The clarified overflow from the Sludge Thickener is directed back to the Oxidation/Flocculation Tank by a Sludge Thickener Discharge Pump (74-P-12 A and B, one operating and one stand-by). The concentrated sludge at the bottom of the vessel is discharged to a Sludge Dewatering Filter (74-F-2) by a Sludge Dewatering Filter Feed Pump (74-P-8 A and B, one operating and one stand-by).

In the Sludge Dewatering Filter, the sludge forms a filter cake. The filter cake is discharged to a Belt Conveyor (74-CV-2) which conveys it to disposal area described in Section 4.3.8. The clarified water is recirculated back to the Equalization and Holding Tank by the Sludge Dewatering Pump (74-P-10 A and B, one operating and one stand-by).

As shown on Drawing EE-371-002 (Appendix E), a liquid stream is discharged from the plant cooling towers. The flow is monitored by the Cooling Tower Blowdown Flow and Sample Chamber (74-ME-5) before being discharged to the Delaware River. Cooling tower blowdown control is described in Section 4.3.8.

4.3.8 Utilities And Supporting Systems

4.3.8.1 Plant Water Systems (Units 74, 81, 82, 83, and 84)

A diagrammatic representation of the plant water systems are shown on Drawings EE-371-010 and EE-371-011 (Appendix E). The entire process water requirement for the plant is taken from the Delaware River. An inlet channel will be dredged from the river to a Pump House (Drawing EE-071-001, Appendix D).

Within the inlet channel, at the shore line, a Bar Screen (84-SF-1) is provided to prohibit large pieces of debris from entering the Pump House. A Sluice Gate (84-CA-1) is provided, at the nlet to the Pump House, to isolate the river supply from the Pump House.

a. Pump House Equipment (Drawing EE-071-012, Appendix D)

A vertical Traveling Screen (84-SF-2A and B, one operating and one stand-by) is provided at the Pump House inlet to strain out the smaller debris, from the influent, that has passed through the Bar Screen. Water jets at the top of the moving screen remove the debris and transfer it, via a trough, to a portable container for disposal.

Three vertical Makeup Water Pumps (84-P-2A, B and C, two normally operating and one stand-by) are provided at the Pump House to distribute the raw river water to all plant systems. In the design, two pumps at 50 percent of maximum plant water requirement were selected. Since the Gasification Plant design is based on two parallel gas trains, and since most of the water requirement is for the gas trains, the economics of splitting the water supply capacity to match gas production seems logical.

b. Water Filtration (Drawing EE-071-012, Appendix E)

The Makeup Water Pumps discharge the raw river water to a Clarifier (84-CL-1). Within the Clarifier, solids are precipitated from the water and primary treatment of the raw river water begins. The river water is introduced into the center well of the Clarifier. Before the water reaches the Clarifier, a dilute solution of Chlorine is injected into the stream to control the biological activity of the process water. A Chlorinator Booster Pump (81-P-8C and D, one operating and one stand-by) draws chlorine through an Ejector (81-CH-2). Chlorine gas is fed to the ejector from a Chlorinator (81-ME-2B) controlled by a Residual Chlorine Analyzer (81-ME-1B). Chlorine is metered to the river water proportionate to the flow.

As the raw river water rises upward through the center well of the Clarifier, Alum and Polyelectrolyte are added. Alum acts as the coagulant for the solids suspended in the river water. The Polyelectrolyte is added as a coagulant aid. A Coagulant Tank (84-TK-7), an Agitator (84-AG-2) and a Coagulant Pump (84-P-4) are provided to meter the Alum to the Clarifier. A Flocculant Tank (84-TK-6), an Agitator (84-AG-1) and a Flocculant Pump (84-P-3) are provided to meter the Polyelectrolyte to the Clarifier.

The sludge formed in the Clarifier settles to the bottom. A slow speed rake propels the sludge to a central cone. The sludge is drawn off periodically, by use of an adjustable timer, into a sump where a Clarifier Sludge Pump (84-P-11A&B, one operating and one stand-by) discharges the sludge to the Waste Treatment Facility (described in Section 4.3.7).

The clarified river water overflows the Clarifier and is directed to five Gravity Filters (84-F-1A through E). In the Gravity Filters, the balance of the undissolved solids are removed from the process water. Each Gravity Filter design incorporates its own backwash storage tank, which is part of the filtered water compartment. When a filter is exhausted, a valve closes automatically (activated by the filter bed pressure drop), isolating the filter from the water stream. A control valve opens in the backwash line, automatically, and the filtered water stored in the section above the filter bed washes the accumulated solids from the bed. Before backwash, compressed air is injected under the filter bed to loosen accumulated solids. The backwash flows to a Dirty Backwash Sump. The dirty baskwash is metered to the Waste Treatment Facility (see Section 4.3.7) by a Filter Backwash Water Pump (84-P-12 A and B, one operating and one stand-by). The Gravity Filters have been sized so that four of the five units can handle the maximum flow of water from the Clarifiers; thus, a filter can be isolated for regeneration while the process water demand is at its maximum.

c. Cooling Water System (Drawings EE-371-010 and EE-371-011, Appendix E)

At the discharge of the Gravity Filters, the filtered water is split into two streams. Most of the filtered water is directed to the Cooling Water System (Unit 81), the plant's largest user.

The effluent from the Gravity Filters flows to a cooling tower cold well, a large concrete in-the-ground storage tank that provides a surge capacity for the system. Four Cooling Water Pumps are provided (81-P-6A through D, three operating and one stand-by). The three-pump operating configuration was selected for the design mostly for economic reasons. Using one or two pumps for operation would have increased capital outlay.

After the pump discharge, the residual chlorine content of the cooling water is checked by an Analyzer (81-ME-1A). Should the water require further treatment, a controller in the Analyzer panel will activate a Chlorinator Booster Pump (81-P-8 A and B, one operating and one stand-by) and a Chlorinator (81-ME-2A). The Booster Pump flow will draw chlorine from the Chlorinator by use an Ejector (8-CH-1). The diluted chlorine will then be injected into the cooling water supply. A chlorine gas storage is provided at the plant. Four 2000-pound chlorine cylinders (81-TK-5A through D) are provided for the process requirements.

A Scale Inhibiting System is also provided in the design, to protect both the water quality and the piping distribution system. A Scale Inhibitor Tank (81-TK-8) is used to mix the inhibitor solution with an Agitator (81-AG-3). The dilute solution is injected into the cooling water distribution line by a Scale Inhibitor Pump (81-P-7A and B, one operating and one stand-by).

The cooling water is then distributed to the following major process users:

1. The Air Separation Facility Cooling Tower (50-CT-3);
2. Makeup to Settling Basins for Wash Water System Losses;
3. Quench Water to the Gasifier Off-Gas Streams;
4. The Gasifier Burner Cooling Jackets;
5. The Wash Water Coolers (72-E-1A and B);
6. The Settling Basin Dosing Station (Flocculant Tank 72-TK-1);
7. Product Gas Oil Coolers (62-zE-1A,B,D and E and 62-E-2A and B);
8. The "Stretford" System (42-TK-2 and 42-TK-4);
9. The "Stretford" Incineration System (44-TK-1, 44-E-3,4 and 5);
10. The Glycol Regenerative System Boiler (64-E-1);
11. Product Gas Aftercoolers (62-E-6A,B and C);
12. Make-Up to Coal Handling Dust Suppression System (Unit 15);
13. The Product Gas Turbine Condenser (82-CN-1);
14. The Turbine Condenser Exhausters (82-EJ-1A and B);
15. Gas Booster Oil Coolers (42-E-5A through D);
16. Gas Booster Aftercoolers (42-E-1A and B);
17. Plant Air Compressor Oil Coolers (85-E-1A and B and 85-E-4A and B);
18. Plant Air Compressor Intermediate Coolers (85-E-1A through D); and
19. Plant Air Compressor Aftercoolers (85-E-2A and B).

Most all of the water is returned to the Cooling Tower Hot Well, except for the following systems:

1. Losses from the Air Separation Facility Cooling Tower (evaporation);
2. Losses from the Wash Water System (water carried out of the plant with the ash, slag and sludge removal);
3. Quench water to the Gasifier Off-Gas Streams (evaporation);
4. Seal Pots, when drained and/or filled;
5. "Stretford" system Evaporation; and
6. Losses from the Coal Handling Dust Suppression System.

This quantity of water must be made up by the River Water Pumping Station (84-P-2A, B, and C).

The water returned to the Cooling Tower Hot Well, from the process, is lifted to the top of the Cooling Tower (81-CT-1) by the Cooling Tower Circulating Pumps (81-P-5A through D, three operating and one stand-by). As in the Cooling Water Pumps, a three-pump configuration was selected for economic reasons.

A slip-stream is taken from the Circulating Pump discharge and directed through a Pressure Filter (81-F-2A and B, one operating and one stand-by). The filter removes a portion of the solids buildup in the circulating water. By using the filter, solids content in the cooling water system can be controlled.

The temperature of the recirculated water is lowered in the cooling tower by the evaporative cooling process. Water evaporated from the tower is made up from the River Water Pumping Station (84-P-2A, B, and C).

The Cooling Tower is comprised of three cells, each having its own two-speed fan. The "three cell" design affords flexibility to the water cooling system; that is, only the cells and fan speeds needed to perform the system cooling requirements are used.

d. Boiler Feedwater Makeup System (Drawing EE-371-011, Appendix E)

The other portion of the Gravity Filter effluent provides the makeup requirement for the Boiler Feed System. A Filtered Water Storage Tank (84-TK-1) is provided as surge capacity for the Boiler Feedwater Makeup System. Filtered water is drawn from the tank by a Filtered Water Pump (84-P-1A&B, one operating and one stand-by). The Pump directs the filtered water to a demineralization facility, provided to remove move of the dissolved solids from the water which will be used to generate steam. Also, a branch is taken off to provide filtered water that is required for the process Seal Pots and Gasification Equipment (see Drawing EE-371-015, Appendix E).

A demineralization process was selected for Boiler Feedwater treatment because:

1. The demineralization process is the most effective water treatment sysem for higher pressure steam generation with respect to protection of steam generating equipment and steam users, and the minimization of energy losses due to excessive system blowdown, and

2. The condensate from all steam using equipment, regardless of pressure level, is collected in a common system for reuse; consequently, the water quality of the entire condensate system is dictated by the quality required by the highest pressure level.

Two parallel Demineralizer Trains (82-DM-1A&B) are provided to remove the dissolved solids from the water stream. Each train is sized to produce 50 percent of the total feedwater quantity required for one gasifier train. Normally, condensate returned from the process will furnish 92 percent of the water required to generate steam. However, there are occasions when the total quantity of water required for one gas train will have to be made up from a fresh water supply. They are:

1. When a gasification train is first activated, and
2. When a large portion of the return condensate becomes temporarily contaminated and must be wasted.

During normal plant operation, however, only one demineralizer train is in operation with the second train on stand-by status until the first train is exhausted.

Each demineralizer train will be furnished as a "package" system consisting of:

1. A vessel containing activated carbon;
2. A Cation Vessel with resin and internals;
3. An Anion Vessel with resin and internals;
4. All interconnecting piping between the vessels;
5. All control valves required for system operation; and
6. All meters, interconnecting wiring and instrumentation required for either an automatic or semi-automatic operation.

Each demineralizer train will be provided with a local control panel for system operation and a remote panel, located in the central control room, for monitoring the system performance.

An activated carbon unit is included in each demineralization train to remove the unreacted chlorine that was previously injected into the water for biological control.

After a measured quantity of dissolved solids have been removed from the water flowing through the Demineralizer trains, the resin beds become exhausted. Therefore, the resin beds must be regenerated; that is, the deposited ions removed from the resin. Sulfuric acid is used to regenerate the Cation resin bed and Sodium Hydroxide (caustic) is used to regenerate the Anion resin bed.

Two large storage tanks are provided for bulk storage of chemicals at the plant site, one tank for storing the acid and the second tank for storing the caustic. Both tanks are located indoors and in a diked area for safety.

A Sulfuric Acid Feed Pump (82-P-15) is provided at the Sulfuric Acid Storage Tank (82-TK-3) to transfer the more concentrated acid to an Acid Day Tank (82-TK-11) for dilution to the strength required by the Cation regeneration process. Also, a Caustic Feed Pump (82-P-14) is provided at the Caustic Storage Tank (82-TK-2) to transfer the more concentrated caustic to the Caustic Day Tank (82-TK-10) for dilution. Agitators 82-AG-4 and 82-AG-5 are provided to mix the caustic and acid respectively.

Generally, the regeneration of a demineralizer train follows the following sequence:

1. The resin beds are backwashed (timed operation);
2. Cation resin bed is regenerated with acid (timed operation);
3. Cation resin bed is slowly rinsed with filtered water to remove excess acid from the bed (timed sequence);
4. Cation resin bed is thoroughly rinsed until all traces of regenerant chemicals are gone (controlled by a Conductivity Cell); and
5. Anion resin bed is regenerated in the same manner, except caustic is used as the regenerant and the Cation effluent is used for the rinse cycles. A heat exchanger is provided to heat the caustic regenerant entering the Anion Vessel.

All regenerative wastes are discharged to a Neutralizing Tank (74-TK-9). The wastes, on a batch basis, are mixed together by an Agitator (74-AG-9). Acid and caustic are added to the tank contents, as required, to neutralize the waste solution. After the waste is neutralized, the contents of the tank are drained to the Equalization and Holding Tank at the Waste Treatment Facility (see Section 4.3.7 for description). The effluent from the Demineralization Trains, containing less than one part per million of dissolved solids, flows to the Demineralized Water Storage Tank (82-TK-9).

