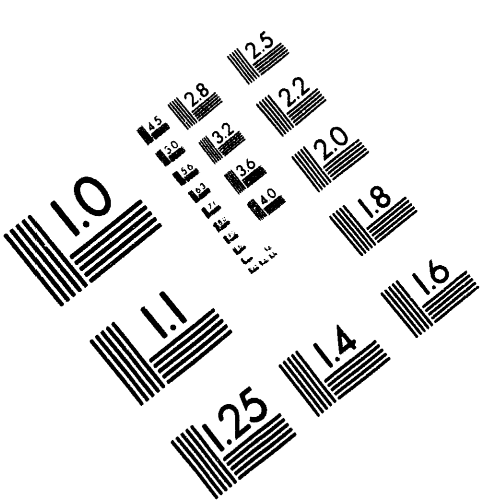

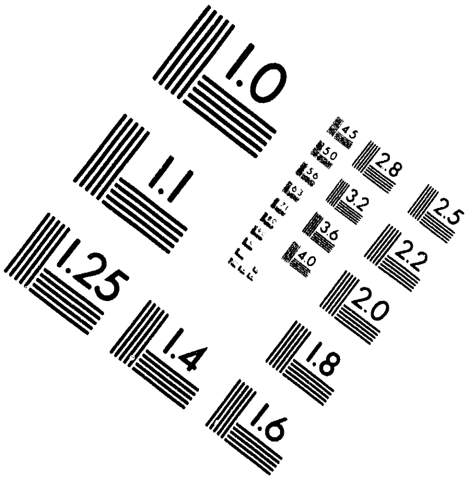

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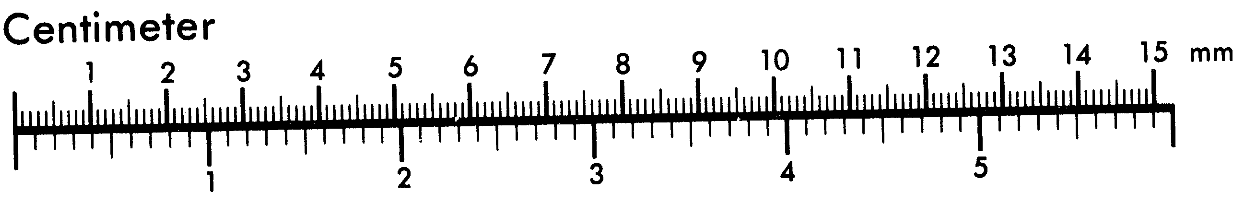

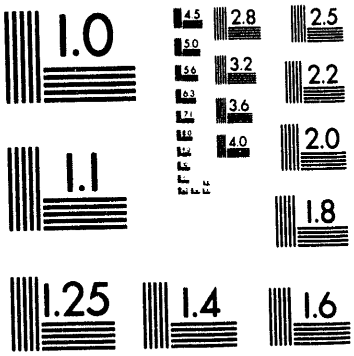

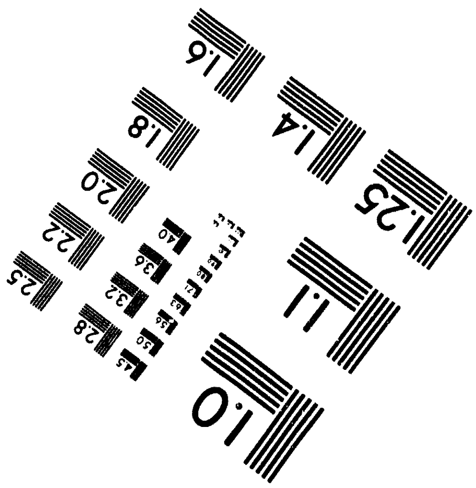

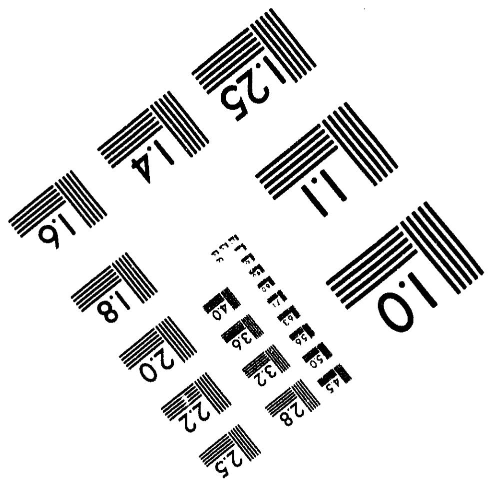

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York County Energy Partners CFB Cogeneration Project

Annual Report

Work Performed Under Cooperative Agreement No.: DE-FC21-91MC27403

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
York County Energy Partners, L.P.
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Allentown, Pennsylvania 18195

March 1994

TECHNICAL PROGRESS REPORT (FINAL)

TECHNICAL PROGRESS REPORT (FINAL)
(continued)

LIST OF FIGURES

YORK TECHNICAL PROGRESS REPORT (FINAL)

I. INTRODUCTION

A. Purpose of Report

This Technical Progress Report (Final) is submitted pursuant to the Terms and Conditions of Cooperative Agreement No. DE-FC21-90MC27403 between the Department of Energy (Morgantown Energy Technology Center) and York County Energy Partners, L.P. a wholly owned project company of Air Products and Chemicals, Inc. covering the period from 10/01/92 to the present for the York County Energy Partners CFB Cogeneration Project. The Technical Progress Report summarizes the work performed during this period including technical and scientific results.

B. Overview Description of Facility

The Department of Energy, under the Clean Coal Technology program, proposes to provide cost-shared financial assistance for the construction of a utility-scale circulating fluidized bed technology cogeneration facility by York County Energy Partners, L.P (YCEP). YCEP, a project company of Air Products and Chemicals, Inc., would design, construct and operate a 250 megawatt (gross) coal-fired cogeneration facility on a 38-acre parcel in North Codorus Township, York County, Pennsylvania. The facility would be located adjacent to the P. H. Glatfelter Company paper mill, the proposed steam host. Electricity would be delivered to Metropolitan Edison Company.

The facility would demonstrate new technology designed to greatly increase energy efficiency and reduce air pollutant emissions over current generally available commercial technology which utilizes coal fuel. The facility would include a single train circulating fluidized bed boiler, a pollution control train consisting of limestone injection for reducing emissions of sulfur dioxide by greater than 92 percent, selective non-catalytic reduction for reducing emissions of nitrogen oxides, and a fabric filter (baghouse) for reducing emissions of particulates.

C. Outline of Report

The next section of this report (Section II) provides a general description of the facility. Section III describes the site specifics associated with the facility when it was proposed to be located in West Manchester Township. After the Cooperative Agreement was signed, YCEP decided to move the proposed site to North Codorus Township. The reasons for the move and the site specifics of that site are detailed in Section IV. This section of the report also provides detailed descriptions of several key pieces of equipment. The circulating fluidized bed boiler (CFB), its design, scale-up and testing is given particular emphasis. Other unique aspects of the facility located in North Codorus Township are also described in Section IV including water usage and treatment and air emissions reductions associated with starting up the new facility.

