the design basis for Budget Period 2 work.

During 1992 ABB Lummus Crest concentrated work on the civil/structural aspects of the Lakeside Building with respect to foundations, use of existing floors and structures, architectural plans and demolition requirements. This work must be done as the prelude to piping location plans for the smaller auxiliary equipment associated with the combined cycle and utility support systems.

A chronology of the work performed is as follows:

May 1992 Issue of Building Location Grid Plan - Approved for Construction

June 1992 Initiated foundation and floor plans and sections-22 Drawings

August 1992	Issued standards and details covering anchor bolts, paving, foundations, ladders, cages, handrails, stairs, grating, platform and vessel clips - 11 Drawings.
October 1992	As part of the Cost Reduction Studies - Relooked at previous layout options and submitted recommendations to CWL&P. CWL&P chose to retain the original layout as the basis for the 1993 cost estimate.
November 1992	Developed 32 architectural plans and elevations as basis for the 1993 cost estimate (70% complete).
November 1992	Developed 32 steel framing and cross-section plans as basis for 1993 cost estimate (70% complete).

c) Overall Site Plot Plans

An overall conceptual site plan was developed by ABB Lummus Crest in 1992. The site plan, Dwg E-06851-00010A, was used in early 1992 as a basis for the factored cost estimate prepared by ABB Lummus Crest in April. The plan was continually updated as key information became available. In particular considerable input was developed by working closely with CWL&P with regard to the coal handling and receiving system, construction philosophy, sulfuric acid unit and electrical substation. Integrating traffic and roadway access for coal delivery and slag removal in relation to the existing Dallman and Lakeside facilities was an important accomplishment.

Figure 19 shows a conceptual plot plan of the site. Figure 20 shows an isometric view of the plot plan which makes it easier to visualize the installation.

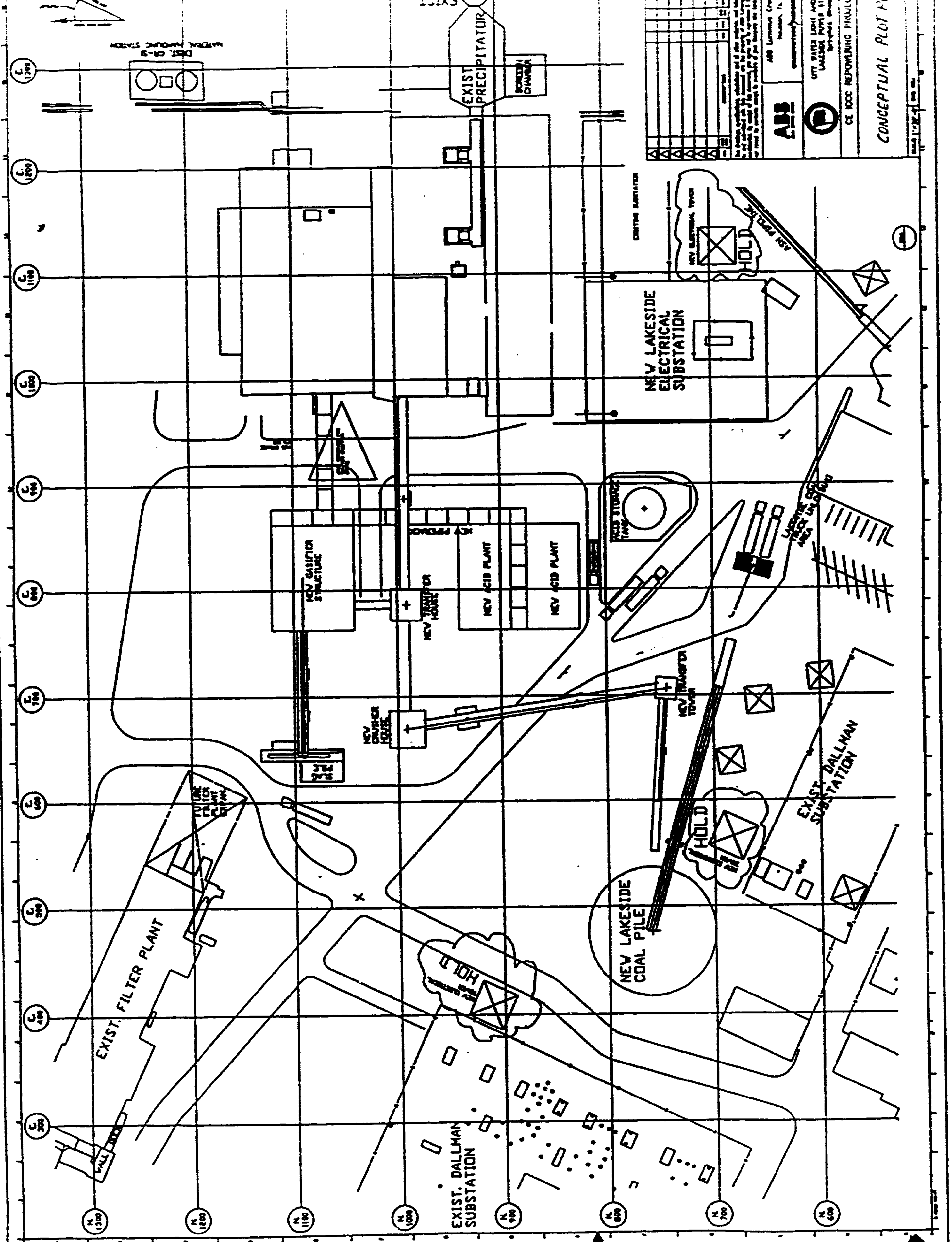
At the close of 1992, the site plan has been updated to include information for the sulfuric acid plant, construction crane location and water treatment systems associated with the combined cycle and gasifier systems.