4.3.8.2 Boiler Feedwater and Condensate Return Systems (Unit 82)

a. Boiler Feedwater System (Drawing EE-371-005, Appendix E)

The demineralized water is contained within a Storage Tank (82-TK-9), which provides surge capacity for the feedwater system. A combination Safety Relief Valve and Vacuum Breaker (82-VE-2) is provided at the top of the vessel. A Demineralized Water Pump (82-P-13A and B, one operating and one stand-by) lifts the water to a Deaerator (82-DA-1).

The Deaerator is a water heater with a storage tank as an integral appendage. The Deaerator serves three functions:

1. It removes dissolved gases from the feedwater;
2. It preheates the feedwater; and
3. It provides surge capacity for the Boiler Feed Pumps.

Steam is added at the tray section of the Deaerator. The steam heats the incoming water and drives off gases from the fluid. Gases escape through a multiport-type Safety Valve (82-VE-1). The de-gassed water drops down to the storage tank.

As previously stated, approximately 92 percent of the steam utilized in the Gasification Process is normally condensed and returned to the feedwater system. The condensate is returned to the Deaerator for de-gassing. Approximately eight percent of the steam escapes the system. Therefore, for the system to be balanced, that quantity of water must be made up from the demineralized water system.

The flow quantity of demineralized water to the Deaerator is determined by a level controller in the Deaerator Storage Tank. Normally, there is no metering requirement for the condensate to the Deaerator when both Gasifiers are operational, since the flow of condensate will be lower than the feedwater demand (steam losses). Therefore, demineralized water must be put into the Deaerator to maintain a predetermined operating level in the storage tank. If, however, one Gasifier becomes inoperable, the steam demand, and therefore the feedwater demand, will be cut. An inherent system delay will cause more condensate to be returned than is required. Therefore, the level in the Deaerator Storage Tank will rise above the operating level. The demineralized water makeup valve to the Deaerator will close and the condensate return will be modulated accordingly, in response to the level rise in the storage tank.

The Deaerator feeds three sets of Boiler Feed Pumps:

1. The High Pressure Feedwater Pumps (82-P-4A, B and C);
2. The Low Pressure Feedwater Pumps (82-P-5A, B and C); and
3. The Auxiliary Boiler Feedwater Pumps (82-P-3A and B).

The high-pressure pumps provide feedwater for generating steam in the Waste Heat Recovery Units (30-E-1A and B). There are three high-pressure pumps, two operating and one stand-by. Two operating pumps are furnished since there are two heat recovery units controlled separately.

The low-pressure pumps provide feedwater for generating steam in the water-jacketed Gasifiers (30-V-1A and B). There are three low-pressure pumps, two operating and one stand-by. As in the high-pressure system, two operating pumps are furnished for the same reason (two Gasifiers).

The auxiliary feedwater pumps furnish water to the Auxiliary Boiler (82-B-1) which is used for plant startup and to provide more steam than is generated by the gasification process when required. There are two pumps in the system, one operating and one stand-by.

Before the feedwater can be used for steam generation, all dissolved oxygen must be removed to protect the steam drums from corrosion. Therefore, a Hydrazine Oxygen-Scavenging system is provided in the feedwater system. The system consists of a Dilution Tank (82-TK-14), an Agitator (82-AG-9) and a Pump (82-P-18A&B, one operating and one stand-by). The Hydrazine is injected in the suction headers of the Boiler Feed Pumps. An alternate injection point is provided in the Deaerator storage tank. Hydrazine was selected as an oxygen-scavenger in lieu of Sodium Sulfite because:

1. It acts in a shorter time period, and
2. It contributes less solids to the feedwater in the steam drums.

Should the condensate return system, the Demineralization system or the Deaerator be temporarily inoperative, an emergency feedwater system is provided. Connections have been provided in the Boiler Feed Pump suction headers to feed filtered water into the steam generating drums.

Should necessity require the use of filtered water for generating steam, alternate chemical treatment systems have been provided in the design. They are:

1. A Phosphate Dilution Tank (82-TK-12) and Agitator (82-AG-7);
2. A Phosphate Pump (82-P-16A and B, one operating and one stand-by);
3. An Ammonia Dilution Tank (82-TK-13) and Agitator (82-AG-8); and
4. An Ammonia Pump (82-P-17A and B, one operating and one stand-by).

Both the Phosphate and Ammonia solutions would be injected into the Boiler Feed Pump suction headers, along with the filtered water, to control the solids concentration and the alkalinity in the steam generating drums.

b. Condensate Return System (Drawing EE-371-00, Appendix E)

The condensate recovered at the Gasification Plant is collected from the following major equiment:

1. The Air Separation Facility Compressor Turbine Condenser;
2. The Product Gas Compressor Turbine Condenser;
3. The "Stretford" System Startup Heater (when in use);
4. The Sulfur Pit Heat Exchanger;
5. The Dehydration System Glycol Reservoir;
6. High and Low Pressure Flash Tank Effluent; and
7. Condensate from Plant Steam Coil Heaters.

All condensate is collected in piping throughout the plant and discharged to a Condensate Tank (82-TK-1). The tank provides a surge capability for the system, cushioning irratic flow rates from plant sources. A conductivity cell is provided in the pipeline upstream of the Condensate Tank. The conductivity cell controls a diversion valve that will divert the condensate to the Cooling Tower Hot Well if contamination is detected. A combination Vacuum Breaker-Safety Valve (82-VE-3) is provided for pressure equalization within the tank.

Condensate Pumps (82-P-2A, B and C, two operating and one stand-by) are provided to return the condensate to the Deaerator. The design provides for two operating pumps, each capable of 50 percent of the maximum flow, which is compatible with the 50 percent split of the Gasification Trains at the plant.

A diversion valve is provided at the discharge of the Condensate Pumps to empty the condensate system when necessary. The flow is diverted to the Cooling Tower Hot Well.

Condensate Pumps are provided, at the Air Separation Facility Turbine Condenser, the Product Gas Compressor Turbine Condenser and for the flash tank discharges (see Section 4.3.8.3), to push the condensate back to the Condensate Tank. Conductivity cells, controlling diversion valves, are provided in both areas in case the condensate becomes contaminated.

4.3.8.3 Steam Generation and Distribution System (Drawing EE-371-D16, Appendix E)

The Steam Generation and Distribution System is shown, diagrammatically, on Drawing EE-371-016. Steam is generated at three different pressure levels:

a. High Pressure (approximately 925 psig);
b. Intermediate Pressure (approximately 150 psig); and
c. Low Pressure (approximately 28 psig).

All steam levels are generated at saturation temperature. The high and low pressure levels are determined, and therefore dictated, by the Gasifier manufacturer, since the two are products of the Gasification Process. The intermediate steam pressure level, produced by the Auxiliary Boiler (82-B-1), has been selected by design. This level provides optimum flexibility for other steam requirements at the plant.

The high-pressure steam, generated in the Waste Heat Recovery Systems (30-E-1A and B), is collected in two Steam Drums (30-V-5A and B). Each Gasification Train has its own high-pressure steam drum. The steam flow from both drums is collected and distributed in a common steam line. The majority of the high-pressure steam is distributed to the Air Separation Facility (Unit 50). Approximately 84 percent of the high-pressure steam is transmitted to that facility to provide power for the air compressor turbines. Approximately 12 percent of the high-pressure steam is transmitted to the Gas Dehydration Facility (Unit 64) where it is utilized to strip water from the recirculating Glycol solution. The Gas Dehydration facility, however, requires a lesser pressure and temperature than that of the high-pressure steam. Therefore, a Heat Exchanger (82-E-1) is provided to lower the steam temperature to be compatible with that reuqired for Glycol Regeneration. A pressure-reducing station is also provided, upstream of the Heat Exchanger, to reduce the pressure of the steam required for Glycol regeneration. The balance of the High Pressure Steam generated, approximately four percent, is available for potential deficiencies in the lower pressure steam systems. A cross-tie, between the steam line to the Gas Dehydration Facility and the distribution line for the Auxiliary Boiler, is provided, along with a pressure-reducing station and a Desuperheating Station (82-DS-1). The Desuperheater uses demineralized water. Safety relief valves are provided in the high-pressure distribution piping, as well as the distribution piping to the Dehydration System. Condensate is collected, in a header, from:

1. Heat Exchanger (823-E-1);
2. The Glycol Reservoir (64-B-1); and
3. The distribution line to the Air Separation Facility.

The header transfers the collected condensate to a High Pressure Condensate Flash Tank (82-TK-6). In the flash tank, a lower pressure steam is generated, compatible with the low-pressure steam being made by the Gasifiers, by the flashing action of the pressurized condensate to a lower pressure maintained in the tank. A control valve in the Flash Tank Discharge (at the top) directs the steam to the low-pressure steam distribution header in the process. A vent control valve is also provided on the flash tank, to vent the steam in case the low-pressure steam system cannot accept the steam being generated. The blowdown from each Steam Drum goes to a Blowdown Vessel (30-V-15A). In the Blowdown Vessel, the pressure of the liquid is lowered to near atmospheric by flashing off steam to atmosphere through a control valve at the top of the tank. The condensed liquid from the Blowdown Vessel exits through a control valve and is directed to the Waste Water Treatment Facility (Unit 74).

The low-pressure steam, generated in the Gasification Reactor water jackets (30-V-1A and B), is collected in two Steam Drums (30-V-4A and B). Each Gasifier has its own low-pressure drum. The steam flow from each drum is collected and distributed in a common steam line. The majority of the low-pressure steam, approximately 76 percent, is distributed to the Product Gas Compressor Turbines (62-C-1A-T and 62-C-1B-T) to provide power for final gas compression. Approximately 16 percent of the low-pressure steam is transmitted to the Deaerator (82-DA-1), to heat and drive off gases from the feedwater system. The balance of the low-pressure steam, approximately eight percent, is distributed to the Gasifier Oxygen-Steam Mixers (30-V-9A through D), where the steam is utilized for coal gasification. Before the low-pressure steam is transmitted to the Product Gas Compressor Turbines, it is superheated to increase Turbine efficiency. The steam is passed through Heat Exchanger 82-E-1 (previously described in the high-pressure steam segment of this section), where the steam temperature is increased. Safety relief valves are provided on all low-pressure steam headers to protect the system from being overpressurized. The blowdown from each steam drum goes to a Blowdown Vessel (30-V-15B). In the Blowdown Vessel, the pressure of the liquid is lowered to near atmospheric by flashing off steam to atmosphere through a control valve at the top of the tank. The condensed liquid from the vessel exits through a control valve and is directed to the Waste Water Treatment Facility (Unit 74).

An intermediate pressure steam, as previously stated, is generated by an Auxiliary Boiler (82-B-1). At startup, the Boiler is fired with fuel oil, but as gas is produced at the plant, the combustion sytstem will be switched to Product Gas. The Boiler steam drum furnishes steam to a distribution header which services the following systems:

a. The "Stretford" Facility Sulfur Melter (42-E-3);
b. The "Stretford" Facility Startup Heater (42-E-4);
c. The "Stretford" Facility Pit Heater (42-E-6);
d. The Plant Steam Tracing System; and
e. The Plant Steam Coil Building Heaters.

A cross-tie is provided between the Auxiliary Boiler steam header and the Low Pressure steam header to allow for potential deficiencies in the low-pressure steam system. The cross-tie is provided with a Pressure Reducing Station and a Desuperheating Station (82-DS-2) to insure compatibility of the makeup steam with the low-pressure steam. Demineralized water is provided for the Desuperheater. A relief valve is provided in the Auxiliary Boiler steam header to protect the system from overpressure.

A low-pressure condensate header is provided to collect the condensate from the areas previously listed. The header transfers the collected condensate from both the Intermediate Pressure and Low Pressure Steam systems to a Low Pressure Flash Tank (82-TK-7). In the Flash Tank, the condensate pressure is lowered to near atmospheric by flashing of steam through a multiport-type valve at the top of the vessel.

A Condensate Pump (82-P-7A and B, one operating and one stand-by) is used to collect the combined condensate from the High and Low Pressure Flash Tanks and transfer the fluid to the Condensate Storage Tank (82-TK-1). In the same manner, Condensate Pump 82-P-1A&B (one operating and one stand-by) will transfer the Product Gas Compressor Turbine Condenser condensate to the Storage Tank and Condensate Pump 50-P-13A and B (one operating and one stand-by) will transfer the Air Separation Compressor Turbine condensate to the Low Pressure Condensate Header.

4.3.8.4 Fire Protection (Drawing EE-371-007, Appendix E)

The Fire Protection System (Unit 83) is shown, diagrammatically, on Drawing EE-371-007. The primary source of water for fire protection is the Delaware River. A secondary (backup) water source is the City of Philadelphia fire line, running along the western border of the property.

The Delaware River was selected as the primary water source because of a lack of sufficient pressure in the City fire main. Anticipated pressure loss in the plant fire protection loop and the residual pressure required to operate sprinkler systems and hose stations in elevated structures negated the concept of using the City fire line as a primary water source.

The Main Fire Pump (83-P-1) and Jockey Pump (83-P-2) are located in the Pump House adjacent to the Delaware River (see Drawings EE-071-001 and 012). Both pumps are electrically driven and are vertical in configuration. The Jockey Pump is used to maintain pressure in the Fire Protection System.

An Auxiliary Fire Pump (83-P-3) is provided as the secondary, or backup, source of water for fire protection. The Auxiliary Fire Pump is diesel driven and is located near the property boundary, adjacent to the warehouse. The diesel-driven pump is automatically started upon failure of the Main Fire Pump. If the Jockey Pump fails to maintain pressure in the plant fire loop (water is being drawn due to system activation), the Main Fire Pump will automatically start. If, within a predetermined period of time, the pressure in the fire loop continues to drop (failure of Main Fire Pump), the diesel fire pump will be automatically activated.