II. GENERAL YCEP DESCRIPTION

A. General Description

The YCEP facility is a coal-fired CFB boiler cogeneration facility producing 250 MWe (gross) or 227 MWe (net). The power island consists of a Foster Wheeler Circulating Fluidized Bed (CFB) boiler and a "utility style" reheat turbine generator. The facility also includes a baghouse, a stack, a cooling tower, coal unloading and storage facilities, limestone unloading and storage facilities, demineralization system, and a gray water treatment facility.

The purpose of this project is to help demonstrate the commercial viability of using a utility-scale circulating fluidized bed technology in a cogeneration facility to generate electric power for a local utility and steam for local host industries. This project is one of a number planned to be conducted pursuant to the Clean Coal Technologies program to demonstrate different approaches and applications of clean coal technologies. Successful future commercial application of circulating fluidized bed technology could result in reductions in air emissions at costs lower than those of conventional pollution control technologies. In addition to the direct economic benefits accruing from the lower cost of producing electric power and the environmental benefits of decreased air pollutant emissions, the future commercial application of circulating fluidized bed technology would also assist in reducing the dependence of the United States upon imported energy.

The proposed facility would also assist in meeting an energy shortfall projected by the Pennsylvania Public Utility Commission to occur in the region served by Metropolitan Edison Company. To meet this need for electric power in the region, new power generation facilities will be required. In addition, the provision of steam to the steam host enhances the efficiency of energy use at that facility. The proposed cogeneration facility would therefore assist in serving the needs of the community for electrical power and the needs of local industry for steam power, while meeting its primary objective of demonstrating a clean coal technology.

B. Technology Description

The facility will use eastern bituminous coal as its primary fuel in a Foster Wheeler CFB boiler. The steam produced in the boiler will generate 227 MW (net) of electricity in a Westinghouse turbine generator consisting of an opposed flow high pressure - intermediate pressure turbine element and a dual flow low pressure turbine element coupled to a surface condenser. A Process Flow Diagram is shown in Figure 1.

Emissions will be minimized through the use of the CFB boiler technology. Limestone will be injected into the boiler to capture sulfur dioxide ("SO_2"), reducing SO_2 emissions by 92%. Combustion air will be staged, combustion temperatures controlled, and aqueous ammonia or urea will be injected into the cyclones to control nitrogen oxide ("NOx") emissions. Carbon monoxide and hydrocarbon emissions will be minimized through the efficient combustion process which occurs in a circulating fluidized bed boiler. Particulate emissions will be controlled with a baghouse prior to the flue gas entering the stack.

The major new technology area involves the CFB boiler which will be the largest single train unit in the U.S. For large scale steam generator design, mechanical design requirements such as structural support, tube thickness, material selection, etc. and many process considerations such as steam/water circuitry design for natural circulation and steam superheating have been standard practice for many years. The main areas of scale-up for the subject unit are the processes related to fluidized bed combustion: furnace design, cyclone design, recycle heat exchanger design, and heat recovery area design.

In designing a large scale CFB furnace, the primary area of concern is to provide the conditions for optimum emission control, fuel burn-up, and heat transfer. These conditions can be achieved by providing good fuel, sorbent and air mixing, as well as the proper configuration of heat transfer surface. In designing a utility scale unit furnace, good fuel mixing for uniform fuel burning will be achieved by:

- Limiting the furnace depth so that fuel distance of travel from front to rear wall is minimized and good penetration and mixing of secondary air can be achieved.

- Telescoping the furnace width and adding more fuel, limestone, and secondary air feed points as well as the number of recycled solids return ports which uniformly distribute recycled solids and promote mixing.

- Adding a full division wall that distributes heat transfer surface for uniform heat removal.

C. Buildings and Structures

A main power island building will be constructed which consists of a number of adjacent or interconnected buildings, the largest of which will be the boiler building. This building will house the boiler combustor, cross-over, cyclones, air preheater, fuel day silos, primary air fan, and ash collection system. The building will be equipped with a freight style elevator to facilitate maintenance.

The next building is the feedwater heater building. This building, which is adjacent to the boiler building contains all facility feedwater heaters. All heaters are arranged in a stacked fashion to facilitate piping and minimize foot print requirements.

The next building is the turbine/generator building. This building is adjacent to the feedwater heater building. This building houses the turbine/generator train and support systems, surface condenser, boiler feedwater pumps, and auxiliary pumps and equipment. This building will be equipped with a maintenance bridge crane for servicing the major machinery within. The building has also been designed to allow direct loading and unloading of flatbed delivery truck by means of a drive-in bay on the first floor of the building.

A control/maintenance/visitor's center building which will house all power island and main operations overseeing functions, offices, showers, restrooms, spare parts storage, and maintenance areas. In addition, a complete visitor's center with conference room and reception area will be included in this building.

Other miscellaneous buildings on the site include the coal unloading building, the ash leading building, and water treatment buildings. All buildings will be constructed with an architectural siding to accomplish a "commercial" look for the facility which will compliment the architecture of the existing P. H. Glatfelter Company structures.

D. Major Equipment List

A list of major equipment include:

One Foster Wheeler Circulating Fluidized Bed Boiler (CFB)
One Steam Turbine Generator
One Single Flue Stack
14 Compartment Baghouse & I.D. Fans
Coal, Ash and Limestone Handling Equipment
Water Treatment System

Three Boiler Feed Pumps (electric motor driven)
Emergency Boiler Feed Pump (steam-turbine driven)
8 Cell Cooling Tower
Condenser
Power Transformers and Switchyard
Distributed Control System
Fire Protection system
Miscellaneous Buildings (administration, maintenance/control, guard and utility)
Railroad Spur and Fuel Unloading System
7 Feedwater Heaters Plus Deaerator
Primary and Secondary Air Fans
Emergency Diesel Generator
2 Fly Ash, 2 Bed Ash, and 2 Sorbent (Limestone/Dolomite) Steel Silos
Five 56'-0" Diameter Remote Coal Storage Silos
Four Steel Coal Bunkers

III. WEST MANCHESTER SITE

As originally proposed by YCEP, the project site would be adjacent to the J. E. Baker Company site in West Manchester Township, York County, Pennsylvania. This section briefly describes the facility as proposed at that site. Figure 2 shows a site plan at this site.

A. Location

The site was located 6 miles west of York City, 1/4 mile North of Rt. 30 off of Emig Mill Road. The site is bounded on the south by Yorkrail, on the east by Emig Mill Road, and on the north and west by private property. The J. E. baker manufacturing facility is just across Emig Mill Road.

B. Specific Site Parameters (West Manchester Township)

For the J. E. Baker site the key design basis criteria include:

Site Size	45 acres
One Foster Wheeler Circulating Fluidized Bed Boiler:	1,725,000 lb/hr
One Turbine-Generator:	227 MW Net
Start-Up Fuel:	Natural Gas
Auxiliary Boiler Fuel:	Natural Gas

Coal Delivery:	Rail via Loop Track
Disposal of Bed and Fly Ash:	Truck to Offsite Disposal Location
Voltage:	230 kV
Power Purchaser:	Metropolitan Edison Company
Export Steam Host:	J. E. Baker Company
Export Steam Flow:	
200 psig	40,000 lb/hr Maximum 26,000 lb/hr Nominal
50 psig	40,000 lb/hr Maximum 26,000 lb/hr Nominal
Cooling Water Make-Up Source:	York Water Company
Condensate Return:	100%

C. Utilities/Interface

1. Electric Interconnection

A 230 kv interconnection facility was required to loop feed to the existing 230 kv Met-Ed line.