ix) CWL&P Interfaces

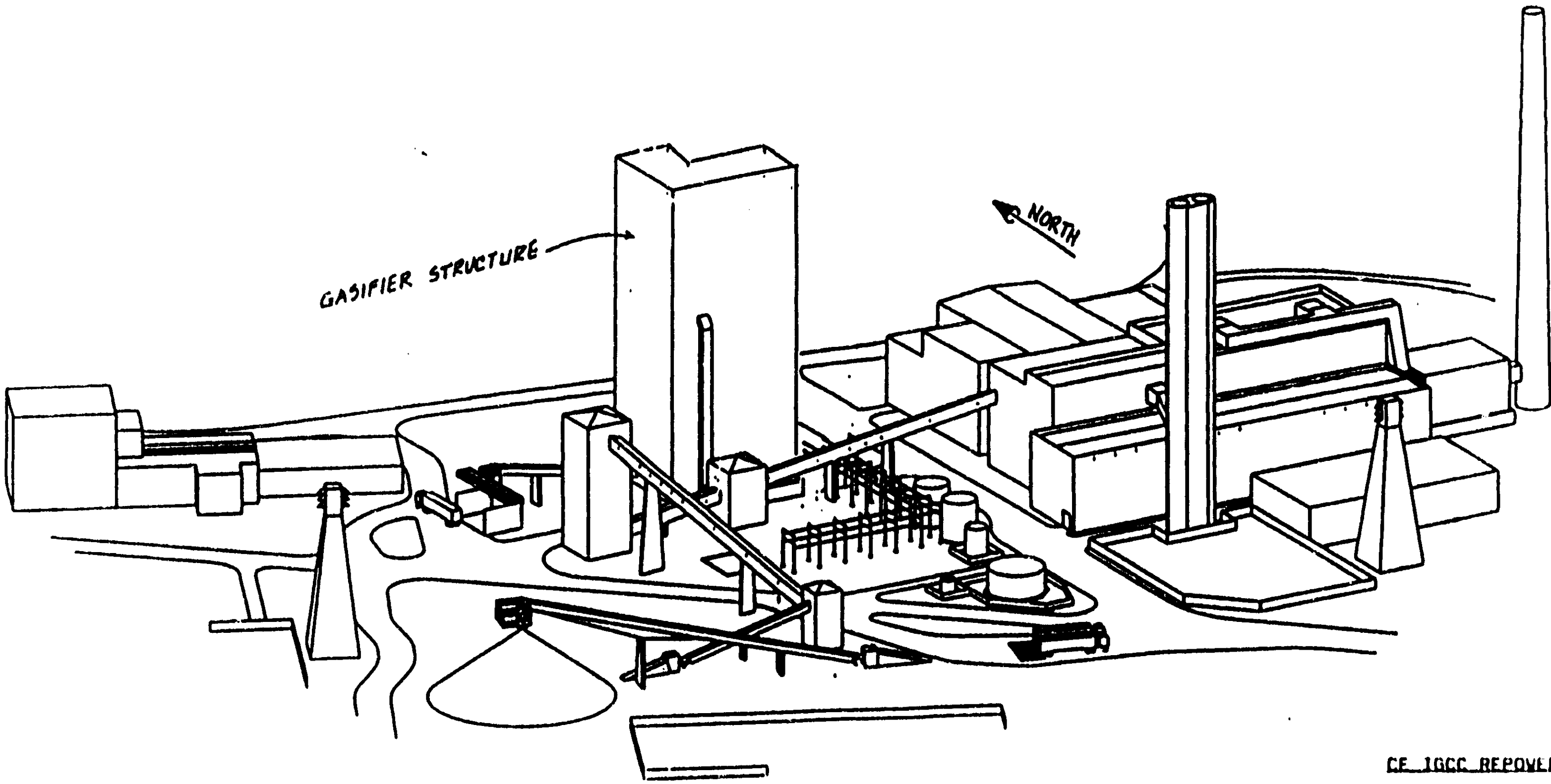
ABB Lummus Crest Inc. interfaced with CWL&P in a number of areas to establish a consistent design basis that would enable ABB Lummus Crest to proceed with the Budget Period 2 work. These areas included defining a split of work scope for the electrical system, defining the technical requirements and mapping out a procurement strategy for the gas turbine generator and steam turbine generator, defining coal handling requirements, finalizing the project design questionnaire, reviewing possible cost reduction measures for implementation and defining a ABB Lummus Crest/CWL&P interface strategy for completing the cost estimate.

Efforts began in December, 1991 to establish a split of work scope. A meeting was held among ABB Lummus Crest/CWL&P/Burns & McDonnell personnel to start the process on December 11, 1991. In February 1992, a basic agreement was reached. CWL&P's agent, Burns & McDonnell, would provide the design and the overall one-line

FIGURE 19



EXIST. STACK
EXIST. PRECIPITATOR
NEW LAKESIDE ELECTRICAL SUBSTATION
HOLD
NEW GASIFIER STRUCTURE
NEW ACID PLANT
NEW ACID PLANT
NEW TRANSFER HOUSE
NEW CRUSHER HOUSE
NEW TRANSFER TOWER
EXIST. DALLMAN SUBSTATION
NEW LAKESIDE COAL PILE
EXIST. FILTER PLANT
EXIST. DALLMAN SUBSTATION
CITY WATER LIGHT AND POWER LAKESIDE POWER STATION
CE 100C REPOWERING PROJECT
CONCEPTUAL PLOT PLAN



CE IGCC REPOWERING PROJECT

CONCEPTUAL PLOT PLAN
LOOKING NORTH 30 DEGREES EAST

11-19-92

FIGURE 20

diagram for the high voltage substation. This would be funded through CWL&P's renewal and replacement funds. ABB Lummus Crest would specify, procure and install the high voltage substation equipment utilizing project funding. ABB Lummus Crest's engineering responsibilities would begin with the routing of 13.8 kv cables to the substation transformers.