The Auxiliary (Diesel) fire pump draws its water supply from a Firewater Tank (83-TK-1) adjacent to the pump. The tank provides a constant suction head and small storage facility for the pump. The water level in the tank is kept constant by a level control valve, which will open if the water level in the tank drops. The water source for the makeup to the tank is the City of Philadelphia fire system. A pipe is provided to connect the Firewater Tank with the City fire main. Enough capacity is available from the City fire main to:

1. Provide the flow quantity for the Plant fire protection requirement, and
2. Provide sufficient pressure to lift water to the top of the Firewater Tank.

The primary water distribution system consists of a closed pipe loop around the perimeter of the plant, with branches taken from the loop to furnish water to the various processes and buildings at the facility. The "loop" design allows water to be fed to the system from both pumping sources (Main Fire Pump and Auxiliary Fire Pump). Isolation valves are provided in the pipe loop, at strategic locations, so that water can be furnished to a fire from two directions, and also to permit isolation of a section of the loop for maintenance or repair without deactivating the entire system.

The fire protection design incorporates two different types of systems:

a. "Wet System," and
b. "Dry System."

The "Wet System," as the term implies, refers to the design concept that all piping systems above the ground are filled with water, ready to be released when required. The "Dry System" is used when piping is exposed to temperature conditions that would cause failure (freezing). In the "Dry System," all weather-exposed piping is filled with dry air to prevent freezing. The air is pressurized to prevent water from entering the piping system. When a firefighting device is actuated, the air pressure in the piping feeding that device drops, and water flows to the fire source.

The following is a list of areas serviced by "Wet Systems":

1. All fire hydrants;
2. The Administration Building (heated area); and
3. The Warehouse (heated area);

The following is a list of areas serviced by "Dry Systems":

1. The Gasification Structure;
2. The Coal Bunker Structure;
3. The Desulfurization Structure;
4. The Main Cooling Tower;
5. The Air Separation Facility and Cooling Tower; and
6. Coal Handling System tunnels and conveyor systems.

a. Wet Systems

Since all piping to the fire hydrants is underground, the system will be full of water all the time. Each hydrant is provided with a shut-off valve for maintenance purposes.

The Administration Building is a temperature controlled facility which will be sprinklered. Hand-held fire extinguishers are provided for use by employees.

The Warehouse will be heated in winter and is provided with a sprinkler system and hose reels for employee use.

b. Dry Systems

Since the Gasification structure is not enclosed, a dry system is utilized for protection. Two risers are provided, with branches for hose racks at each operating level. A dry pipe control valve is provided, along with a small compressor to maintain air pressure in the piping system. The system is activated from any station by extending the hose out of the rack.

The Coal Silo structure is not enclosed. Therefore, dry systems are provided. Two types of systems are furnished, a water deluge and a standard system. The standard dry system is identical to the Gasifier system, a control valve and compressor. The deluge-type piping system is not pressurized with air; rather, temperature sensing devices located in strategic areas activate a control valve (enclosed in a valve house) which, when opened, admits large quantities of water to the area experiencing a fire. The coal conveying system above the silos is provided with the deluge system. The balance of the structure is protected by the standard "dry pipe" system.

The rest of the dry systems previously listed are provided with deluge-type fire protection systems, activated by temperature sensors.

4.3.8.5 Plant and Instrument Air (Drawings EE-371-017 and 018, Appendix E)

The Compressed Air System for the Plant is shown, diagrammatically, on Drawings EE-371-017 and EE-371-018 (Appendix E). The equipment arrangement is shown on Drawing EE-071-007 (Appendix D).

Two Compressors (85-C-1A and B) are furnished for the plant, one operating and one stand-by system. Air is taken in through a Filter (85-F-2A and B) equipped with a Silencer (85-F-3A and B) and enters the first compression stage of the machine (low-pressure stage). The air is partially compressed and passed through two Intercoolers (85-E-1A thru D), where the heat of compression is removed by cooling water from the plant cooling tower. The air then passes to the second, or final, compression stage of the machine, where it is compressed to the required system pressure. The final stage heat of compression is removed by an Aftercooler (85-E-2A and B), using cooling water from the tower.

The compressed air then passes through a Moisture Separator (85-SE-1A and B), where the condensed water from the cooled compressed air is removed and drained to the Waste Water Treatment System. The compressed air is then stored in a Receiver (85-TK-1). The Receiver is, in essence, a vessel that is used for the following purpose:

a. It stores compressed air at a higher pressure than the required system pressure, thus insuring that the minimum system pressure is always maintained;
b. It mollifies system surges (cuashions pipe hammer effects);
c. It controls the compressor input to the system.

A pressure switch in the Receiver, set slightly above the minimum system pressure requirement, will activate the compression cycle in the Compressor when the pressure in the Receiver approaches that minimum value. The Compressor will then bring the pressure in the

Receiver back up to the high-pressure set point (high-pressure switch), which will stop the compression cycle in the machine.

The compressed air flows, from the Receiver, through an Oil Filter/Separator (85-F-1A and B, one operating and one stand-by), which removes entrained oil mist from the air stream. When the air stream leaves the Filter/Separator, it is split into two separate systems, the Plant Air System and the Instrument Air System.

The plant air is then distributed throughout the plant to the various facilties requiring compressed air to operate pneumatic devices. Two Receivers, 85-TK-2A and C, are provided, one at each end of the Plant Air distribution header, to cushion pressure variations in the system and to provide a temporary air source in case of a plant power failure.

The portion of the compressed air diverted to the Instrument Air system passes through a desiccant-type Air Dryer (85-DR-1A and B, one operating and one stand-by). The Instrument Air Dryer is a regenerative type; thus, two full-size units are provided so that one can be regenerated while the other is operative. The dried air is then distributed throughout the plant to all facilities requiring air to operate instruments and controls. Two Receivers, 85-TK-2B and D, are provided, one at each end of the Instrument Air distribution header, to cushion pressure variations in the system and to provide a temporary air source in case of a plant power failure.

Both the Plant and Instrument Air distribution systems are shown, diagrammatically, on Drawing EE-371-018.

Pressure relief valves are provided in the Compressor discharge header and all equipment to prevent the system from being overpressurized.

4.3.8.6 Flyash Removal and Storage (Unit 92)

The Flyash system is designed to transport the concentrate extracted from the Wash Water System (Unit 72) to two separate areas of the plant. The areas are:

a. The Coal Preparation Area (Unit 20), and
b. The Flyash Storage and Disposal Area.

The flyash removed from the gas stream by the Wash Water System (Unit 72) contains a relatively large quantity of unreacted carbon which can be recycled back to the gasification process. Therefore, the flyash conveying system is designed to provide this option.

Belt Conveyor 92-CV-1 transports the dewatered flyash concentrate from the Rotary Vacuum Filters (Unit 72, Section 4.3.7.1) to the feed end of conveyors 92-CV-2 and 92-CC-5 (as shown on Drawings EE-071-001 and 013, Appendix D). At this point, the option is provided to divert 50 percent of the flyash back to the Coal Preparation System (Unit 20). A bifurcated chute and flow splitter are provided at the discharge of Conveyor 92-CV-1 to divert half of the flyash to Conveyor 92-CV-5 and the other half to Conveyor 92-CV-2. Conveyor 92-CV-5 recycles flyash back to the Coal Preparation System and Conveyor 92-CV-2 transfers the ash to a Storage Building. The discharge chute of Conveyor 92-CV-CV-1 is designed to divert the entire flyash quantity to Conveyor 92-CV-2, should the recirculation of ash tc the system not be desir' for any given time period. Conveyor 92-CV-2 is designed to carry the maximum plant flyash output to the Storage Building.

a. Flyash Recycle

Conveyor 92-CV-5 transports the flyash concentrate (50 percent of the flow as a maximum) back to the pulverization area of the Coal Preparation Facility (as shown on Drawing EE-071-005,

Appendix D). The recycled flyash discharges to two belt conveyors (92-CCV-7A and B) which transfer the flyash to the "Pug Mill" of the Pulverizers (20-PU-1A, B, and C). A flow splitter is provided in the discharge of 92-CV-5 to equalize the flow split between Conveyors 92-CV-7A and 92-CV-7B. Conveyors 92-CV-7A and B are reversing type, thus giving the system the capability of feeding the flyash to any two of three pulverizers.

b. Flyash Storage and Disposal

Conveyor 92-CV-2 transfers half, or all, of the flyash reclaimed from the Rotary Filters to Conveyor 92-CV-3 (shown on Drawing EE -071-001, Appendix D). Conveyor 92-CV-3 extends the entire length of the Flyash Storage Building, its support structure attached to the building roof trusses. Conveyor 95-CV-3 is provided with a Tripper (92-ME-4) mechanism which will enable the conveyor to distribute the flyash throughout the length of the building. The Tripper discharges to a reversing-type shuttle Conveyor (92-ME-4), which is supported by a Carriage (92-ME-5) mechanism. The Tripper mechanism is attached to the Carriage. The carriage terminals ride on tracks supported on the building side walls. The tracks run the entire length of the building. In this manner, the flyash can be distributed over the entire area of the Storage Building in the following way:

Flyash is retrieved from the Storage Building, for disposal, by the use of a Bulldozer. The Bulldozer pushes the flyash into a trough running the entire length of the Storage Building. At the bottom of the trough, also running the entire length of the building, is Conveyor 92-CV-8. Conveyor 92-CV-8 is a belt conveyor with rubber skirting running the entire length of the belt. "Skimming" plates are placed, periodically, across the length of the conveyor, within the Building, to level the flyash burden on the belt. Conveyor

92-CV-8 transfers the flyash out of the Building to an elevated Flyash Surge Hopper (92-TK-1), which provides temporary storage for the ash. The Surge Hopper then discharges the flyash to either a truck or railcar for removal from the plant site.

1. Tripper 92-ME-4, located on Conveyor 92-CV-3, discharges flyash on to Reversing Conveyor 92-CV-4 (92-CV-4 has the capability of reversing flow directions);

2. Conveyor 92-CV-4 traverses the width of the Building (mounted on a trolley mechanism riding on tracks) on Carriage 92-ME-5, discharging the flyash across the width of the Building (shuttle conveyor reverses direction, automatically, as it nears the side walls of the Bulding);

3. Carriage 92-ME-5 traverses the length of the Building (rides on tracks mounted on Building walls), enabling Conveyor 92-CV-4 to distribute flyash over the entire length of the Building (Carriage 92-ME-5 reverses direction, automatically, as it nears the end walls of the Building).

Flyash is retrieved from the Storage Building, for disposal, by the use of a Bulldozer. The Bulldozer pushes the flyash into a trough running the entire length of the Storage Building. At the bottom of the trough, also running the entire length of the building, is Conveyor 92-CV-8. Conveyor 92-CV-8 is a belt conveyor with rubber skirting running the entire length of the belt. "Skimming" plates are placed, periodically, across the length of the conveyor, within the Building, to level the flyash burden on the belt.
Conveyor 92-CV-8 transfers the flyash out of the Building to an elevated Flyash Surge Hopper (92-TK-1), which provides temporary storage for the ash. The Surge Hopper then discharges the flyash to either a truck or railcar for removal from the plant site.

4.3.8.7 Slag Removal and Storage (Unit 94)

a. Slag Storage

The Slag System is designed to transport the slag extracted from the bottom of Gasifiers 30-V-1A and B to the Slag Storage and Removal Area. The System arrangement is shown on Drawings EE-071-001, 007, and 008 (Appendix D).

The Gasifier Slag Extractors (30-ME-2A and B) discharge the water-quenched slag to Belt Conveyors 30-CV-1A and B (one for each Gasifier). Conveyors 30-CV-1A and B discharge the wet slag to Belt Conveyor 94-CV-2, which transports the wet slag out of the Gasification area.

Conveyor 94-CV-2 discharges the wet slag to Belt Conveyor 94-CV-3, which elevates the burden to the top of the Storage Building. Conveyor 94-CV-3 discharges to Belt Conveyor 94-CV-4, which transfers and begins the distribution of wet slag throughout the Storage Building.

Tripper 94-ME-4 is located on Conveyor 94-CV-4 and acts as the primary distribution mechanism. The balance of the wet slag distribution system within the Storage Building is identical, in configuration and operating procedure, to that of the flyash distribution system described in Section 4.3.8.6, differing only in the physical size of the components. The balance of the distribution equipment in the Storage Building consists of a "Shuttle" Conveyor Assembly 94-CV-5 which includes:

1. A reversing belt conveyor mounted on a trolley carriage which shuttles the conveyor back and forth, across the width of the Building, automatically reversing direction when nearing the Building sidewalls;
2. A bridge, supporting the trolley carriage, having motorized end trucks which are supported on rails extending the length of the Building; and

3. A drive system for the bridge which will move the conveyor trolley carriage the length of the Building and reverse its direction, automatically, when it approaches the Building end wall.

b. Slag Disposal

Retrieval of slag from the Storage Building for disposal is similar to the system described in Section 4.3.8.6 The slag is pushed, by a Bulldozer, into a trough running the entire length of the Building. At the bottom of the trough, also running the entire Building length, is Belt Conveyor 92-CV-6, a rubber-skirted conveyor with skimming plates to equalize the burden over its length. Conveyor 94-CV-6 elevates the burden to a Surge Hopper (94-TK-1), which provides temporary storage for the disposal system. The slag is extracted from the bottom of the Surge Hopper by a metering Screw (94-CV-7) to either a truck or railcar for removal of the slag from the plant site.

4.3.8.8 Potable Water System (Unit 84)

Since the potable water system is relatively simple, no flow diagram or equipment arrangement drawings have been included in the drawing appendices.

Potable, or drinking quality, water will be taken from the City of Philadelphia water supply, a tap being made from the city main at the western boundary of the property. Sanitary wastes, a by-product of the potable water system, will be returned to the City of Philadelphia sanitary sewage system, again at the western boundary of the property.