2. Steam Line and Condensate Return Line

New approximate 1 mile steam and condensate lines.

3. Water Supply

A new approximate 6 mile pipeline from The York Water Company was required.

4. Wastewater

Approximate 3 mile to Codorus Creek.

IV. NORTH CODORUS TOWNSHIP SITE

A. Evolution of Site Change

The site initially selected by YCEP was at The J. E. Baker Company in West Manchester Township. The J. E. Baker Company site met all key site selection criteria. Specifically, that site had approximately 50 acres of mostly flat property available that was zoned for industrial use, had access to rail, water, and roadways, was near existing Met-Ed electric lines, and was in close proximity to the required steam user (J. E. Baker).

During development and permitting activities at the West Manchester site, YCEP committed to obtain air emission reductions from existing sources from within York County. In August 1992, during the process of evaluating offset opportunities, YCEP representatives contacted officials at P. H. Glatfelter Company to determine what offsets might be available. In October 1992, P. H. Glatfelter officials determined that significant offsets would be available only if P. H. Glatfelter Company #4 Boiler could be curtailed and if the YCEP facility could provide a large quantity of steam to the P. H. Glatfelter mill, therefore requiring the YCEP facility to relocate to North Codorus Township. In February 1993, YCEP officials determined that this relocation was beneficial from a business and environmental point of view as compared to the West Manchester Township site. In consideration of all relevant criteria including the opportunity for significant air emission reductions and the reuse of process wastewater for cooling purposes, this site best satisfied the selection criteria. The specific advantages of the site are as follows:

- **Proximity to Steam User** - The proposed site is located adjacent to the industrial steam host, P. H. Glatfelter with an economical steam source that would meet the mill's projected needs will into the 21st century.

- **Appropriate Land Use** - North Codorus Township does not have a zoning ordinance, but does have a land development and subdivision ordinance. The proposed project can achieve the ordinance requirements and is consistent with the adjoining P. H. Glatfelter operations.

- **Infrastructure** - The proposed site is located near existing interconnections to Met-Ed electrical lines and the site has good access to rail. The water service and wastewater treatment facilities necessary were also present.

- **Environmental Effects** - As a result of receiving steam from YCEP, P. H. Glatfelter can curtail operation of an existing coal-fired boiler, thereby significantly reducing air emissions. The reuse of the process wastewater for cooling purposes eliminates the need of fresh water supply sources.

The project will be located on P. H. Glatfelter (PHG)-owned property in North Codorus Township immediately south of the paper mill and would provide up to 400,000 pounds per hour of high pressure steam to PHG. YCEP would purchase sulfur dioxide allowances and nitrogen oxide offsets from PHG to fulfill certain obligations under the federal Clean Air Act Amendments of 1990 ("CAAA"). On February 1, 1993, a Land Development Plan was filed in North Codorus Township and the move was simultaneously announced to the public. YCEP's request to suspend the zoning hearings in West Manchester Township was granted shortly thereafter.

In February 1994, DOE was formally requested by YCEP to change the project site from the West Manchester site to the North Codorus site. As part of the review process conducted by DOE, YCEP conducted an environmental site assessment of the North Codorus site and provided the results to DOE. The environmental site assessment concluded that these were no pre-existing conditions at the site and that the site is environmentally acceptable. DOE approved the site change in June 1993.

B. Site Location

The approximately 38-acre site proposed for the YCEP cogeneration facility is located in North Codorus Township, York County, Pennsylvania (Figure 3). The parcel is bounded on the west by the P. H. Glatfelter Roundwood facility, on the south by Pennsylvania Route 116, and on the east and north by Kessler Pond and the mill pond (an impoundment of the west branch of Codorus Creek) and the west branch of Codorus Creek. The site is situated approximately eight miles southwest of York, Pennsylvania.

Land uses in the vicinity of the site are mixed. The P. H. Glatfelter paper mill is the closest industrial use. Small commercial uses and a cluster of eight residences characterize development along Route 116 south of the site. Agricultural uses exist west and north of the site.

The site is located near major transportation facilities. An existing rail line owned by Yorkrail, with a right-of-way through the P. H. Glatfelter property, is located just to the north of the proposed cogeneration site. Rail access would be provided to the YCEP site by construction of a new rail spur from the existing rail line into the YCEP facility. This new rail spur would provide for efficient coal delivery with minimal impact to the existing community transportation infrastructure. Convenient roadway access is available from Route 116 by way of the existing driveway to the P. H. Glatfelter Company Roundwood facility. Route 116 connects with Route 30, a major east-west arterial roadway, approximately six miles northeast of the site. Interstate 83, approximately 10 miles east of the site, provides regional access from the north and south, through its interchange in York with Route 30.

C. Facility Description

YCEP proposes to construct, own and operate a 227 MW cogeneration facility consisting of one CFB boiler and supporting equipment. The proposed YCEP facility would be designed to operate continuously (24 hours per day, 365 days per year), with the exception of outages for maintenance purposes. Facility output would vary between 114 and 227 MW, depending on Met-Ed's hourly power requirements. When operating at less than full capacity, coal and limestone use would be decreased. The steam generated in the CFB boiler would be used to drive a steam turbine to produce electricity for sale to Met-Ed. A portion of the high pressure steam exiting the steam turbine would be sold to the P. H. Glatfelter Company for use in its paper mill operations.

As part of this operation, the P. H. Glatfelter Company would be curtailing operation of one of their existing coal-fired boilers. During periods when the YCEP CFB unit is down for maintenance, Power Boiler #4 would operate to provide the steam supply needed for the paper mill operation.

The primary fuel supply for the proposed cogeneration facility would be United States eastern bituminous coal from western Pennsylvania and/or West Virginia. Run-of-mine (coal as produced at the mine) would be washed at the coal mine preparation plant, loaded into rail cars, and delivered to the YCEP site by rail. The washed coal would have a sulfur content of two percent or less. Propane would be used as supplemental fuel under limited circumstances (for example, during facility startup when this supplemental fuel would be needed to operate the start-up burners in the CFB boiler to warm the CFB boiler prior to firing the coal fuel). The propane would be stored on-site in three 30,000-gallon horizontal tanks located north of the boiler baghouse.

An artist's rendering of the proposed YCEP cogeneration facility is provided in Figure 4 and the site plan is presented in Figure 5. These drawings show that project operations would be completely enclosed. Landscaping and berming would be incorporated into the facility design to screen ground level activities from Route 116. The new rail spur would be designed to ensure that rail cars delivering coal to the site are accommodated completely off the main line to eliminate potential impact to rail traffic on the Yorkrail line.

D. P. H. Glatfelter Company

PHG is a manufacturer of printing, writing and specialty papers. PHG operates three paper mills located in Spring Grove, Pennsylvania, Pisgah Forest, North Carolina and Neenah, Wisconsin, respectively. The company is headquartered in Spring Grove which is also the location of its largest mill and near the site of the proposed YCEP facility.