ABB Lummus Crest required significant input from CWL&P to finalize the project design questionnaire, the primary document which defines design bases. Initial input was obtained from CWL&P in 1991, but in April, 1992 the project design questionnaire was issued for approval to CE and CWL&P. CWL&P issued their comments on the document in June, 1992. After receiving approval from ABB Combustion Engineering, the project design questionnaire was issued approved for design on August 20, 1992. Following implementation of cost reduction measures, the design questionnaire was updated and reissued in December, 1992.

M) Cost Estimate

At the end of 1992 the cost estimate was still being developed. A working cost estimate was established by taking the BP1 numbers and changing the individual line item values as better numbers were established. However, the majority of the cost estimate requires that all of the engineering work described above be done before more accurate numbers are obtained. This method produces intermediate numbers that are usually very conservative and early numbers have been higher than expected. Because of this several studies were undertaken to determine if the cost could be reduced.

N) Cost Reduction Studies

A cost reduction study was undertaken with the intention of identifying areas which may be able to significantly impact the total costs of the plant. A list of 55 items was developed and the cost impact for each item was estimated. The problem with many of the suggestions was that the savings in capital cost was offset by penalties in plant heat rate which increases operating costs. Some of the items affected the safety or reliability of the plant and a decision had to be made whether the savings were justified.

The first attempt at cost cutting was successful, however, by reducing the capacity of some equipment which had been originally sized more conservatively then necessary. This capacity reduction was compatible with the selected design conditions described above. The difference in cost was enhanced by the effects on the plant arrangement due to a reduction in size of some equipment.

As the cost estimate is being developed, additional areas for cost reduction are being identified and evaluated.

O) Support Studies

i) Materials Studies

A study was undertaken to determine which materials should be used in the gasifier and other areas of the plant. This was necessary because much of the equipment used will be seeing conditions of temperature, pressure, and composition not usually encountered in previous applications. The purpose of this study was to identify non-standard applications and compare them against the current knowledge of materials in this application.

A preliminary report for recommended materials for use in the gasifier at suggested temperatures and pressures was put together April 30, 1992. The use of alloys with increasing chromium content, reinforced by surface chromizing, was based on the results of laboratory and pilot testing by CE for the Department of Energy (DOE) during the 1977-81 test period as well as the successful use of chromized tubing in sulfidizing atmospheres in operating fossil fuels and chemical recovery boilers. Most of the materials selection is largely based on in house test programs under DOE contract and others are taken from references.

The following equipment was identified as requiring special material consideration: pressure vessel, gasifier water walls, convection section (evaporator, low temperature superheater, intermediate temperature superheater, high temperature superheater), transitional hopper, lock hoppers, flow feed lines, nozzles, and connector section hopper.

A revision of the preliminary report was made in August 1992. Additional equipment was added for material suggestions including: crossover duct, heat exchanger vessel, heat exchanger waterwalls, char and natural gas nozzles. Also, some changes were made in the temperature suggested for the pressure vessel and gasifier water walls. A different material was suggested for the lock hoppers.

In the final report most suggestions were not changed. More detail was given as to why certain materials would be best for operation based on laboratory and/or field experience and a section for recommendations was included at the end. The recommendations were reviewed by experts in fuel transport and revisions were made to balance cost, constructability, and reliability issues.

ii) Permeability of Gasifier Char

A permeability test was done on a small sample of char obtained from an operating unit. These tests were done to help design the char removal system.

The current design of the cyclone and baghouse removal system has a pressure drop across the cyclone to the baghouse that causes gas to go from the cyclone solids discharge through a tank and up to the baghouse preventing particulates to be removed from the baghouse for recycling. The testing of the char sample will allow a modification to the system to allow the particulates to be removed properly from the baghouse. The modification will consist of a column of char that will be located after the cyclone solids discharge that will cause the same pressure drop as between the cyclone and the baghouse. The gas leaking through the column of char will be very small, therefore the velocity of the gas will be negligible and particulates can move freely to the tank to be recycled.

The permeability testing was done at KDL on a small sample of gasifier char. The testing consisted of measuring pressure drops through a sample of gas flow rates.