Potable water will be distributed to, and sanitary wastes drained from, the following areas of the plant:

a. Administration Building

(1) Two rest rooms (one female and one male), and
(2) One drinking fountain.

b. Warehouse

(1) One rest room, and
(2) One drinking fountain.

c. Locker Rooms (adjacent to Gasifier Switchgear/Central Control Room)

(1) Two rest rooms (one female and one male);
(2) Two shower rooms (one female and one male); and
(3) One drinking fountain.

d. Air Separation Facility Control Room

(1) One rest room, and
(2) One drinking fountain.

e. Waste Treatment Facility

(1) One rest room, and
(2) One drinking fountain.

Electric water heaters will be provided in each of the areas listed.

4.3.8.9 Steam Sewer System (Unit 84)

As in the potable water system, rainfall drainage from the plant site is relatively straightforward; therfore, no flow diagram is included in the drawing appendices.

The Storm Sewer design (pipe sizing) is based on the "50 year - 24 hour" density criteria for the City of Philadelphia area. In simpler terms, the system is designed to drain off the average quantity of rain that would fall in one hour, within a 24-hour period, based on historical data documenting the maximum quantity of rainfall for a 24-hour period within a 50-year time frame. The design of the drainage piping system is also based on the relative elevation of the plant finished grade to the maximum river level, since all rainwater will be discharged to the Delaware River.

The Storm Sewer System is designed as two separate, independent systems, since the size of the plant site is too large to enable one system to flow, via gravity, into the river and have the discharge above the river level. Catch basins and manholes are provided, in strategic locations, to collect and direct the flow of rainwater to the river.

4.4 PLANT ELECTRICAL DESIGN

4.4.1 Plant Electrical Design Criteria

The plant electrical distribution system design was based on providing the following:

a. Design a distribution system with utility system reliability level to minimize power outages in all areas of the plant.
b. Provide an emergency power source to shut down the plant in a safe manner in the unlikely event that the utility power is lost to the facility.
c. Provide sufficient capacity in equipment to allow for addition of loads in the future.
d. Minimize voltage disturbances on the system when starting large 13.2 kV and 4 kV motors.
e. Maximize plant efficiency.
f. Provide centralized control for each process area.

4.4.2 Plant Electrical System

4.4.2.1 Plant Utility Power Supply

The plant power will originate in a Philadelphia Electric Co. (PEC) 13.2 kV substation ring bus located approximately 3/4 mile from the plant site. The PEC system is a 13.2 kV wye solidly grounded system. Three PEC lines will leave the substation and run underground all the way to the plant site. The three lines run under Dyott Street at the southeast end of PGW plant site and terminate in three 15 kV, 1200 A kirk key interlocked disconnect switches in outdoor houses. Each switch is equipped with station class lightning arresters and surge capacitors.

See 13.2 & 4.16 kV cable tray Drawing EE-271-004 and one line Diagram EE-271-001.

The three lines will leave the load side of these disconnect switches and go back underground running to the 13.2 kV switchgear building where they will terminate in three 13.2 kV Metal Clad Switchgear incoming line breaker compartments. Each incoming line breaker will be kirk key interlocked with the outdoor switch house disconnect switch to prevent opening of the disconnect switch until the incoming line breaker is open. The main power supply to the plant will come through double ended 13.2 kV 500 MVA metal clad switchgear operating with the bus tie breaker closed to parallel the two PEC lines. With this operations the PEC lines will provide the maximum plant power demand of 22 MVA. If one line is lost, the remaining line can supply 22 MVA of load for 24 hours only. After this period, the second line must be returned to service or the plant load reduced to 14 MVA. The third line will terminate in a single 13.2 kV metal clad breaker dedicated to supplying the plant coal handling and thaw shed load. This line is rated to carry 7 MVA load continuous and 11 MVA on a 24 hour emergency basis.

4.4.2.2 Plant Load Centers

The transformer sizing for all double ended 4.16 kV and 480 V load centers was done on the basis of being able to supply the total load from one transformer with the bus tie breaker closed if one line is lost. Also, extra capacity has been added for future loads. (Refer to appendix 4.16 kV and 480 V load center calculation).

4.4.3 Plant Short Circuit Levels

4.4.3.1 13.2 kV Bus

PEC has given a tentative three phase fault contribution from their two lines on the 13.2 kV metal clad switchgear bus as 262 MVA symmetrical RMS. (See appendix short circuit calculations, Page 5.) When the three phase fault contribution from the 10,000 HP, 13.2 kV synchronous motor and 4 kV and 460 V induction motors are added to PEC line contribution the total produces an interrupting in three phase fault level on the 13.2 kv bus of 352.77 MVA. (See page 4 of the short circuit calculation in appendix and one line diagram EE-271-001). Therefore, 500 MVA, 13.2 kV, 5 Hertz metal clad switchgear breakers were selected for the conceptual design.

4.4.3.2 4.16 kV Bus

The interrupting fault level for the 4.16 kV bus was calculated for the desulfurization load center which is the largest having two 10 MVA transformers. The interrupting fault level on this 4.16 kV bus is 191.43 MVA; therefore, 250 MVA, 4.16 kV, 5 Hertz metal clad switchgear breakers were selected.

4.4.3.3 480 Volt Load Center Bus

At the 480 V level the larges double ended load center is the Water Treatment Load Center with 2000 kVA transformers. The fault level on this bus is 38,541 amps symmetrical RMS. (Refer to appendix short circuit calculations, Page 17.)

The Coal and Handling and Thaw Shed Load Center 480 V bus will have a fault level of 33,421 amps symmetrical RMS. The PEC line is the only main source of fault current (See appendix fault calculations, Page 16).

4.4.3.4 480 Volt Motor Control Center Bus

All motor control centers are provided with main incoming line 600A current limiting fuses to limit fault level on the motor control center bus to 22,000 AMPS.

4.4.4 Plant Power System Operation

4.4.4.1 13.2 kV Power Distribution

The main part of plant power will enter the plant through two Philadelphia Electric Co. (PEC) lines supplying a double ended line-up of 13.2 kV, 500 MVA metal clad switchgear with electrically operated stored energy breakers. A third (PEC) line will enter a separate 13.2 kV incoming line breaker section with PEC CT and PT metering section. This breaker will supply power to four single ended coal handling and thaw shed 480V load centers. The switchgear is in the 13.2 kV switchgear building located at the east end of the plant north of the desulfurization process area. (See appendix, Plot Plan, Drawing EE-071-001). Power is metered in each incoming line breaker section. PEC PT's and CT's are located in three sections each adjacent to their incoming line breakers. The utility CT's and PT's are connected to a separate PEC totalizing metering panel mounted in the switchgear building. 13.2 kV power will be distributed to five process area switchgear buildings which house the 4.16 kV switchgear, 480V switchgear and 480V motor control centers for their respective and adjacent areas. These switchgear buildings are located in and identified as Air Separation Unit, Gasification, Desulfurization, Water Treatment and Coal Handling, and Thaw Shed. 15 kV three conductor cables with overall continuous imprevious aluminum sheath and outer PVC jacket, will run in an overhead tray from feeder breakers and one incoming line breaker to the load centers in each of the five switchgear buildings. One 13.2 kV feeder breaker is dedicated to supplying the 10,000 HP unity P.F. synchronous motor driving the air separation unit main compressor.

4.4.4.2. 13.2 kV System Relay Protection

Each incoming line breaker section is provided with a distance directional relay (21) providing fault protection for the PEC incoming line cables all the way back to the substation. Back up relaying is provided for these lines by directional overcurrent relays (67) and a direction overcurrent ground relay (67N).

If a line fault should occur, the (PEC) line protection relays will trip and lock out the switchgear incoming line breaker and PEC substation breaker approximated 3/4 mile away. The plant will now be supplied through one line without interruption of power to the load. Bus differential relays 87BA and 87BB will be provided to trip and lock out the incoming line, bus tie breaker and feeder breakers on either half of the bus for a bus fault. A standard complement of coordinated phase and ground overcurrent relays will be provided in the incoming line and feeder breakers. This 13.2 kV switchgear distribution system has an extremely high degree of reliability.

4.4.4.3. 4.16 kV Power Distribution

Four double ended 4160 volt load centers for desulfurization, gasification, water treatment and coal handling and pulverization loads, distribute power to 300 HP and larger motors in their respective areas (See Appendix One Line Diagram EE-271-001 and

Switchgear Building Arrangement Drawings EE-271-001 and 012). The 4.16 kV system will operate as a low resistance grounded system with neutral ground resistors in the secondary windings of each load center transformer.

The switchgear will be composed of two main secondary and one bus tie electrically operated 250 MVA metal clad breakers and medium voltage 4 kV current limiting fused starters on the same bus. Each load center will operate with the bus tie breaker closed providing the same high degree of reliability for loss of a transformer or incoming line as for the 13.2 kV system. Operating with the bus tie breaker closed also minimize voltage drop when starting large motors connected to these load centers. Typically, three conductor 5 kV cable will leave switchgear building running part way in overhead tray and part in conduit to the motors in their respective areas.

4.4.4.4 4160 Volt Relay Protection

The complement of relays used on the main secondary breakers and the bus tie breaker will be similar to the 13.2 kV switchgear. These will consist of directional phase overcurrent relays (67) and directional ground overcurrent (67G) for the main secondary breakers. Bus differential relaying will also be provided. The medium voltage motor starter will have a complete complement of motor protective relay consistent with operating requirements and motor size.

On large motors 1000 HP and above, differential (87) protection will be provided. Automatic single phasing protection will be installed in all starters.

4.4.4.5 480 Volt Power Distribution

480V power is distributed by five double ended and four single ended load centers which are: Air Separation and Delumper, Gasification, Desulfurization, Water Treatment, Pulverization and four Coal Handling and Thaw Shed. (For location, see Appendix, Switchgear Building Equipment Arrangement Drawings EE-271-011 and 012). In double ended load centers the two main secondary and bus tie breakers will be electrically operated. All feeder breakers will be manually operated except where used as motor starters which will be electrically operated. The 480/277V system has a solidly grounded neutral. The load centers will operate in a secondary selective mode with the main secondary breakers closed and the bus tie breaker normally open. On loss of either a line or transformer, their main secondary breaker will trip and the bus tie breaker close supplying the total load through a full rated transformer.

Load center feeder breakers supply Motor Control centers in the same switchgear building. Motor Control Center power and control cables run in tray and underground conduit to the motor loads in the area.

4.4.4.6 480 Volt Relay Protection

All breakers are spring charged stored energy breakers with solid state units providing long time, short time instantaneous and ground sensing protection. These unit provide a complete coordinated selective trip system between main secondary bus tie and feeder breakers.

4.4.4.7 480 Volt Emergency Power

Two emergency 200 KW, 480V, 3 Ph, 60 Hertz diesel generators, one located in the Gasification are and the other in the air separation area will supply power to critical load in the unlikely event of total loss of utility power to the facility. (See appendix one line diagrams EE-271-002 and 003). The gasification area diesel generator is located in the gasification switchgear building on the ground floor under the locker room. (See appendix Plot Plan EE-071-001 and Switchgear Building Equipment Arrangement Drawing EE-271-011).

The air separation unit (ASU) diesel generator and all other electrical equipment associated with the process will be provided by the vendor as part of this complex on a turn key basis. This diesel generator will be located in the (ASU) switchgear building shown on Plot Plan Drawing EE-071-001.

Both diesel generator units will supply power for an orderly shutdown of the complete facility. Each unit has its own 125V DC cranking motor, starter, battery and charger. Each unit is equipped with a daytank, fuel forwarding pump and underground fuel storage tank with sufficient capacity to run the generators for three days.

In the event that normal power is lost to the ASU complex only, its diesel generator will provide power to liquid oxygen pumps which will continue the supply of oxygen to the coal gasification trains to keep them running. Instrumentation and control power will also be provided for the ASU complex at this time.

The gasification diesel generator will provide power for the total plant emergency lighting and auxiliary boiler load. In addition, instrumentation and control power for all other plant processess (except ASU) will be supplied by this unit.

4.4.4.8 Uninterruptible Power Supply (UPS)

UPS units will be located near and provide power for critical instrumentation and control loads. 480V power from the Emergency Motor Control Center bus will be transformed down to 208/120V, 3 Ph, four wire power for input to the battery charger, inverters and bypass circuits of the UPS units.

4.4.4.9 Plant Grounding and Lightning Protection

A grounding grid will be installed using soft drawn stranded copper. The cable will ring and cross each process area. Ground rod will be installed and spaced as required along the ground cable ringing each area. All equipment will be grounded to this grid as required. Lightning rods will be installed on building and equipment as required.

4.4.5 Plant Motors and Motors Control

4.4.5.1 13.2 kV Motor

The only 13.2 kV motor in the facility is the 10,000 HP, 1.0 PF, 1200 RPM synchronous motor driving the main compressor in the Air Separation Unit Complex. This motor will be totally enclosed water cooled with a brushless shaft mounted rotational excitation system. The water to air coolers will be mounted in a pit under the motor.

4.4.5.2 4 kV Motors

All induction motors 300 HP and above will be 4 kV motors. All 4 kV motors will have class "F" insulation with a 1.15 service factor. The normal unity service factor operating range will have a class "B" temperature rise which will provide higher efficiencies and longer life.

Weather protected type II motors will be used in hazardous outdoor locations. Motors in hazardous coal handling areas will be specified as Class II, Division I, Group "F" motors. Hazardous motors for the coal gasification area will be Class I, Division II, Group "C" motors.

4.4.5.3 460 Volt Motors

All 460 V induction motors will be severe duty TEFC high efficiency type motors with class F insulation and 1.15 service factor. The motors will have a Class B temperature rise when operating in the 1.0 service factor area. All motors 50 HP and above used in full voltage nonreversing starter applications will have P.F. correction capacitors. Hazardous area motors for coal handling will be Class II, Division I Group "F" motors.

These motors will conserve energy and provide economical operation over the life of the plant.