The Spring Grove mill manufactures printing and writing papers. The mill employs 1200, 800 of whom are represented by the United Paperworkers International Union. The facility is electrically self-sufficient, capable of producing over 1.1 million pounds of steam per hour from three coal-fired boilers and two chemical recovery boilers (to be replaced by a single recovery boiler by mid-1994). One of PHG's coal-fired boilers is a CFB which began operating in 1989. Steam provided by the YCEP facility will obviate the need to continuously operate an existing pulverized coal boiler (called the No. 4 boiler) which has been in use since the 1950's. As a result, overall emissions of sulfur dioxide will be cut in half, and net emissions of nitrogen oxides and particulate matter will be reduced by more than 20%.

E. Specific Site Parameters (North Codorus Township)

For the site, the P. H. Glatfelter key design basis criteria include:

Site Size	38 acres
One Foster Wheeler Circulating Fluidized Bed Boiler:	2,100,000 lb/hr
One Turbine-Generator:	227 MW Net
Start-Up Fuel:	Propane
Auxiliary Boiler Fuel:	None
Coal Delivery:	Rail via Spur
Disposal of Bed and Fly Ash:	Trucks to Offsite Disposal
Voltage:	115 kV
Power Purchaser:	Metropolitan Edison Company
Export Steam Host:	P. H. Glatfelter Company

Steam Flow:

575 psig/680°F	400,000 lb/hr Maximum 300,000 lb/hr Nominal
Cooling Water Make-Up Source:	P. H. Glatfelter Company Wastewater Treatment Plant
Condensate Return:	100%

F. Plant Equipment Overview

Coal will be delivered to the site via unit trains roughly every 4 to 5 days at full facility capacity. The coal will be unloaded in an enclosed building and conveyed to storage silos for later use. Limestone will be delivered via truck and loaded pneumatically into storage silos for later use.

The boiler will use approximately 98.5 tons per hour of coal and 18.2 tons per hour of limestone to produce 2.1 mm lbs/hr of 2550 psig steam at 1005°F. The steam is sent to the "utility style" reheat condensing turbine which has a combined high and intermediate pressure section along with a low pressure section to produce approximately 250 gross MW of electricity. Of that electricity, 227 MW will be sold to Met-Ed under a power sales agreement.

Combustion gas produced by the boiler is sent through a baghouse where the gas is filtered and directed to the stack.

The facility's gray water treatment system consists of a series of clarifiers and mixing tanks which take gray water from the PHG paper making operation and produce water of adequate quality for all uses in the facility with the exception of potable needs.

The demineralization system includes three trains each capable of producing 500 gpm of demin water (total facility need is 1000 gpm). Each train consists of anion, cation, and mixed beds along with all regeneration equipment, regeneration waste neutralization equipment, chemical storage and injection equipment, and a 360,000 gallon storage tank.

The cooling tower will provide more than 100,000 gpm of water to the surface condenser along with additional minor flows to other facility uses.

The facility auxiliary power needs of approximately 21 MW will be met by the turbine/generator when the facility is operating. When the facility is down, Met-Ed can back feed the facility from the main step-up transformer.

Control, monitoring, optimization and load following, billing, guarantee administration and stack emission monitoring of the facility will be accomplished using a state-of-the-art distributed control system ("DCS").

Fire protection of the facility will be provided by an underground piping system which will service hydrant stations and sprinkler systems water will be provided from a fire water pump package taking supply from the Codorus creek adjacent to the facility. The pump package will be located so as to take water supply from the same intake structure as the existing PHG fire water and back-up water supply pumps.

Several off-site features are associated with the proposed YCEP project. These are:

- an electrical interconnection with the existing Met-Ed system;
- a steam line connecting the facility with the P. H. Glatfelter Company;
- a condensate return line from the P. H. Glatfelter Company to the facility;
- connections to and from the P. H. Glatfelter Company's water systems for water supplies and wastewater disposal; and
- a connection to Spring Grove Water Company.

Each is briefly described below.

Electric Interconnection

The primary electric interconnection proposed would be a single circuit 115 kV line which would interconnect with an existing Met-Ed 115 kV line.

A secondary 115 kV double circuit line would extend north from the YCEP site across Codorus Creek and tie into an existing Met-Ed 115 kV line on the P. H. Glatfelter plant site.

During construction, electricity would be provided by Met-Ed through a connection with the P. H. Glatfelter Company using an existing electrical box located at the west side of the property. The main temporary feeders from this electrical box to the cogeneration facility construction area would be run via a temporary overhead cable; the location would be coordinated with permanent site facilities to avoid future interferences. Telephone cables, providing phone service to the on-site construction office, would be strung from lines extending along Route 116.

Steam Line/Condensate Return Line

A 18-inch steam line would be required to transport process steam from the proposed cogeneration facility to the P. H. Glatfelter Company. The insulated steam line would be supported aboveground on piers, with the exception of locations where the line traverses transportation features. The steam line would extend from the proposed YCEP facility in an easterly direction, crossing the breakwater between Kessler Pond and the mill pond before crossing the Codorus Creek on an existing P. H. Glatfelter Company pipe bridge. The condensate return line (eight inch) from the P. H. Glatfelter Company would closely parallel the steam line route.

Water Supply Line

A small portion of the total facility water (primary potable water) need is proposed to be supplied from the Spring Grove Water Company. The interconnection would be via an eight-inch supply line which would interconnect with an existing Spring Grove Water Company line along a private road, owned by P. H. Glatfelter Company, leading to the P. H. Glatfelter Company primary wastewater treatment facility. The line would follow the private road, cross under S.R. 116, cross the P. H. Glatfelter Company truck parking lot, then extend over the breakwater between Kessler Pond and the mill pond to the facility. Process and raw water back-up supplied by P. H. Glatfelter would be met by a six-inch supply line extending across the breakwater, then north across the existing pipe bridge. A temporary interconnection to P. H. Glatfelter Company along this route would also be used to supply water needs during the construction period.

The supply of the P. H. Glatfelter Company treated wastewater to the cogeneration facility for plant cooling would be handled by a 14-inch pipeline constructed from the treatment plant effluent area to the east side of the YCEP facility. This preferred pipeline route would run along corridors which contain existing underground pipelines. This route would cross the breakwater between Kessler Pond and the mill pond, extend through the P. H. Glatfelter parking lot and under Route 116, and continue along a private road to the P. H. Glatfelter Company wastewater treatment plant. A ten-inch firewater line would also be run from the P. H. Glatfelter Company intake structure, across the breakwater to the proposed YCEP facility.

Wastewater Discharge Lines

The proposed YCEP facility wastewater (cooling tower blowdown and treated sanitary wastewater) would be discharged to the P. H. Glatfelter wastewater treatment system equalization basin. The preferred route for the connection to the equalization basin would be a corridor heading east across the breakwater, through the P. H. Glatfelter parking lot, under Route 116, and along a private road to the equalization basin. This route would be the same as the route for cooling water makeup.

In addition, a line would be run from the P. H. Glatfelter equalization basin to the secondary treatment unit to handle additional flow. This line parallel the route for the cooling water makeup pipeline.

G. Detailed Equipment Descriptions

The following sections provide a detailed description of each of the major equipment groups.