Three pieces of data were taken at each flow rate: inches of water pressure drop through the sample, inches of water pressure with shunted flow, and the volumetric flow rate measured with a bubble meter. The samples analyzed were two bed heights of a pulverized coal, the char, and the empty cell.

The results of the tests and calculations show the char to be much more permeable than the coal and that the amount of gas leaking through the column will be very small.

iii) Lockheed Kinetic Extruder

The Kinetic Extruder Process was studied to find an improved method for coal delivery across a pressure barrier for Combustion Engineering's Coal Gasification Process. It was believed that a 25 ton/hr kinetic extruder system could provide a smooth flow of pressurized coal to the gasifier while greatly reducing the structural size and cost of the gasifier island. A remaining design concern for the kinetic extruder system in this application is the development of high-temperature seals. At the present time it is desired that a seal capable of 500°F be utilized, though no such equipment has been successfully demonstrated.

Initially it was concluded that a 2 ton/hr (tph) version of the kinetic extruder would replace the 25 tph Extruder if pilot testing was successful. Because of the uncertainty in the ability to develop a mechanical seal that could withstand a significant continuous operation, the 2 tph system was also omitted from the plant layout.

Alternate methods of pulverized coal delivery across a pressure barrier are being evaluated. The most promising at this time is the Dynamic Piston Coal Feeder, developed by Conspray Construction Systems, Inc.

iv) Preliminary Hazard Analysis

A Preliminary Hazard Analysis (PHA) was conducted on the CE IGCC Repowering Project by representatives from various disciplines within ABB using as a basis the available technical data/documentation. The PHA identified several hazards which will be the basis for a subsequent detailed Hazard And Operability (HAZOP) study which will be performed at a later stage of this project.

The PHA study and documentation followed the sequence of process. Nine hazards are identified which include contained explosion, toxic exposure, corrosion/erosion, thermal burn, fire, noise, vibration, tube rupture and mechanical integrity of equipment. Asphyxiation hazard due to confined space entry was found to be a common hazard to all process equipment. Four categories are assigned to the hazards, these are: negligible, marginal, critical and catastrophic. Two major areas of concern that require further detailed analysis during the design stage are the vent stack and bag filters.

The two main purposes of the PHA are to recognize and identify hazards early in the engineering design and to define the need for action steps that must be taken to ensure that there are no major impediments to the realization of a design that meets the designer risk criteria. The results of this study are included in the report and are also intended to highlight corrective/preventive measures to mitigate these hazards during the detailed engineering phase.

v) **Gasification Data**

With the help of the DOE, a visit to an operating gasification plant was arranged. The plant was visited to obtain data from tests about the operation of the plant in order to see if operation was as expected. Tests have been done on oil burning, ignition, load increasing, steam system safety valves, and gasifier purging with gas and/or oil as fuel. After the success of these tests coal was used to test coal feeding, fuel switch-over, and product gas heating value based on air ratio in the gasifier.

Next, coal gas was fed to a gas turbine to test steam injection, air extraction, coal gas ignition, and fuel switch-over.

In the future the plant will switch to design coal and long-term continuous tests will be conducted. Overall the gasifier ran well with minor problems with the slag grinder, lockhopper valves, and fouling.

Based on this information, the 600 tpd gasifier should work well. The 200 tpd gasifier agrees with predicted values and was equal to baseline performance of CE's demonstration design.

vi) **Lakeside Boiler Performance on LBG**

The possibility of firing low Btu gas (LBG) in the lakeside boilers seven and eight was investigated as an alternative to using the flare. It was later determined that this would be too expensive for the project, but the calculations showed that this approach is feasible from a technical standpoint with certain limitations.

The approach taken uses calculations and computer programs to obtain data on efficiency and performance of the boiler and cyclone furnace and also to investigate potential problems. The following specific problems were investigated: furnace heat absorption profile, heat absorption distribution, convection pass performance, boiler performance, circulation system performance, and metal performance. The unit studied is a pressurized, natural circulation, Babcock & Wilcox cyclone-fired boiler.