4.4.5.4 Plant Motor Control

Five switchgear buildings - Desulfurization, Gasification, Air Separation, Water Treatment and Coal Handling - will house central motor control panels with necessary pushbuttons indicating lights and or selector switches, etc. Every motor that receives power from 4 kV starters and 480V motor control center starters in the five switchgear buildings will be controlled from these control panels. Pushbutton stations will also be provided at each motor location. The central control room plant wide process control system will also control some key motors and give permissive control to the local process. The plant wide process control system is located on the third floor of the Gasification Switchgear Building. All control wiring between switchgear room starters and local process motors will be conventional hard wire. Status annunciators will be located in each local swithgear room. The annunciator status points will be sent to the plant wide process control system through I/O multiplexing system via coaxial cables as described in the following instrument and control system section.

4.4.6 Plant Instrument and Control System

4.4.6.1 General

Overall control of the gasification facility will be effected utilizing a centralized control system. This will be a high speed microprocessor-based digital electronic process controller. The plant operators will have full supervisory functions and complete manipulation capabilities from a single control room location. Operating stations local to various areas of the process will be provided having interaction with central control operation.

The centralized control system will utilize status and analog signals from and dispatch status and analog signals to the primary devices in the facility via a dual redundant coaxial cable data highway network. This signal transport system will make possible any form of interaction required enabling control systems throughout the facility to work together in coordinating plant functions.

The following sections will describe the overall process control system and its components.

4.4.6.2 Centralized Control

The main control room location will be in the gasification area switchgear building on the third floor. This third floor level is to be used solely for the main control system, related hardware, recording equipment, etc.

The primary control devices will be in the local areas for each respective process. They shall be either microprocessor-based multiple loop controllers or conventional individual loop controllers depending on complexity, reliability, and suitability to be determined in final design.

4.4.6.3 Control System Architecture

Plant operator interface will be via CRT consoles with all necessary control functions offered at the console keyboards. The CRT consoles will be provided in duplicate and both shall be operated continuously such that there is an immediate backup. Use of the CRT consoles places control information and responses conveniently in front of the operator in a manner which promotes better surveillence of systems and more rapid response to control situations. The operator will have easy access to all data from the process as well as being able to modify setpoints, valve positions, etc. without having to walk from device to device among panels in the control room. The entire gasification facility can be operated from this main control room location.

A coaxial cable data highway system provided by the process controller manufacturer is used to transport signals to and from the main control room. Actual wiring for control signals need only be routed to and from satellite stations strategically placed at chosen locations in the plant. Actual wire lengths and costs are greatly reduced.

All plant instrumentation, with the exception of special purpose or local only situations, will be electronic. Conversion of flows, temperatures, pressures, etc. to electronic signals will be by conventional means using two and four wire transmitters. These signals will be hardwired to the nearest satellite station. for the operation of valves, electronic signals from the satellites will be converted to pneumatic signals using standard current to pneumatic converters.

The following five locations have been selected for satellite stations:

a. The gasification area switchgear building itself is in a suitable location to hardwire many signals such as those from the gasifiers, coal handling area, etc. A satellite station should be placed on the second floors.

b. A satellite station must be placed in the air separation plant control room for the purpose of collecting operating data and to provide demand signals to that facility.

c. A satellite station should be placed in the desulphurization switchgear room to interface with the vendor supplied Stretford desulphurization equipment and to deal with gasification and storage signals in that vicinity.

d. The product gas area shall have a satellite station to deal with signals involved in final pressurization, conditioning and measurement of the gas.

e. A satellite station shall be placed in the wastewater treatment area due to the number of signals to and from that area as well as the cooling tower and raw water intake areas nearby.

All signal information at these satellite stations is automatically transmitted over the coaxial cable data highway system and becomes available at any other satellite or the CRT consoles. Electronic transmission of these signals and all system internal organization is automatically regulated by a master executive system which is located in the main control room. This master executive system, the CRT consoles, and the coaxial cable networks all will be installed in duplicate to provide redundancy for fail safe operation.

The satellites and the devices in the main control room will have an uninterruptible power supply with chargers and batteries such that the entire system will continue to function for up to two hours in the event of line voltage failure. This sytem will be powered from the 480 volt critical load bus such that the UPS unit will only need to supply backup power if the line voltage fails and the diesel generator has not yet started.

The actual routing of the dual coaxial cables will be via the uppermost level of the cable tray where possible.

In some instances control functions may be considered too critical to use the process controller due to possible controller or data highway failure. Provision is made to easily utilize a dedicated conventional process controller in that area with an interface to the overall process controller. Decisions as to when to do this will be left to final design.

The various field mounted instrumentation is shown on the flow drawings (EE-371-001 through 016) to indicate their relative locations and uses. The devices bear numbers which relate to their flow drawing and area of use. An instrument summary list is provided in Appendix H. The analog logic drawings (Appendix G Drawings EE-271-015 through 041) show the complete interconnection of the devices. The use of I/O, the data highway system, and the overall process controller is not indicated on the logic drawings. A process controller vendor has not been selected and without vendor information and methods available, actual layouts for I/O, electronic modules, etc. are impossible.

4.4.6.4 Process Controller Capabilities

The following control capabilities must be provided in a system suitable for the overall operation of the gasification plant.

a. Complete data acquisition and display - the process controller system must be capable of transporting to and displaying on the CRT consoles any analog or digital signals which are generated by the process and delivered to a satellite location. The system must also transport control signals from the consoles to any satellite location as needed.

b. Operator interface - using the CRT displays and the console keyboard, the main operator must be able to monitor all process variables and be able to manipulate all control setpoints, valve positions, etc. as required to have complete control over the gasification process.

c. Alarm capabilities - the process controller must have the ability to detect an abnormal condition on any input or output and be able to audibly and visually alert the operator to these conditions on a first out basis. Some type of sounding device will be provided and visual indications will be on the CRT console.

d. Recording capabilities - sufficient hard copy and electronic recording equipment will be provided in the central control room location. Hard copy will be made utilizing multi-pen strip chart recorders in instances where a permanent record of process variables is desired. Electronic recording of signals will be with magnetic memory techniques such as floppy disk and should be available for large numbers of signals. These recordings are useful as an operator aid in debugging and fine tuning the plant. Most modern process controller systems offer the operator choices as to which signals are to be recorded. He can change them at will simply by using the CRT console keyboard to address the chosen variables to the electronic recording channels.

e. Computer capabilities - sufficient intelligent capability must be provided either directly in the process controller or through outside computer interface such that the control system can optimize the operation of the plant in the following ways:

   1. Energy Management - Energy uses in the facility are large and the interplay between electric and steam as power sources is complex. The process control system should steer the plant to the highest efficiencies and make the most possible use of internal energy sources.

   2. Process Sequences - The control system should minimize inefficiencies caused by start-up, shut-down, load changes, etc. This can be accomplished by performing

these operations in as timely a manner as possible and by eliminating overshoot, inaccuracy and operator errors.

3. Feedforward Signals - Load following capability and efficiency of the plant should be improved using the computer to predict the arrival of load savings which tend to be predictable or periodic.

4.4.6.5 Plant Control Subsystems

Major plant control subsystems are as follows:

a. Gasification Production Rate

The gasifier production rate control system is the most complex and most critical. This control system involves the gasifier combustion control loops, the oxygen plant demand control, and the gas holding tank volume control. It is a feedback control loop which adjusts the existing production rate to match the gas usage rate and to stabilize the gas holding tank volume. This is done on an automatic basis. As long as the gas demand remains within the allowable gasifier maximum or minimum firing rate limitation, no operator actions are required. If the demand drops below 70 percent of plant capacity, the system will automatically divert to excess gas production to the flare since the gasifiers cannot be turned down to less than 70 percent each. If the demand drops to less than 50 percent and the operator feels that flaring is excessive or that this low demand will persist, he must manually shut down one gasifier unit. The control system will then automatically increase the firing rate of the remaining gasifier and reduce the extent of flaring. If plant demand drops to and persists at a level below 35 percent. If necessary, all control can be done by manual means. Flaring will be unavoidable since this demand is below the minimum production of one gasifier alone.

Signal logic for the automatic production rate control system is based on algebraic manipulation of flow signals and the gas holding tank level signal. Pressure control loop 1243 regulates the gas pressure in the distribution pipeline by modulating pressure control valve PV-1243. The flow indicating transmitter FIT-1240 produces a signal which is proportional to the gas flow required to maintain the steady supply pressure in the pipeline. This flow is the customer demand. Flow indicating transmitter FIt-1242 produces a signal which is proportional to the gas flow required for internal uses. These signals from FIT-1240 and FIT-1242 are summed and the result is a total gas usage signal. To this signal, a factor from the gas holding tank level (from LT-1555) signal is added to produce an actual gasifier production rate target value. Thusly if the gas holding tank is not at the desired standby level, the gasifier production rate is modified slightly to produce an excess or deficiency in order to steer the gas holder to the desired level. The target production rate signal is applied to the plant master controller FIC-1580 as a remote setpoint. This controller utilizes as feedback flow signals from flow indicating transmitter FIT-1580, which indicate the current production rate. The output from controller FIC-1580 is conditioned for maximum and minimum limits and ramp rate limits. It is then utilized as the actual gasifier feedstock firing rate signal to the gasifier combustion control systems. This feestock firing rate determines the quantity of gas produced.

Two control functions are provided to protect the plant from excessive gas load draw which would disrupt the dehydration and desulphurization operations. First, flow indicating controller FIC-1580 is conditioned for maximum and minimum limits and ramp rate limits. It is then utilized as the actual gasifier feedstock firing rate signal to the gasifier combustion systems. This feedstock firing rate determines the quantity of gas produced.

Two control functions are provided to protect the plant from excessive gas load draw which would disrupt the dehydration and desulphurization operations. First, flow indicating controller FIC-1240 will respond to any excessive flow rates by overriding pressure control loop 1243 and closing the final pressure control valve PV-1243 as much as required to limit the gas flow rate to a predetermined limit. Second, if a plant gas supply pressure drop is sensed by pressure indicating controller PIC-1240A, this controller will also ovverride loop 1243 and close the final pressure control valve PV-1243.

b. Oxygen Plant Interface

The oxygen plant receives a feed forward signal from the plant master controller FIc-1580 as an early indication that oxygen demand is changing. The oxygen plant must send a confirming signal indicating that the required oxygen is available before the plant master controller demand signal can reach the combustion control systems. Also, any sudden shortage of oxygen supply will be evident on the availability confirming signal and this will override and reduce the plant demand signal from IC-1580. A warning will be provided to alert the operator that there is a shortage of oxygen.

An actual oxygen usage rate signal which is the current oxygen flow needed at the burners is derived by summing the individual gasifier firing rate demand signals. The oxygen plant operators will also be provided with all available data concerning known and predictable load swings.

c. Gasifier Combustion Control

Combustion control for the gasifiers involves two stages. The first stage requires the mixing of oxygen with steam at a fixed ratio. This is done on a basis which provides an oxygen and steam mixture header from which take-offs are tapped for burner feeds. Both the oxygen and the steam supply to each of these headers is provided with a flow sensor, a flow controller, and a flow control valve so each ingredient can be accurately metered into the mixer. A signal from the gasification production rate control system together with a header pressure signal is used to establish a setpoint to these flow controllers to regulate the quantity of mixture produced.

The second stage of combustion control is the combining of pulverized coal with the oxygen/steam mixture in the proper quantity and ratio. This is accomplished on an individual burner basis, two feed systems, per burner. The firing rate demand signal is brought to the coal feed screws and to the oxygen/steam mixture dispensing valves through lead-lag control systems. The mixture ratio must not go excessive in oxygen, so the lead-lag system require the coal feed screws supply and confirm at a high enough rate before allowing an equivalent oxygen/steam mixture feed rate.

d. Gasifier Drum Level

Feedwater flow to the gasifier boiler drums will be by single element feedwater control loops. Both high and low pressure drums are equipped with electronic level transmitters. Electronic control of the drum feedwater will be effected utilizing conventional current to pneumatic transducers to convert process controller output signals for pneumatic operation of feedwater flow control valves.

e. Gas Booster Compressor Control

The gas booster compressors provide pressure to move the raw gas through the "Stretford" desulphurization system. They discharge into a common header ahead of the static mixers. The gas pressure in this header is regulated to a constant level by modulating the inlet valves to the booster compressors. A pressure transmitter on the common header supplies a signal to a single pressure controller for operation of the inlet valves.

Because of the possibility of insufficient gas being available at the inlet header, a pressure transmitter is provided to sense low pressure there. Minimum pressure controller is provided which has the ability to override the outlet header pressure controller and close the compressor inlets as required to avoid drawing a low pressure on equipment upstream.

f. Product Gas Compressor Control

The product gas compressors are supplied with gas on a common header and all discharge to a common header. One pressure signal is taken from the discharge header and used for control of all three compressors. This signal is taken to three pressure controllers, one dedicated to each compressor. Regulation of header pressure is accomplished by restricting the inlet flow. A recirculation passage with a control valve is used to prevent compressor surge. Operation of the recirculation valve will be decided in final design.

Here again, because of the possibility of insufficient gas being available at the inlet header, a pressure transmitter is provided to sense low pressure there. This controller will override the outlet header pressure controller to avoid drawing a low pressure on equipment upstream.

4.4.6.6 Future Adaptability

A new technology plant such as this one is likely to benefit from the ease with which a modern process controller can be reconfigured to handle alternate control schemes, additional inputs, changed operator interface layouts, etc. The process controller needs only be reprogrammed or reconfigured electronically and little change in actual hardware is required to make major modifications in control philosophy. Typical systems of the nature being considered suitable for this plant can be expanded to five or ten times the complexity required in this gasification plant before becoming fully loaded in terms of inputs, outputs, and data processing capability.

4.4.7 Plant Lighting

4.4.7.1 Outdoor Non-hazardous Areas

All outdoor lighting for roadways and process areas will be 480V high pressure sodium with contactors and photo cell control. The equipment storage area will have high pressure sodium flood lights.