1. Circulating Fluidized Bed Boiler Design

Fuel is fed to the base of the combustor along both the front and back walls and sorbent is fed to the base of the combustor along the front wall. Primary and secondary air flows to the combustor are provided by primary and secondary air fans. Before entering the combustor, these streams are preheated via heat exchange with the flue gases in the air heaters. The heart of the process is a circulating fluidized bed combustor in which the fuel is combusted while simultaneously capturing SO_2. Selective non-catalytic reduction of NOx emissions is accomplished through injection of aqueous ammonia or urea at the inlet to the cyclones. Solid particles entrained by the upflowing gas in the combustor exit the top of the combustor into cyclones which efficiently separate the flue gas from the entrained particles. The flue gas discharged from the cyclone is directed to the downstream convective section of the boiler and the captured solids are recycled to the base of the ACFB by means of standpipes, J-valves, and an INTREX™ fluidized bed Integrated Recycle Heat Exchanger. The J-valves provide a seal between the positive pressure in the lower furnace where the recycle solids are fed and the near ambient pressure in the cyclones. Refer to Figure 6 for an elevation of the CFB boiler.

Coarse ash material (bed ash) accumulating in the ACFB is removed from the bed using a specially designed directional grid and a fluidized bed stripper cooler. The bed ash is cooled by the fluidizing air flow to the stripper cooler. This heated air stream flows to the combustor along with the fines that are stripped out. The cooled bed ash will be conveyed to a bed ash silo. Fly ash collected in the air heaters, economizer, and baghouse hoppers will be pneumatically conveyed to the fly ash storage silo. Depending on the beneficial use for the by-product ash, the bed and fly ash streams may require additional processing to condition the ash.

Boiler feedwater is preheated in the economizer located in the convection heat recovery area. The preheated feedwater is then routed to the steam drum. From the steam drum, the pressurized water flows by natural circulation through the waterwall sections of the ACFB combustor and the INTREX^{TM} heat exchanger. Steam generated in the waterwall boiling circuits is routed to the cyclone enclosure walls, the convection heat recovery area enclosure walls, the primary superheater, and then on to the intermediate and finishing steam coils located in the INTREX^{TM} heat exchanger. This superheated steam flow is expanded through a high pressure steam turbine. A portion of the steam exiting the high pressure turbine flows through a reheater located in the convective heat recovery area. The reheated steam is expanded through an intermediate pressure steam turbine to extract additional power.

A description of the major components which comprise the coal-fired ACFB cogeneration plant is given below.

Circulating Fluidized Bed Combustor

Coal and sorbent, such as limestone, are fed into the lower, refractory-lined portion of the atmospheric circulating fluidized bed where these feedstock materials are mixed with the bed material and initial combustion occurs. To support combustion of the coal, a substoichiometric amount of air is fed to the base of the unit and additional air is injected at two different elevations above the primary air feed location. The total air flow is approximately 20% in excess of stoichiometric requirements. Primary air enters through a specially designed air distribution grid. This process of staging the air flow to the combustor minimizes the formation of NOx within the unit. In addition, the relatively low operating temperature of the ACFB combustor of 1550-1650°F also minimizes NOx formation. The sorbent is fed to the bed to capture SO_2 formed by the combustion of sulfur-containing fuel. Calcium carbonate is calcined to calcium oxide *in-situ* which subsequently reacts with SO_2 and O_2 to stabilize the sulfur in the form of calcium sulfate. Maintaining the bed temperature at approximately 1600°F is also necessary for effective sulfur capture and to minimize sorbent consumption.

The upflowing combustion gases entrain the fine ash, char, and sorbent particles producing a net flow of solids up through the combustor. The combustor temperature is maintained by efficient transfer of heat from the gas-solid suspension to the waterwall tubes. Solids entrained from the bed, including unburned char and unreacted sorbent particles, are captured by hot cyclones and returned to the ACFB combustor. This promotes improved combustion and sorbent utilization efficiency. The recycled solids are also cooled upon passing through the steam-cooled cyclones and the INTREX^{TM} heat exchanger. A side elevation drawing of the INTREX^{TM} unit is given in Figure 7. The cooled recycle solids stream also helps to moderate the temperatures within the combustor. Coarse ash particles are removed from the bottom of the combustor as bed ash. Additional heat is recovered from flue gas and fine ash particles escaping the cyclones within the convective section of the boiler. The fly ash is captured in a baghouse before the cooled flue gas is exhausted through a stack.

Spent Bed Material Cooling System

Coarse coal ash, spent sorbent, and calcium sulfate must be removed from the bottom of the ACFB boiler to control solids inventory in the lower region of the boiler. Directional air distributor nozzles are used on the furnace floor to direct coarse material to the drain openings on each furnace sidewall. The solid flow pattern along the base of the combustor causes the bed ash material to drain to the stripper cooler and also maximizes the residence time of the large fuel particles in the combustor to reduce unburned carbon levels in the bed ash. Four (4) 50% capacity fluidized bed stripper/coolers are designed to selectively remove oversized bed material and return fine material back into the furnaces to increase the solids residence time. The stripper/cooler is a refractory lined box with three fluidized compartments; one stripper zone and two cooling zones. A fraction of combustion air is used to strip and cool the spend bed material to an acceptable temperature level for disposal. Sensible heat in the spent bed material is recovered by injecting the stripping and cooling air back to the furnace as part of the secondary air for combustion.

Water Steam Circuitry

The circulating fluid bed design is comprised of four distinct sections: the furnace, the hot cyclones, the INTREX^{TM} heat exchanger, and the heat recovery area (HRA). All four sections are top supported and are comprised of water or steam cooled enclosures. Use of integrally welded steam generating walls as the enclosure is in accordance with modern design practice and provides both the required cooling and the structural support. The steam circuitry is designed for natural circulation and includes a single drum located above the furnace and between the furnace and cyclones. The boiler is designed to turn down to 40 percent of MCR capacity without firing auxiliary fuel and to have a steam temperature control range between 75% and 100% MCR load.

Boiler feedwater enters the unit at the inlet to the bare tube economizer located in the convection heat recovery area. Water flows through the banks of horizontal coils countercurrent to the flue gas, exiting at the outlet header. Feedwater is then routed to the steam drum. Steam generated in the boiling circuits is separated by the steam drum internals. The steam drum internals are designed to efficiently separate the steam/water mixture, and to insure that the steam leaving the drum is moisture free and of high purity. In addition, the drum internals distribute the flow of incoming water and steam throughout the drum to maintain even drum metal temperatures. The internals consist of horizontal centrifugal separators located along the side of the drum and unit Chevron drier assemblies arranged along the top of the drum.

Steam leaving the drum through the Chevron dryers is routed to the cyclone circular enclosure walls, HRA enclosure walls, the HRA primary superheater, and then on to the intermediate and finishing superheater coils located in the INTREX^{TM} heat exchanger. Two spray type attemperators are provided, located between the primary and the intermediate superheaters and between the intermediate and finishing superheaters to provide control of the final steam temperature. This type of attemperation will afford excellent control flexibility and will not adversely affect steam purity.

Reheat steam enters the unit at the reheater inlet header located in the parallel pass HRA. Steam flows through the reheater banks of horizontal coils countercurrent to the flue gas flow, exiting at the outlet header. Reheat temperature control is achieved through simple flue gas flow proportioning thereby eliminating the need for spray-type attemperators.