The current boiler baseline performance was evaluated at 33 and 18 MW using the daily operating data for a basis. Knowing the boiler efficiency and the output of the unit the coal fired could be calculated. Combustion calculations were then performed to establish air and gas weights.

Calculations for performance were based on 50% gasifier load being diverted to the Lakeside #7 unit. The closest limitation encountered was that of the cyclone at 132 000 lb/hr of LBG. The performance was calculated in the traditional design mode.

An assumption for the primary superheater tube materials had to be made because it is unknown and would not be supplied upon request. The tube material assumed was that of the secondary superheat section. The calculated temperature for the primary superheat steam outlet is higher than typically recommended, but should still be within temperature limits.

The superheater spray water was increased significantly due to the higher gas weight and the higher heat absorption, resulting in a higher primary outlet temperature. The gas weight is greater due to the low Btu value of the gasifier product.

This boiler was designed for coal firing. For the same load, the furnace heat absorption rates will be different for firing low Btu gas due to the increased weight and the cleanliness of the gas walls. The change in absorption rates will affect tube flows and hence the ability of cooling the tubes. Therefore, the performance of the circulation system must be analyzed for the low Btu gas firing conditions to assure safe operation.

The waterwall circulation performance was evaluated for three cases: 33MW baseline (coal firing), 18 MW baseline and 18 MW firing low Btu gas. The results show that the difference between the low Btu gas and the baseline case is insignificant and they both have approximately 93% margin of safety. The waterwall will operate safely under the low Btu gas case for 18 MW load.

Also an investigation of the effect of firing low Btu gas on the metal temperatures of the secondary superheater show that both the midwall and the outside wall temperatures are well within the limits of thermal stress and oxidation temperatures. These investigations were conducted due to the concerns of the reduced steam flow and the increase in gas weight. The conclusion of this study is that it is feasible to fire LBG in the Lakeside boilers.

P) Start-up/Shutdown/Operating Procedures

A study of the Start-up/Shutdown Procedure was done to check safety procedures and to ensure proper operation of the system. The study includes gasifier start-up, start-up conditions other than "cold start", and shutdown, including planned and emergency. Conditions are stated that involve proper procedure to avoid an explosion. Assumptions are made concerning cleaning and functioning of systems and the availability of safety equipment. The conditions of the start-up can vary depending on the state of readiness of the unit, the reason for being shutdown, the length of time it is in shutdown, and if the bins and lockhoppers are full or empty, or a combination.

After studying the procedure, there is some concern with safety. The changing back and forth from flare stack to vent stack could prove to be unsafe. For the flare system having a dual role a very elaborate safety interlock system should be used and even then there is still a risk of an explosion. At no time when there are combustibles in the flare system, can the oxygen exceed one percent, otherwise there is danger of a severe explosion. Other safer methods of disposing of these gases should be considered as a result of the study.

The start-up and shutdown operating procedures were reviewed in the Preliminary Hazard Analysis, discussed above, to determine if any system or equipment changes were required. The Preliminary Hazard Analysis brought out certain safety concerns particularly in the operation of the flare. These concerns were addressed and the procedures modified to correct the problems. Some equipment changes were also required.

Q) Commissioning/Start-up/Operation/Maintenance Plans:

A series of documents concerning maintenance philosophy, commissioning, start-up and normal operation for the Springfield Project were put together to help with the cost estimation for the plant. In the commissioning and start-up phase, the maintenance requirements will be higher than normal due to a much heavier workload that comes from flushing, cleaning and blowing lines, removing valves, installing spool pieces and blinds, and the problems associated with putting new equipment in service. Contract maintenance is suggested for the three phases mentioned to avoid a higher cost.

The term "Initial Operations" is used to describe the entire process of pre-commissioning, commissioning, initial start-up, steady production and performance testing of a plant. The Initial Operations Activities includes a list of duties and responsibilities of the team. It also includes estimated man-months that each job position will require. The purpose of this duty is to see if every position is absolutely necessary and if the time they are needed for the job is correct in order to avoid a higher cost than is necessary.