4.4.7.2 Hazardous Areas

In hazardous coal handling areas, both outdoor and indoor, Class II, Division I, Group F high pressure sodium lighting will be applied. For gasification areas, Class I, Division II, Group D high pressure sodium lighting will be applied.

4.4.7.3 Indoor Non-hazardous Areas

Office areas, Administration Building, Switchgear and Control Room Building will have a 3 phase, 4 wire 208/120V system for fluorescent lights. Illuminating levels will be as required by Illuminating Engineering Society (IES) for the application. Battery pack short term emergency lighting will be provided. Long term emergency lighting will be provided by diesel generators.

4.4.8 Plant Communication Systems

Plant communications consists of a telephone system and a separate paging - intercom system.

4.4.8.1 Telephone System

Telephones are located in the administration building, warehouse, main guardhouse, and the control rooms for the gasifier, desulfurization, coal handling, air separation and water treatment.

4.4.8.2 Intercommunication System

The paging-intercom system consists of hand set stations and speaker amplifiers located throughout the plant. All normal intraplant communications will be done over the paging-intercom system. Hand set stations and speakers have been located to achieve complete plant coverage. The intercom system is a multi-party system which permits up to five simultaneous separate conversations over the hand set stations. Each hand set station has a channel select button and a page button. The page system includes a muting system for all outdoor speakers to limit noise spillover from paging during quiet periods such as evening, night and weekends.

4.4.9 Plant Fire Protection System

The fire alarm system consists of a central control console, two remote annuciators, horns, smoke detectors, heat detectors, water flow switches and manual pull stations. The central fire alarm control panel is located in the gasifier control room with remote annunciators located in the main guardhouse and in the administration building.

The plant has been divided into four main fire protection zones and each zone is further divided into approximately six sub areas. The alarm system is zone coded to indicate the location of the alarm condition. Indication on the control console and remote annunciators will show the exact location of the actuated device. The system is an active system which continually scanned for alarm initiation and failure of the system components. A component failure will be indicated at the control unit to alert the operator as to the system trouble. Operation of an alarm initiating device will start the audible and visual alarm indicating devices.

4.4.10 Plant CO Monitoring System

A carbon monoxide detection system has been provided in the gasifier and desulfurization areas for personnel protection. The CO detection system consists of a combination of remote sensing heads connected to a system cabinet located in the gasifier control room and single units located in remote areas in the gasifier and desulfurization areas. The units will initiate both a visual and audio alarms to warn personnel to evacuate areas with high concentrations of CO.

4.4.11 Plant Security System

The security system consists of an access control computer with printer and security fencing. Security fencing is installed completely around the perimeter of the property with two personnel entrances. Each employee is issued a coded identification card which is inserted in a card reader at the turnstiles on entering and leaving the plant. The card readers are connected to the access control computer which prevents unauthorized access and will maintain a log of personnel on site at any time. Visitors will obtain entry only through a guard station with proper authorization.

4.4.12 Determination of Annual Electrical Usage

The total connected load of the plant is 22 MVA. By reviewing the operational profile of the plant and the demand placed on each process area, the annual consumption of electricity has been calculated.

The motor list for the plant is shown in Appendix K. Each motor has been reviewed for usage, and a load factor is indicated. By weighing the load factor and horsepower, the running KVA for each process area has been determined. This is indicated on Table 4-1. The resistive KW is also indicated from a similar determination.

As indicated on Table 4-2, the weighted KVA is reduced to actual KW by applying a demand factor of 0.8 and a power factor of 0.95. A unity power factor air compressor motor and resistive heating contribute 5,600 and 332 KW, respectively, for a use load of 15,612 KW. This converts to 136,761 KWH per year.

4.5 GAS DISTRIBUTION SYSTEM

4.5.1 Design Basis

The gas network is designed to serve medium Btu gas of approximately 290.5 Btu per cubic foot from the coal gasification plant on Beach Street north of Sciaria to four customers with the following load requirements:

	Company	Load SMCF/Hr.	Minimum Delivery Pressure PSIG	Approximate Distance From Customer to Gas Plant - Feet
1.	Allied Chemical	961	10	23,650
2.	National Sugar	1147	10	4,600
3.	Newman Paper	287	10	27,950
4.	Schmidt Brewery	287	10	7,000

TABLE 4-1

WEIGHTED KVA (Running KVA x L.F.)

UNIT NO.	480 KVA	4160 KVA	KW
10	42	63	162
15	32	-	10
20	170	936	-
30	855	1728	48
42	118	2736	3
44	88	-	-
50	1153	-	109
62	-	-	-
64	160	-	-
72	515	432	-
74	134	-	-
81	782	1080	-
82	350	-	-
83	-	-	-
84	101	-	-
85	2	202	-
92	426	-	-
94	182	-	-
TOTAL	5,110	7,177	322

TABLE 4-2

ANNUAL ELECTRICAL USAGE

Weighted KVA Load	12,287 Motors
	300 HVAC
	150 Lighting
	12,737 KVA
x Demand Factor	0.8
	10,190 KVA
x Power Factor	0.95
	9,680 KW
+ Air Compressor	5,600 KW
+ Resistive Heat	332 KW
TOTAL LOAD	15,612 KW
x Hours per year	x 8,760
ANNUAL USAGE	136,761 KWH

4.5.2 Design Approach

The output pressure at the coal gasification plant on Beach Street is assumed at 35 psig and the minimum delivery pressure at the customers' premises would be 10 psig. The calculations are based on smooth interior coated and wrapped schedule 40 steel pipe. Allowances are made in equivalent pipe lengths for sectionalizing valves in the lines. The valves would be installed primarily at intersections where tees are required.

The pipe design is based on the Weymouth Intermediate pressure formula which is shown below:

$$Q = 1.3124 \frac{(T_b/P_b)}{} \left(\frac{(P_1^2 - P_2^2)\, D^{5.333}}{G\, T_f\, L} \right)^{1/2}$$

Q = MCF/Hr = Flow in Thousands of Cubic Feet per Hour

T_b = Degrees Rankin = Temperature base - assumed 492° Rankin

P_b = Pounds per square inch - pressure base - atmospheric assumed at 14.7

T_f = Degrees Rankin - Temperature of flow = 522.6° Rankin

D = Internal Pipe Diameter in inches

L = Length of pipe in feet

P_1 = Initial pressure in pounds per square inch absolute

P^2 = Final pressure in pounds per square inch absolute

G = Specific Gravity of the Gas = .6946

To solve for the pressure drop $(P_1^2 - P_2^2) = P^2$ the formula is transposed as follows:

$$Q^2 = 1.3124^2 \frac{(492)^2}{(14.7)} \frac{(P_1^2 - P_2^2)\, D^{5.333}}{(.6946)\,(522.6)\, L}$$

$$(P_1^2 - P_2^2) = \Delta P^2 = \frac{Q^2}{1.3124^2} \qquad \frac{(.6946)\quad(522.6)\, L}{\frac{(492)^2}{(14.7)}\, D^{5.333}}$$

$$\Delta P^2 = Q^2 \,(.1684)\, \frac{L}{D^{5.333}}$$

The steps to determine the required pipe diameters for a radial feed gas system are listed as follows:

STEP

1 Determine the maximum allowable pressure drop in the system. For this design the maximum $P_1^2 - P^2_2 = (35 + 14.7)^2 - (10 + 14.7)^2 = 1860$.

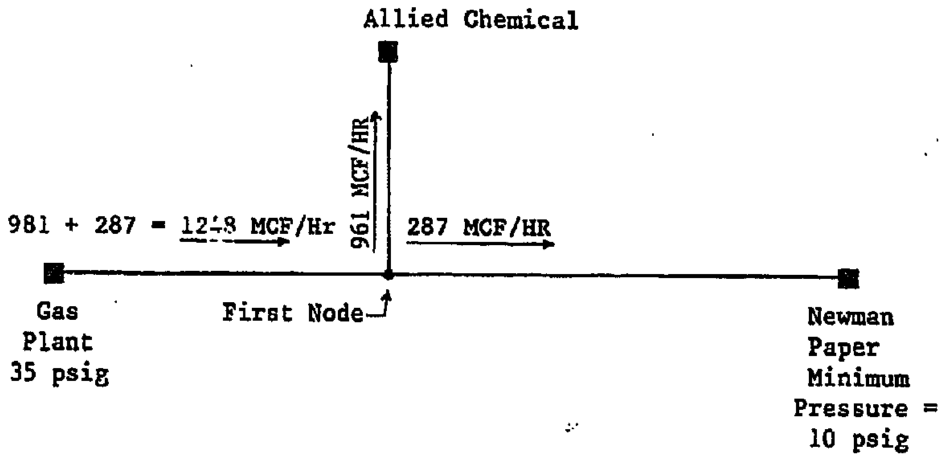
2 Starting with the customer farthest from the source, by trial and error substitute pipe diameters in the flow formula until the $P_1^2 - P^2_2$ for the distance from the customer to the source is less than the maximum allowable drop (in this case 1860). The pipe diameter from the customer to where the flow increases is now established. The place where the flows increase is termed a "Node" point on the system. We will call it the first node point for illustration.

3 Using the flow for the farthest customer and the distance from the customer back to the first node determine the $P_1^2 - P_2^2$ for this section of pipe and subtract it from the maximum allowable (1860 for the start). The remainder is now the maximum allowable $P_1^2 - P_2^2$ for the drop from the first node point back to the source.

4 Repeat the process until all pipes are sized based on the flows in the pipe.

4.5.3 Sample Calculation

The steps to solve for pipe diameter are shown below:



- Solve for pipe diameter between Newman Paper and gas plant

Distance = 5500 + 22450 = 27950 ft.

Flow = 287 MCF/Hr

Maximum allowable pressure drop: =

$$(35 + 14.7)^2 - (10 + 14.7)^2 = 2470.09 - 610.09 = 1870$$

Try 8" schedule 40 pipe - inside diameter - 7.981 inches.

$$P^2 = 287^2 \frac{(.1685)\ 27950}{7.981^{\ 5.333}} = 5995;$$ This is larger than 1860

Try 10 inch schedule 40 - inside diameter - 10.02 inches.

$$P^2 = 287^2 = \frac{(.1684)\ 27950}{10.02^{\ 5.333}} = 1781;$$ This is less than 1860

So the pipe diameter from Newman Paper to the first node point is 10" pipe, and the pressure drop for this section is:

$$\Delta P^2 = \frac{287^2\ (.1684)\ 5500}{10.02^{16/3}} = 350$$

Remaining maximum ΔP^2 from first node point back to the plant is 1860 - 350 - 1510.

STEP III - Solve for pipe diameter from first node point back to gas plant.

First try 16"schedule 40 pipe - inside diameter = 15.000 inches.

$$\Delta P^2 = 1248^2\ (.1684)\ \frac{22450}{15.0^{\ 5.333}} = 3147$$ This is more than 1510

Next try 20" schedule 40 pipe - inside diameter = 18.812 inches

$$\Delta P^2 = 1248\ (.1684)\ \frac{22450}{18.812^{\ 5.333}} = 941.$$ This less than 1510

So the pipe diameter from the Allied top off to the plant is a 20" nominal schedule 40 steel pipe.

4.5.4 Design Description

The distribution system is shown in Appendix E, Drawing DD-371-017. The system design is based on an outlet pressure at the gasification plant of 35 psig and a minimum pressure of 10 psig to any customer.

Approximately 22,450 feet of 20-inch schedule 40 steel pipe is required from the gasification plant on Beach Street to the intersection of Tacony and Bridge Streets. The routing of this line is Beach Street to Richmond; Richmond to Bridge Street; and Bridge Street to Tacony.

Approximately 6,700 feet of 10-inch schedule 40 steel pipe is required on Tacony from the service point for Allied Chemical (about 500 feet south of Bridge Street) to Newman Power at Tacony and Devereaux Streets and two 10 inch sectionalizing valves are needed on Tacony, one north of Bridge and one south of Bridge Street.

Approximately 2400 feet of 8-inch schedule 40 steel pipe is required on Shackamaxon Street from the Schmidt Brewery to National Sugar at the intersection of Beach and Delaware Streets and approximately 4600 feet of 16-inch schedule 40 steel pipe on Delaware Street back to the gasification plant. One 8-inch sectionalizing valve is needed on Shackamaxon just west of the tap into National Sugar. All pipe should be coated and wrapped steel and cathodically protected.

5.0 ALTERNATE OPERATING SCENARIOS

The gasification plant design that is presented in this report is a "grass roots" facility based upon the assumption that the plant will be built and operated with minimal external influence. Throughout the project, the possibility of modifying the design and the operating methodology of the plant to accommodate external influence was reviewed and considered. However, modifications to the basic design are to be considered apart from the base case, in that they have not received sufficiently detailed study to be considered within the definitive design. Several alternate operating scenarios are presented in this section as an indication of areas to be explored at the onset of detailed plant design.

5.1 PURCHASE OF OXYGEN

The basic plant design incorporates an oxygen plant which is owned and operated by the coal gasification project. Operating costs associated with the oxygen plant are shared with the total facility. As a means of reducing the capital requirements of the overall project, it is possible to purchase oxygen from an outside supplier which owns and operates the oxygen plant.

Potential oxygen suppliers have indicated that the cost of oxygen to the project would be based upon debt reduction and operating costs. For a 1,200 tpd oxygen plant, debt reduction would be $6 million per year in 1981 dollars. Operating costs would be passed through. Accordingly, the following impact would be realized on the base case operation:

Decrease Capital by $27 Million (1981 $'s),
Increase unescalated fixed costs by $6 Million per year, and
Operating costs remain unchanged.