Thermal DeNOx System

Low level emissions of NOx generated by the oxidation of fuel nitrogen within the ACFB combustor will be further reduced by decomposing NOx into N_2, O_2, and H_2O using non-catalytic reduction with ammonia. Aqueous ammonia or urea will be injected directly into the flue gas in the (4) ducts connecting the cyclones to the combustor. At this location, the temperature of the flue gas at 100% MCR will be approximately 1630°F. At this temperature the NOx reduction reactions proceed at a sufficient rate to achieve a NOx reduction level of 50%. Since staged combustion and low combustion temperatures already contribute to significantly lower NOx emissions than achieved with conventional pulverized coal boilers, extremely low NOx emissions will be achieved by combining the two technologies.

Technical Challenges in Scale Up of ACFB Design

Evolution of ACFB Technology in U.S.

The size of the YCEP ACFB combustor represents a significant increase in scale over existing ACFB combustors. Currently, the largest single ACFB boiler is the 150 MWe Texas-New Mexico ACFB. This unit will be superseded in 1993 by the 165 MWe Pt. Aconi ACFB. However, when the YCEP project is started up in late 1996, it will become the largest ACFB combustor, capable of generating 227 MWe of net electrical power and up to 400,000 lb/hr of export steam. This scale will be most representative for potential utility-scale ACFB applications.

A significant challenge in the design of the single combustor ACFB for the YCEP project was to anticipate the influence that the scale of the combustor would have on its design and performance. The following sections will discuss several important considerations in designing a 227 MWe ACFB combustor having maximum certainty of successful operation. The major design features to be discussed include:

- Flexibility of Thermal Design
- Solids Mixing/Feed Distribution
- Cyclone Separator Design/Configuration

Design of ACFB Waterwall Surface

In scaling up the design of ACFB combustors, proper thermal design is important to control the temperature within the combustor. A properly designed ACFB combustor will operate at uniform 1600-1650°F temperatures, which will permit combustion to take place below the ash fusion temperature while providing optimal SO_2 capture with calcium-based sorbents and reduced NOx formation. This is achieved by balancing the heat released by the combustion process with the heat absorbed within the boiler. Heat absorption is achieved by withdrawing heat from the gas-solid suspension within the boiler, the cyclones, and INTREX™ heat exchanger. Adequate temperature control and solids distribution/mixing are essential to attaining high combustion efficiencies and minimal gaseous emission rates.

Since the fluidizing velocity of ACFB's is held constant, the cross-sectional area of the combustor increases proportionately with the firing rate. However, as the bed cross section increases, the ratio of bed volume per unit of wall heat transfer surface area increases. As the cross-sectional area increases for a unit of a given height, the amount of heat that can be removed through the waterwalls becomes a smaller fraction of the firing rate.

One method of obtaining the total required heat transfer surface is to increase the combustor height; however, the heat transfer surface that is introduced with added height is least effective at removing heat. This occurs because the rate of heat transfer varies with the solid suspension density and the solid suspension density in the YCEP combustor decreases rapidly with height until reaching a constant value in the upper furnace. This results in a more predictable heat absorption in the upper furnace. Furthermore, a lower density in the upper furnace results in less heat release, which is consistent with the lower heat absorption in the upper furnace.

In the YCEP ACFB design, the required amount of heat is removed through addition of a water-cooled, full division wall extending along the entire height of the combustor. This development introduces additional heat transfer surface throughout the entire furnace height. The division wall reduces the ratio of bed volume to the heat transfer surface area to a value that is typical of existing, smaller ACFB combustors.

Other advantages of the full division wall include:

- *More uniform temperature distribution in the ACFB.* In comparison with a single chamber design, the division wall will help to produce more uniform temperatures across the ACFB due to the more even distribution of heat transfer surface throughout the combustor cross section.

- *Lower unit height.* A full division wall will allow combustor height to be constrained to that required for the cyclones rather than that required to achieve the necessary waterwall surface. Capital cost savings result by eliminating the need for additional structural steel, platforms and building enclosures. Reduced combustor height will also typically result in a lower stack height.

Special design features included in the proposed furnace division wall include:

- *Pressure Equalization Openings*

  From the furnace floor to a height of about 12 ft., the fins between adjacent division wall tubes are removed. This allows the tubes to be bumped sideways, in-plane, to form multiple openings. Additional openings are also provided in the upper furnace over a 12 ft. span beneath the cyclone inlet. The openings in the upper furnace are located beneath the cyclone inlets to minimize lateral cross-flow of solids through the openings. The division wall openings function to equalize the pressure on both sides of the division wall.

The pressure equalization openings eliminate differential forces on the division wall, which simplifies the mechanical design. Also, a uniform air flow can be maintained across the width of the unit. Excess oxygen in the flue gas can be monitored at a common location at the heat recovery area exit and secondary air flow can be modulated to maintain the desired excess air level. Independent monitoring and modulating controls for each side of the division wall are not required.

- *Wear Resistant Design*

At the pressure equalization openings the division wall tubing is protected with the same high conductivity, erosion resistant refractory used on the lower furnace enclosure walls, roof, cyclone inlet walls, and the cyclones. The phosphate-bonded, high-alumina refractory which contains stainless steel reinforcing fibers is mounted on a high density stud pattern to a thickness of 1/2 inch. All the tubes are kept in plan so as not to protrude into the gas/solids flow stream for direct impingement. In this manner, the division wall will be no different from the water cooled enclosure walls which also have openings for solids cooler drains and fuel, limestone, and secondary air feeds.

- *Differential Thermal Growth*

The division wall is welded where it penetrates the air distributor and is held in tension by springs fixed at the top of the unit. A gap is provided between the division wall and the front and rear walls of the furnace. Since the division wall is heated on both sides while the enclosure walls are heated only on one side, the average division wall tube temperature will be slightly hotter than that of the enclosure walls. The support arrangement with no mechanical attachment to the enclosure walls allows both the division wall and the enclosure walls to independently grow downward at their respective rates. Foster Wheeler has designed numerous steam-cooled full division walls on pulverized coal fired steam generators. Steam cooled division walls have more stringent design requirements for differential thermal growth than do water-cooled division walls.

Solids Mixing/Feed Distribution

Solid mixing plays an important role in determining the performance of ACFB combustors. As the combustor scale increases, changes in several design parameters can affect how well the fuel and sorbent are distributed in the combustor. Data taken from other commercial ACFB plants will be presented to show that poor solid mixing can result in inefficient plant operation and higher plant operating costs.

The factors which are thought to influence the degree of solid mixing in the lower region of ACFB's are placed in three categories: (a) mixing due to external solid recirculation, (b) mixing due to internal solid recirculation, (c) mixing limitations caused by solids feeder configuration and boiler dimensions.

Impact of Poor Solid Distribution

Nonuniform fuel distribution results in increased consumption of sorbent to achieve the same SO_2 emission level and may also increase the NOx generation rate. With increased NOx generation, NH_3 consumption increases to achieve the same level of NOx emissions and the NH_3 slip (flow of unreacted NH_3) also increases. When burning coals containing chlorine, greater NH_3 slip increases the potential for NH_4Cl formation. Poor fuel distribution will also lead to a reduction in combustion efficiency through increased hydrocarbon and CO emissions, and increased calcination heat losses. Nonuniform fuel distribution may lead to oxygen deficient reducing zones that cause bed agglomeration and slagging problems, and may produce local hot spots within the combustor.