The commissioning and start-up requires the following services: mechanical completion by test systems,scope of services for start-up and technical services, services provided by Initial Operations Group, method of test system preparation, punch and checkout techniques, tower and vessel inspection procedure.

The final consideration is the client operating staff. This is a plan based on operation of the facility around the clock with the personnel working eight hour shifts. For the combined cycle operation there is a total of thirteen people that would remain until the commencement and start-up activities for the gasification and balance of the plant. A total of twenty-nine would be needed for normal operation for entire facility .

R) Test Plans

A test plan for performance evaluation testing at the plant was developed. The test program described in this plan was designed to achieve two objectives, first to provide the information required to set up and to optimize the operation of the facility and secondly to characterize the system response to various operating parameters. These two objectives were broken down into three phases. Phase one addresses the first main objective of set up and optimization of the system. Phases two and three address the second main objective. Phase two covers the characterization of the performance at equilibrium conditions and phase three covers characterization of the dynamic operation of the facility.

Some of the tests include pressure and temperature measurements of instrumentation. Also there are gas analyses and sample collections. Assumptions for the testing and information regarding the purchaser supplied services are included in the test plan. The purpose of the test plan is to identify any problems that may arise and come up with a plan to control any such occurrences.

VII SITE RELATED ACTIVITIES

Brand Asbestos Abatement Inc. was awarded the contract for the complete abatement and demolition of Boilers #1-#6 and Turbines #1-#5 and all associated equipment located in the Lakeside Plant #1 and #2. Brand mobilized to the job site in early January 1992 with the first craft labor personnel commencing work on January 20th.

Aires Environmental was retained under contract to CWL&P to handle all air monitoring and sampling along with project management support.

Originally the project was broken into 5 major phases. The first major phase of the abatement was #4 and #5 turbine areas, which was completed February 26, 1992. After completion of the abatement on #4 and #5 turbines the abatement crews moved to the 2nd phase (5 and 6 boilers). Actual phase 2 asbestos removal began in early March 1992 with final air testing and clearance was obtained in early August. Phase 3 (Boilers #1-#4) started in mid-August 1992 along with Otshan Demolishing crews mobilizing and commencing demolition work of #5 and #6 boilers. Final air clearance of Boilers #1-#4 was performed in late December 1992. Phase 4 (Turbines #1-#3) began in early November 1992 with completion scheduled for mid to late January 1993. As of late December 1992, the dismantling and removal of #4 and #5 turbines and auxiliary equipment was estimated to be 85% complete.

Due to abnormal amounts of fly ash and asbestos contaminated material within the boilers, completion of the project is taking longer than expected. For these reasons, a contract extension was requested by Brand, and granted by CWL&P.

Although total construction personnel has varied throughout the project, peak was reached in November 1992 at a little over 100 workers.

Completion of demolition and asbestos abatement is now anticipated in late April 1993.

VIII PROJECT MANAGEMENT

A) Project Management Plan

The Project Management Plan (PMP) was written for this project as required by the Cooperative Agreement between CE and DOE. Revision 1 of this plan for Budget Period 2 (BP-2) was issued by CE to DOE in November of 1992. The PMP will be implemented and maintained by CE throughout the life of the project. This document includes the management procedures that are intended to be used for this project as well as the Statement of Work and the Work Breakdown Structure (WBS).

The PMP was updated from the Budget Period 1 (BP-1) version to show BP-1 in the past tense and to properly focus the current PMP to BP-2. Also, all corrections and inclusions requested by the Department of Energy (DOE) in a letter dated March 30, 1992, were addressed.

The latest updates for permit schedules and delivery dates and cost data for WBS and unallowable cost adjustment were also provided.