5.2 COAL VIA THE PORT RICHMOND TERMINAL

Toward the end of this phase of the project, CIBRO Corporation announced that it was going to build an export coal terminal in the Port Richmond Rail Yard, adjacent to the Riverside Site. The terminal is to be completed before 1985 and will transfer as high as 15 million tons of coal per year. It is probable that PGW will be in a position to negotiate an agreement with CIBRO whereby coal is stored at the terminal and transfered to the gasification project on demand.

This arrangement would effect the gasification project in several ways. First, the capital reduction would be significant by eliminating the requirement for coal handling and unloading equipment and associated site improvements such as the coal pile and rail facilities. An 800 foot conveyor system would be installed to convey coal from the terminal to the coal preparation area of the gasification plant.

It is expected that operating costs would not be significantly affected. Both manpower and electricity should trade off in operation maintenance and power comsumption. CIBRO indicated to PGW that they would require a terminalling fee per ton of coal. Rather than adding this to the cost of coal, it is probable that the benefits associated with the volume purchases passing through the terminal in both initial coal cost and transportation will result in a net coal cost equal to the present estimate.

It is expected that the following impact would be realized on the base case operation:

> Decrease Capital by $15 Million (1981 $'s), and
> Operating Costs (Including Coal) remain unchanged.

5.3 CO GENERATION FOR LOAD LEVELING

The two-gasifier coal gasification plant has been designed for base load operation on a seven-day, 24-hour schedule with maximum operational availability. Under conditions of producing synthesis gas or fuel gas for single captive users, baseload operation is to be expected. However, in the case of this project, which is serving multiple users of variable load profiles, a method of levelizing the gas production to maintain baseload operation has been considered. The approach taken to levelize production is to produce electricity with the excess product gas and to sell power to Philadelphia Electric Company as a small producer under the Public Utility Regulatory Policies Act (PURPA) of 1978.

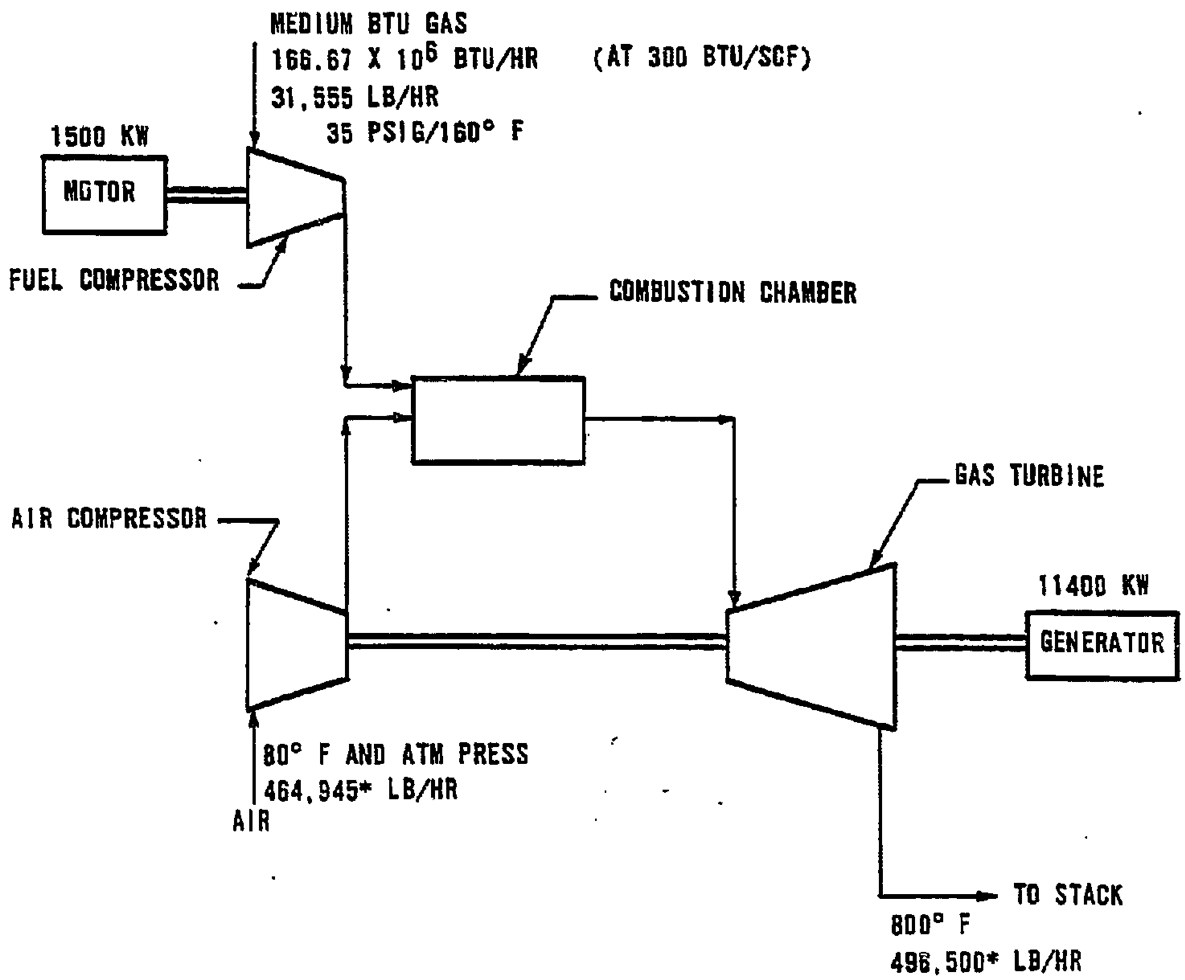
A study was conducted on a conceptual design level to determine the feasibility of generating electricity from excess fuel gas production. It was assumed that 300 Btu per cubic foot gas at the rate of 4 billion Btu per day would be available. Other assumptions were:

Fuel Supply Condition - 35 psig/160°F,
Operating Hours/Year - 7,800,
Plant Elevation - Sea Level,
Selling Price of Power - $.05/kWh, and
Restrictions - Stand-alone installation apart from existing design.

To generate the electricity from the excess gas, three alternates were considered. They are: simple cycle gas turbine, combined cycle gas turbine, and steam turbine cycle

a. Simple Cycle Gas Turbine

The system schematic for a simple cycle gas turbine is shown on Figure 5-1. The heating value of the gas used here is lower than the conventional fuels (natural gas or oil) and,



* ESTIMATED VALUE
NET POWER GENERATED – 9900 KW

FIGURE 5-1
SIMPLE CYCLE
GAS TURBINE

therefore, it requires a slightly bigger size gas-turbine than it would require with the conventional fuels.

With heat input of 166.67×10^6 Btu/per hour into the system, power generated from the gas-turbine is 11,400 KW. This requires a gas turbine nominally rated at 14,000 KW. A fuel compressor is required to compress the gas from 35 psig to combustor pressure condition. This compressor requires 1,500 KW power for its motor drive.

The following major items are included in this system:

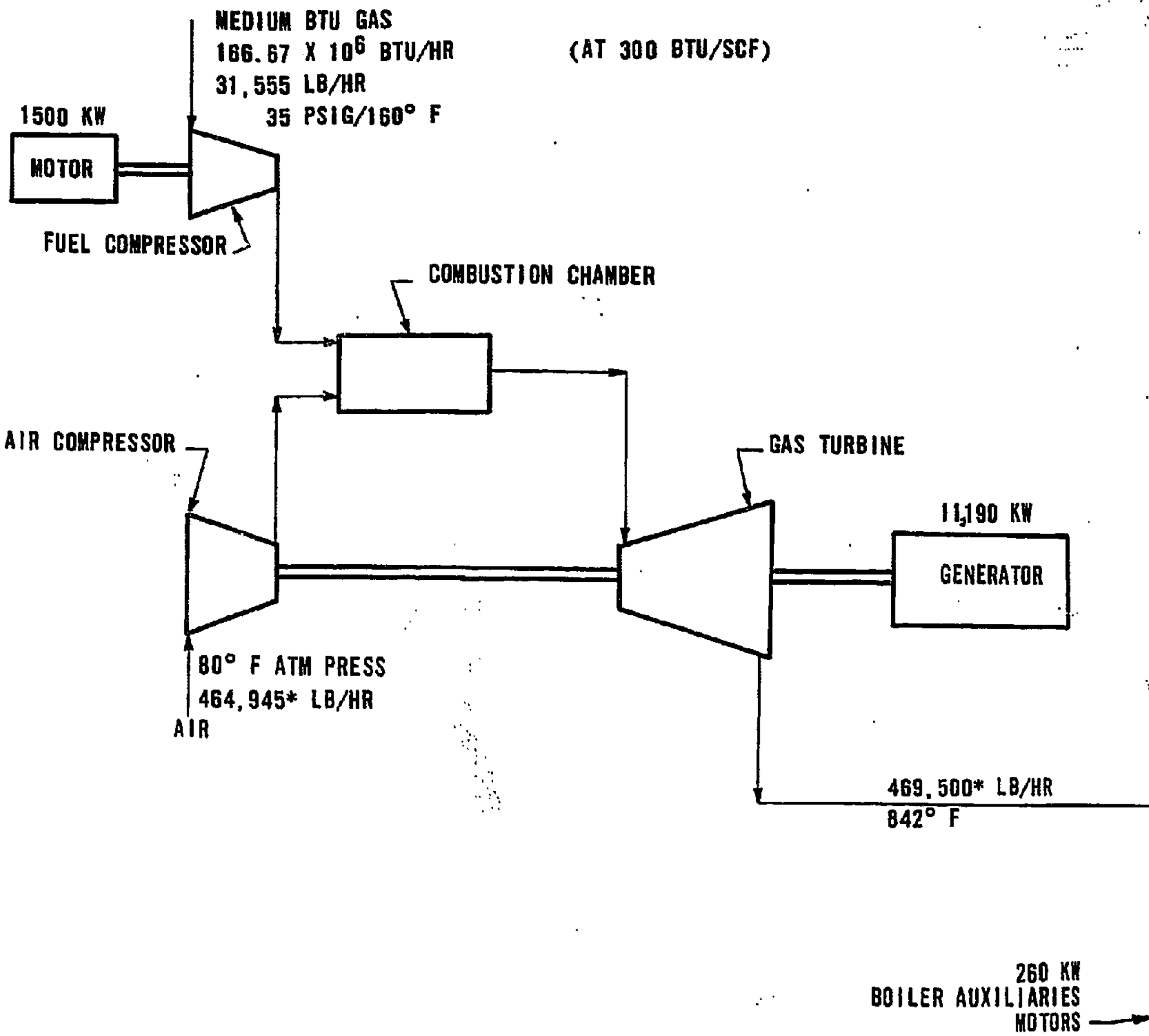
- Gas turbine with generator and exciter,
- Fuel compressor,
- Switchgear and necessary electrical auxiliaries,
- All necessary controls for the system,
- Piping, duct work, etc.,
- Exhause stack and silencer, and
- Building.

b. Combined Cycle Gas Turbine

The system schematic for a combined cycle gas turbine is shown on Figure 5-2. With heat input of 166.67×10^6 Btu per hour into the system, power generated from the gas turbine is 11,190 KW and from the steam turbine is 4,760 KW. It requires 14,000 KW of nominal rating gas turbine and 5,000 KW steam turbine. In this case also a fuel compressor is required. The system requires 1,760 KW power to run the all auxiliary drives including the fuel compressor motor.

The following major items are included in this system:

- Gas turbine with generator and exciter,
- Fuel compressor,



* ESTIMATED VALUE

NET POWER GENERATED – 14,190 KW

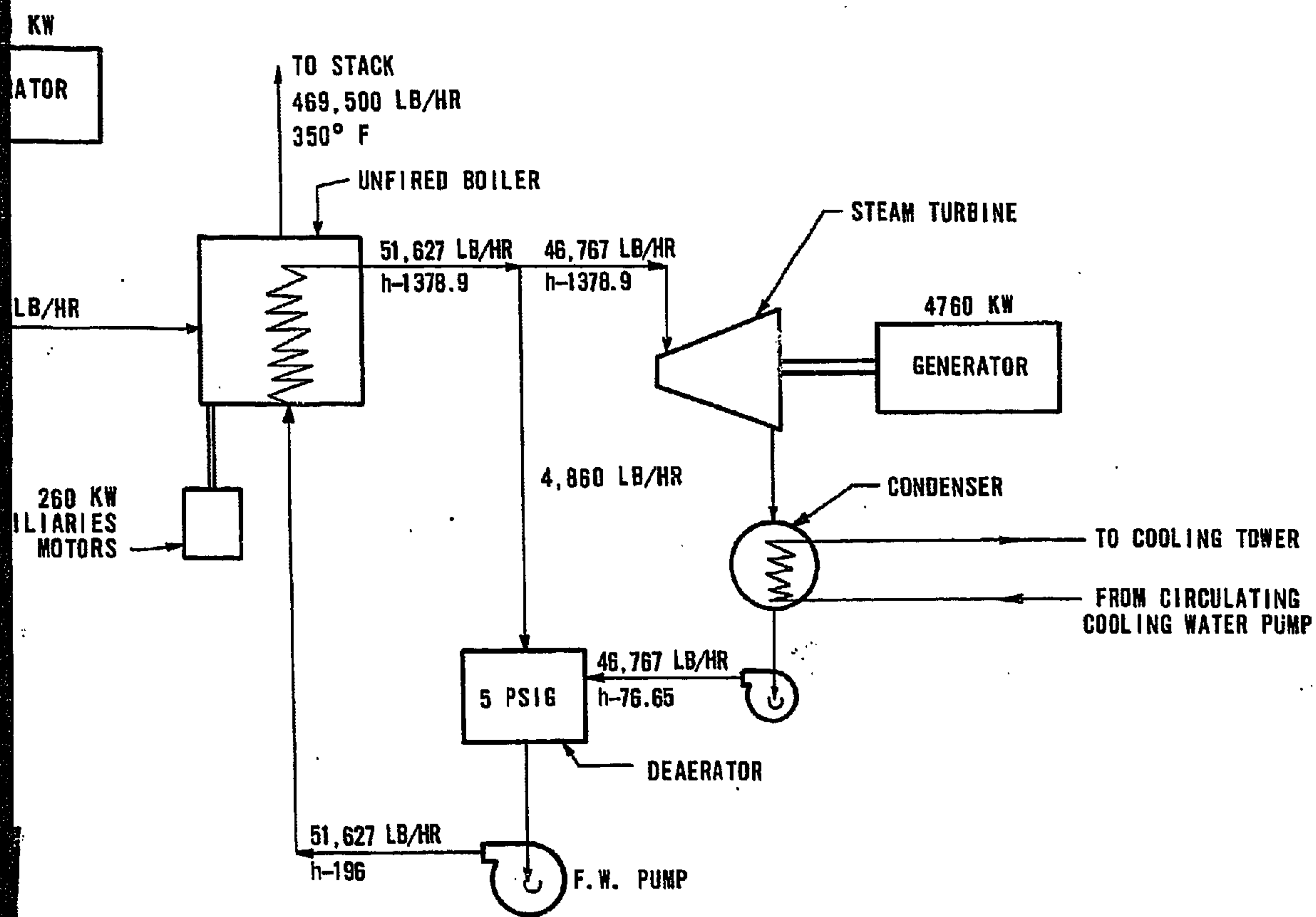


FIGURE 5-2
COMBINED CYCLE
GAS TURBINE
600 PSIG/750° F STEAM

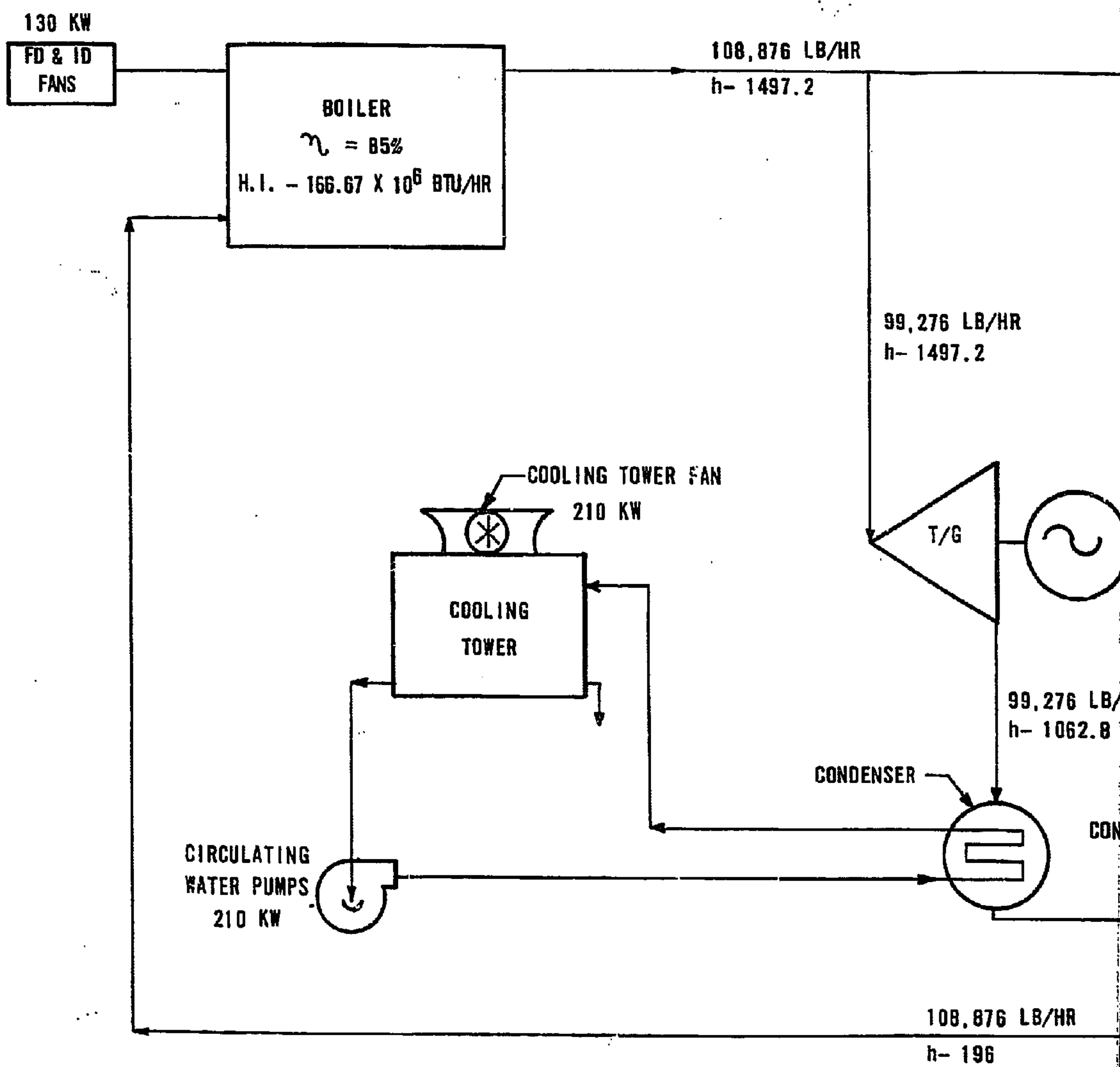
Switchgear and necessary electrical auxiliaries,
All necessary controls for the system,
Piping, duct work, etc.,
Unfired boiler,
Steam turbine with generator and exciter,
Condenser,
Cooling tower,
Deaerator,
All required pumps and fans,
Enclosed building, and
Stack.

c. <u>Steam Turbine</u>

The system schematic for a steam turbine cycle is shown on Figure 5-3. With heat imput of 166.67 x 10^6 Btu per hour to the boiler, power generated from the steam turbine is 12,630 KW. This requires a steam turbine nominally rated at 14,000 KW. The system requires 560 KW power to run the auxiliary drives.

The following major items are included in this system:

Boiler,
Steam turbine with generator and exciter,
Switchgear and necessary electrical auxiliaries,
All necessary controls for the system,
Piping, duct work etc.,
Condenser,
Cooling Tower,
Deaerator,
All required pumps and fans,
Enclosed building, and
Stack.



NET POWER GENERATED - 12070 KW

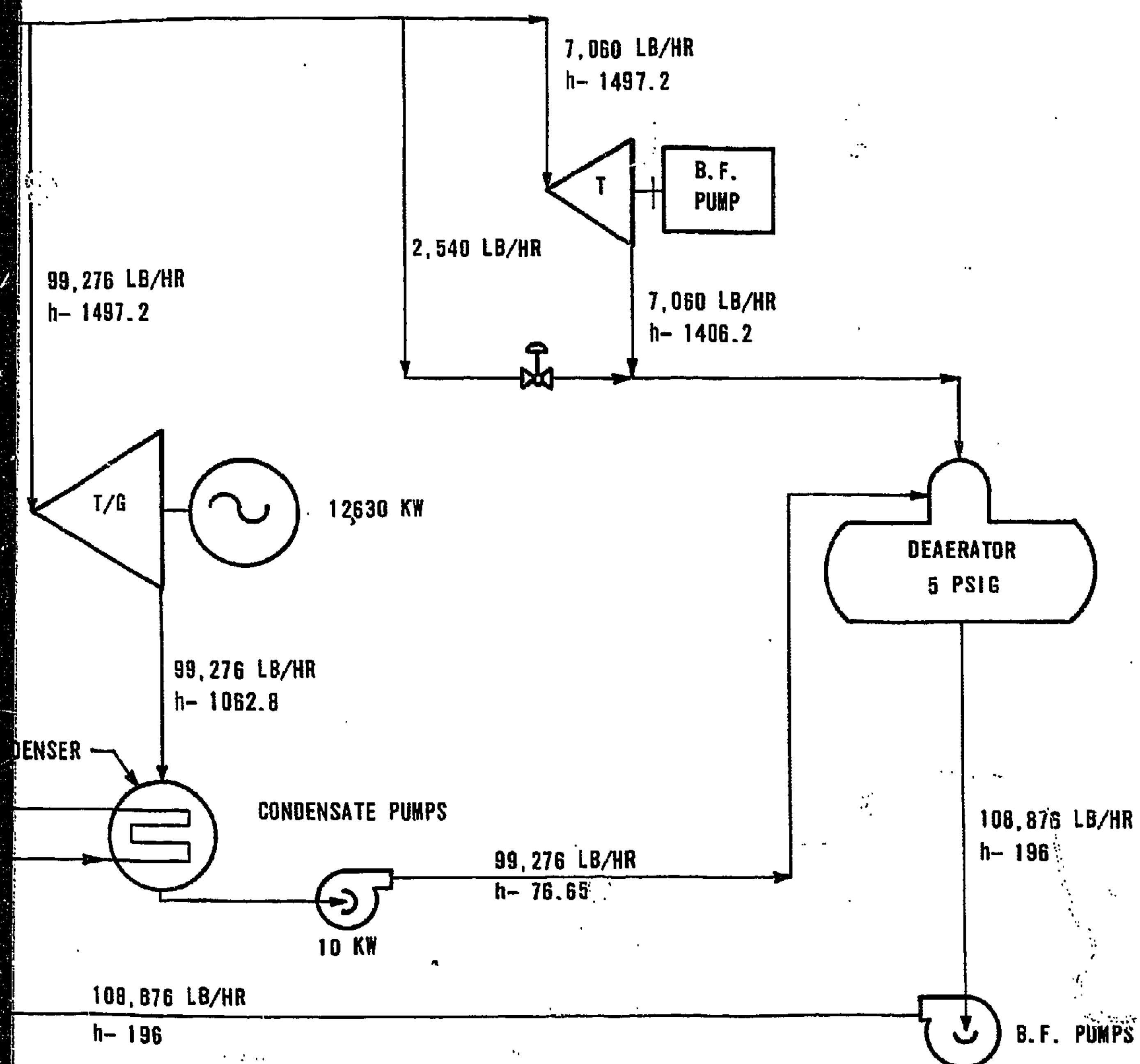


FIGURE 5-3
STEAM TURBINE CYCLE
1250 PSIG/1000° F STEAM

5.3.1 Capital Costs

The capital cost estimate is shown on Table 5-1. The type of estimate submitted is one of the preliminary concepts and the degree of accuracy which can be expected for the capital costs estimate is -10 to +30 percent. The capital costs for the three alternates are:

Simple cycle gas turbine - $7,348,000,
Combined cycle gas turbine - $13,655,000, and
Steam turbine cycle - $10,860,000.

5.3.2 Operating Costs

The operating costs (or net revenue) were developed for the three alternates and are shown on Table 5-2. The operating costs are catagorized by the electrical power requirement for auxiliary drives and manpower requirements. Fuel costs associated with gas production is not considered here. The excess power generated is sold back to Philadelphia Electric Co., at the rate of $0.05/kWh.

The net revenue generated from the three alternates are:

Simple cycle gas turbine - $3,721,000,
Combined cycle gas turbine - $5,294,000, and
Steam turbine cycle - $4,467.000.

TABLE 5-1

ESTIMATED CAPITAL COSTS (1981 $'s)

SUPPLEMENTARY TURBINE GENERATOR CYCLES

	Simple Gas Turbine 12000-14000 KW Westinghouse 191	Combined Cycle Gas Turbine 12000-14000 KW GT 5000 KW ST	Steam Cycle 14000 KW 1250 psig - 1000 °F
Site Preparation	$ 10,000	$ 15,000	$ 20,000
Gas Turbine Generator Delivered	4,000,000	4,000,000	-
Steam Turbine Delivered	-	1,800,000	2,700,000
Erect and Assemble Turbines	100,000	300,000	250,000
Turbine Foundation	150,000	225,000	80,000
Fuel Compressor	800,000	800,000	-
Boiler Delivered and Erected	-	800,000	1,200,000
Condenser, Cooling Tower & Aux.	-	600,000	1,000,000
Cooling Tower Basin	-	50,000	100,000
Building Work	200,000	800,000	700,000
Piping Mechanical	200,000	800,000	1,800,000
Instrumentation and Controls	30,000	60,000	100,000
Switchgear	150,000	175,000	160,000
Electical & Wiring	50,000	150,000	200,000
Sub Total Direct Costs	5,690,000	10,575,000	8,310,000
Engineering	450,000	950,000	800,000
Construction Supervision	150,000	200,000	200,000
Startup Services	100,000	150,000	150,000
Sub Total Indirect Costs	700,000	1,300,000	1,150,000
Sub Total	6,390,000	11,875,000	9,460,000
Contingency (15%)	958,000	1,780,000	1,400,000
Total	$7,348,000	$13,655,000	$10,860,000

TABLE 5-2

OPERATING COST (1981 $'s)

SUPPLEMENTARY TURBINE GENERATOR CYCLES

	Simple Gas Turbine	Combined Cycle Gas Turbine	Steam Cycle
			1250 psig - 1000°F
Available Btu/per hour	166.67×10^6	166.67×10^6	166.67×10^6
Heat Rate (HHV) Btu/KWH	14,650 est.	10,450 est.	13,200
KW Generated - Gas Turbine	11,400	11,190	-
KW Generated - Steam Cycle	-	4,760	12,630
KW Generated - Total	11,400	15,950	12,630
KW Req'd. for Fuel Compr.	1,500	1,500	-
KW Req'd. for Aux.	-	260	560
KW Net	9,900	14,190	12,070
Operating Hours	7,800	7,800	7,800
KWH/Year Sale - M	77,220	110,682	94,146
Unit Sale Price to PE	$ .05	$ .05	$ .05
Sales Value, Gross	$3,861,000	$5,434,000	$4,707,000
Labor Cost	100,000	200,000	200,000
Sup. Cost	40,000	40,000	40,000
NET REVENUE	$3,721,000	$5,294,000	$4,467,000