Factors Affecting Sorbent Utilization

The factors which are thought to influence sorbent utilization include: sorbent and fuel properties, solid mixing, combustor temperature, fuel and sorbent distribution, and cyclone grade efficiency. Important sorbent properties include the reactivity, friability, and feed size distribution. These properties will help determine how long the sorbent stays in the ACFB, how it is distributed between the lower and upper furnace, the extent to which the particle breaks apart to expose fresh CaO, and the reaction rate. Important fuel properties include: volatile content, reactivity, sulfur content and forms (organic, pyritic, sulfatic), and feed size distribution. The firing rate per fuel feeder will determine the local concentration of fuel at the feeder outlet. Increasing the firing rate per feeder will (for more volatile and reactive fuels) increase the reaction rate within this region, which will result in zones of low O_2 and high SO_2 gaseous concentrations and elevated local temperatures.

Combustor temperature plays an important role due to the strong dependence of the sulfur capture reactions and combustion reactions on temperature. Sorbent distribution is also important to ensure a uniform concentration of unreacted CaO in the ACFB at the location where the SO_2 is released. The extent of solid mixing in the ACFB will help determine how well the fuel and sorbent are distributed. Finally, a cyclone with high capture efficiency for fines will retain the fine unreacted sorbent particles in the ACFB longer to react more completely. It should be noted that the YCEP ACFB boiler has a relatively short mixing zone, a distinct lower furnace bed that uses relatively coarse fuel and sorbent, as well as air swept fuel distributors, which promote more effective mixing in the furnace.

Cyclone Separator Design and Configuration

Another design issue important to the successful scale up of ACFB combustors is the design of the cyclone gas-solid separation system. As the size of the combustor increases, the mass flow of gas and solids exiting the top of the combustor to the cyclones increases proportionally (given same particle size, combustor height, etc.). One method of performing this separation with the increased flow of particle-laden gas is to increase the size of the cyclone. Unfortunately, as the cyclone size (diameter) increases the centrifugal force field is reduced (at the same gas inlet velocity) and the particle collection efficiency deteriorates. In the absence of high solids collection efficiency, smaller sorbent, carbon, and ash particles escape through the cyclone rather than being recycled to the combustor with the cyclone underflow. This would result in inefficient fuel and sorbent utilization and a reduction in inventory of particles capable of circulating and transferring heat. Another drawback of increased cyclone size is that the increased cyclone height may dictate increased combustor height for the solids recirculation system to function properly.

To enable high gas-solid separation efficiency with the YCEP ACFB boiler design the size of the cyclones was held similar to that utilized in smaller units. However, to accommodate the increased gas flow rate the number of cyclones was increased.

The cyclone separator designs features steam cooling and is an integral part of the steam superheat circuit. Steam cooling of the cyclones offers the following advantages:

- Faster unit start-up
- Reduced heat losses
- Reduced requirements for high-temperature refractory ductwork and expansion joints

Technical Innovation

The following section describes several innovative features of the ACFB system design:

INTREX™ Integrated Recycle Heat Exchanger

The INTREX™ heat exchanger is simply an unfired fluidized bed heat exchanger with a non-mechanical means for diverting solids. It will take advantage of the high heat transfer coefficients for tubes immersed in bubbling fluidized beds and will also operate advantageously with fine (200 micron) particles. Due to the fine recycle solids and the low fluidizing velocities (0.5 to 1.5 ft/s), tube erosion will not be a concern. The INTREX™ heat exchanger allows for part of the heat released in the combustor to be removed outside of the combustor. This method of heat removal will eliminate the need for excessively tall combustors or the need to install furnace panels which protrude into the erosive flow in the combustor and are subject to excessive wear.

The INTREX™ heat exchanger will be enclosed by the same water-cooled membrane construction used in the furnace. The integrated configuration will allow it to grow downward with the rest of the boiler steam/water pressure parts, minimizing differential thermal movement. Placement of serpentine superheater coils within the recirculated solids flow path enables the entire reheater to be located in a conventional parallel pass heat recovery area. Final main steam temperature will be controlled by spray water attemperation, while reheat steam temperature will be controlled by gas flow proportioning in the heat recovery area.

FWEC has extensive experience in the design of atmospheric bubbling fluidized bed (BFB) heat exchangers from the 46 BFB steam generators that it has designed and put into operation. Scale up of the INTREX™ BFB is not an issue since the main cell in the 130-MW Northern States Power Black Dog unit is about four times greater in plan area than the largest INTREX cell in the YCEP ACFB. The INTREX™ heat exchanger will be divided into four cells.

DOE Clean Coal Demonstration Tests

This demonstration program is designed to provide the following important information:

- Demonstrate unit start up and shut down capabilities and provide data and experience on ACFB boiler operation during these transients.

- Demonstrate ACFB boiler dispatching capabilities and constraints.

- Demonstrate ACFB boiler operation at full-load conditions for extended periods and continuous operation at part-load conditions.

- Provide quantitative results from a systematic study on the effects of important operating parameters and fuel characteristics on boiler performance which will aid in the optimum economic design and operation of future units.

- Identify constraints governing fuel selection based on test results from four different fuels.

- Provide guidelines for inspection and maintenance along with information on maintenance costs.

Included in the test program are specific operating tests to evaluate the effects of the following operating parameters on ACFB performance:

- Fuel size and quality
- Sorbent size and quality
- Fuel and sorbent rates
- Combustor temperature
- Excess air
- Primary/secondary air ratio

Specific boiler performance parameters to be quantified include:

- Boiler thermal efficiency
- Steam/Electrical Generation Capacity
- Ability to control steam temperature and pressure
- Ash production and quality
- Bed ash/fly ash split
- Unburned carbon losses in bed and fly ash
- Stack emissions: NOx, SO_2, CO, VOC and particulate
- Power consumption of auxiliary equipment
- Percent SO_2 capture and Ca/S ratio
- Control of bed inventory
- Combustor temperature profile

Tests are proposed for four different coals: the design coal (basis for combustor design) and three test coals having different properties from the design coal. The purpose of performing tests with coals having properties which differ from the design coal is to determine what range of coal properties can be utilized and the impact of fuel characteristics on the performance and operating economics of the ACFB. The same sorbent material would be used throughout all of the tests.

In addition to performing tests at 100% maximum continuous rating (MCR), tests would be performed to demonstrate operation of the boiler and other ACFB system components during start-up, shutdown, and dispatch of the facility. To demonstrate the capability of the system, a 30-day test with the boiler operating at a minimum of 96% MCR is proposed.

2. Boiler Pilot Plant Tests

a. Introduction and Summary

A pilot plant test burn was conducted by Foster Wheeler Development Corporation at their Livingston, New Jersey facility.