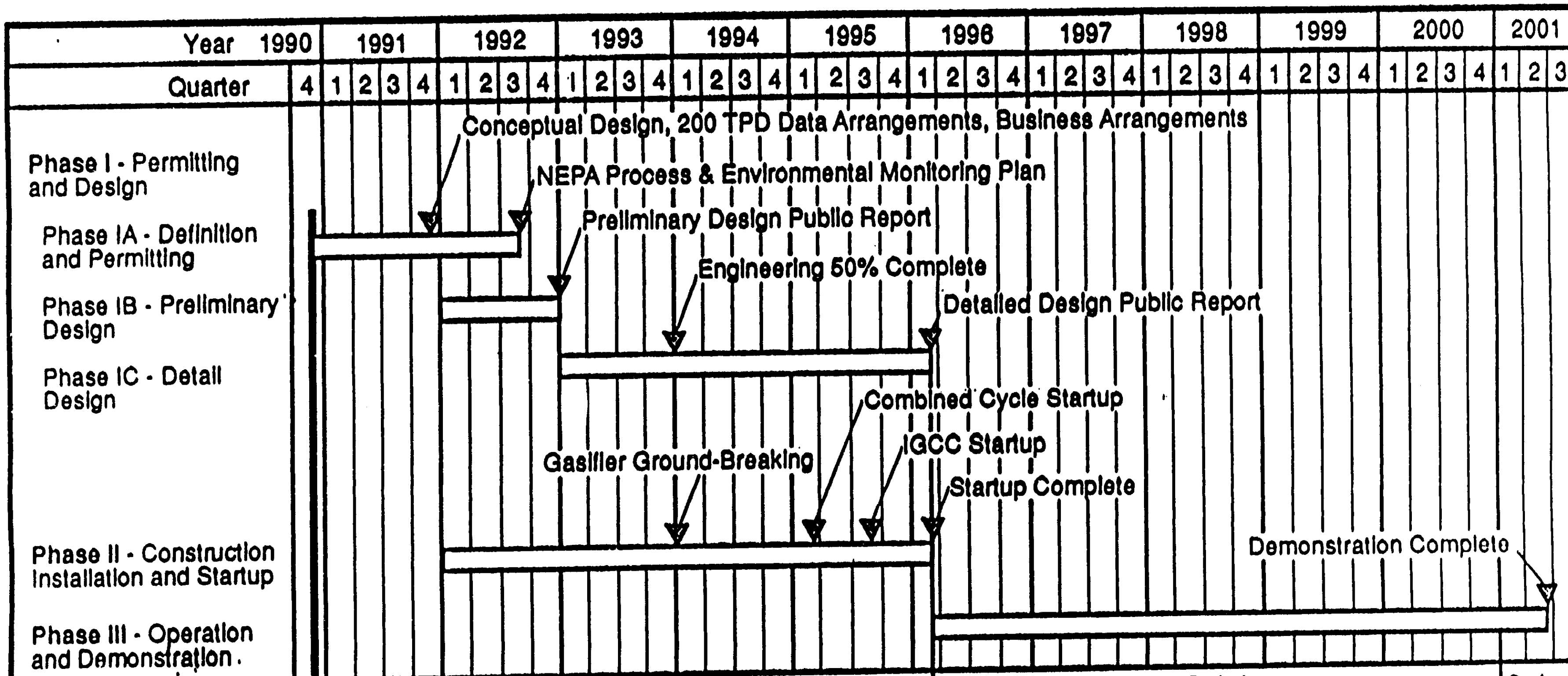
B) Schedules

A schedule for the overall project was developed during BP-1. This schedule is shown in Figure 21. The schedule breaks down the project duration into 3 phases and 5 budget periods and shows major milestones.

At the end of 1992, a request was submitted to extend BP2 into 1993. This will affect the schedule shown by a small amount. A new schedule will be submitted with the Continuation Application.

FIGURE 21

Combustion Engineering IGCC Repowering Project – Schedule and Budget



BUDGET ($MM)	Period #1	Period #2	Period #3	Period #4	Period #5	Budget Totals
Phase I	5.8	11.0	22.3	17.6	–	56.7
Phase II	–	–	6.0	88.3	–	94.3
Phase III	–	–	–	–	119.7	119.7
Totals	5.8	11.0	28.3	105.9	119.7	270.7

Project Funding Plan
(Dollars in Millions)