The objective of the test burn was to evaluate certain coals and limestones for possible use in the project. The test burn took on more importance after a series of bench scale and pilot plant screening tests showed that certain limestones had potential attrition problems. Accordingly, the test protocol was set up to first evaluate the attrition problems. Accordingly, the test protocol was set up to first evaluate the attrition potential of the limestone and then generate performance and emission data.

b. Pilot Plant Test Facility

The circulating fluidized bed combustion pilot plant and laboratory facilities located at Foster Wheeler Development Corporation in Livingston, New Jersey, were utilized for the test program. These facilities are described below:

Circulating Fluidized Bed Pilot Plant

The new test unit, which has a capacity of approximately 2,000 lb/h of superheated steam, is capable of operation in either the bubbling or circulating bed mode. The unit is dedicated to the advancement of the technology and incorporates the latest design features including a welded waterwall furnace enclosure, a castable refractory-lined cyclone, and provisions for heat transfer surface adjustment in both the furnace and heat recovery area. A schematic of the CFB pilot unit is shown in Figure 8.

The fluidized bed test module is constructed of monowall and consists of a 48-ft-high combustion chamber, monowall-monowall-enclosed integral cyclone separator, and downflow heat recovery area. The 14-in. x 26-in. combustion chamber has a heat release capacity of 2 to 4 million Btu/h depending upon configuration. Heat transfer to the combustion chamber walls is limited by a 3-in. layer of medium-weight catable refractory.

Fluidizing air enters the combustor through a distribution grid mounted at the centerline of the lower waterwall headers.

Directional nozzles introduce the fluidized air. Thermocouple wells mounted through the distribution plate permit the monitoring of bed temperatures.

Air is supplied to the distribution plate plenum, start-up gas burners, fuel feel line, and overfire air ports by a positive displacement compressor rated at 1,000 aft^3/min and 18 psig. All air flows are metered by orifice plates fitted with electronic flow transmitters.

The freeboard space of the test module is fitted with adjustable levels of overfire air ports. Gas sampling, and thermocouple ports are provided on 1-ft vertical centers throughout the bed and freeboard zones.

The combustion gas-solids mixture exits the combustor and passes through the integral hot cyclone separator which has a corner volute inlet. The water wall enclosed separator is constructed of erosion resistant/castable refractory lining. The hot solids are separated from the gas and fall by gravity into a 6-in. standpipe which runs adjacent to the combustor along its outer wall. The solids are recycled back to the combustor by use of an aerated J-valve. Sample connections, pressure, and temperature ports are provided on the standpipe and J-valve.

The hot gas stream exits the cyclone and enters the heat recovery area where it is cooled. The cooled gas stream leaves the heat recovery area and passes through one of two parallel baghouses to remove particulates and ash.

A variable-speed I.D. fan is used to pull the gas through the system and discharge the gas from the pilot pant through a stack.

Sample ports for both batch sampling of solids and gases and continuous monitoring and provided at several levels in the test module. The control gas sampling pot (used for both process control and acquisition of the continuous average gas analysis) is located in the heat recovery outlet flue where the gas temperature is approximately 450°F. A real-time gas analysis system provides continuous analyses for oxygen, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides, and total hydrocarbons.

c. Feedstock Characterization

Representative samples of coal and limestone sorbent were analyzed using standard physical, chemical and thermal techniques. Results of these analyses provided the basis for stoichiometry calculations and the selection of pilot plant operating parameters.

Coal

Proximate, ultimate, heating value, and ash fusion results for the test coal are presented in the accompanying table. One coal was a high volatile bituminous coal from western Pennsylvania which has been cleaned to lower the ash and sulfur contents (5.9 percent and 1.4 percent, respectively). The ash fusion temperatures were moderately low in both reducing and oxidizing atmospheres. The ash was relatively high in iron (13.0 percent Fe_2O_3), which can form eutectics at temperatures above those encountered during normal CFB operation. The coal contained only a minor amount of fine material, with only 3 percent less than 200 mesh.

Thermogravimetric analysis (TGA) was also performed on the coal utilizing a DuPont TA analyzer. The coal was first devolatilized under a nitrogen atmosphere at a heating rate of 36°F/min to a final temperature of 1,832°F. The reactivity of the resultant char was then evaluated in the TGA by burning it in air at a heating rate of 18°F/min. Compared to the other coal chars, the char appeared to have a relatively low reactivity and a high burnout temperature (1,380°F). Other tested coals had a relatively low char burnout temperature (1,200°F) in the TGA and CFB pilot plant carbon combustion efficiency as high as 96 percent. Based upon this TGA data, complete carbon burnout for the coal may be difficult to obtain in the pilot plant, especially due the relatively short gas residence time (2 seconds).

Limestone

Characterization of the limestone was achieved through elemental, size and thermal analyses. While the techniques for elemental and size analyses are well known, the TGA sorption test is equipment dependent and, therefore, has been summarized below.

Table - Coal Analysis

Sample Description: Coal-92-8-76					
Air Dry Loss,	3.86%		Equilibrium Moisture, %		
	As Received	Dry			
Proximate Analysis, wt%			Reactivity Index, °C		
Fixed Carbon	53.74	57.01	Activation Energy, cal/g-mol		
Volatile Matter	34.62	36.72	Hardgrove Index		
Ash	5.91	6.27	Free Swelling Index		
Moisture	5.73	---	Specific Gravity		
Total	100.00	100.00	Viscosity		
Ultimate Analysis, wt%			**Ash Fusion Temperature, °F**		
Carbon	75.25	79.83		Red.	Oxid.
Hydrogen	4.77	5.06	Initial Deform.	2220	2186
Oxygen	5.23	5.54	Soft. Temp. Sph.	2259	2190
Nitrogen	1.69	1.79	Soft. Temp. Hem.	2269	2198
Sulfur	1.42	1.51	Fluid Temp.	2272	2207
Ash	5.91	6.27			
Moisture	5.73	---			
Total	100.00	100.00			
HHV, Btu/lb	13,438	14,255			
Sulfitic S	---	---			
Pyritic S	---	---			
Organic S	---	---			
Remarks: Dulong's = 14,381 Btu/lb					

The general procedure used for limestone reactivity measurements is as follows: The sample was first ground and screened to -100 mesh + 200 mesh. This size cut was chosen because the specific surface area contained provides good weight response over a wide range of stone activities. Then using a specially modified TGA, the sample was calcined under nitrogen and immediately sulfated isothermally at 1,550°F under an artificial atmosphere. The synthesized gas contained 5 percent oxygen, 2,000 ppm sulfur dioxide and the balance nitrogen. Changes in weight of the stone sample during sulfation were recorded versus time to provide data related to reaction rate and extent of reaction.

The limestone was fairly low in calcium and the ASTM ash yielded 79.7 percent CaO. TGA sorption results indicated that the stone had a moderate reactivity. Based upon the limestone analysis and the TGA sulfation weight gain, one limestone had a 37.3 percent calcium utilization in the TGA. The TGA calcium utilization is usually greater than 50 percent for high reactivity stones and less than 30 percent for poor reactivity stones.

A Rosin-Rammler plot indicates that the limestone size distribution contains a considerable amount of fines (21.5 percent less than 200 mesh), even though the D_{50} is about 600 microns.

The hardness of this limestone was qualitatively assessed using the Hardgrove test. The limestone would be classified as moderately soft because it had an HI of 80. The change in sorbent particle size after calcination was also evaluated in a static bench-scale test. The limestone was first screened to obtain a 16 x 20 mesh size fraction, then calcined in a muffle furnace at 1,600°F for one hour. After calcination the limestone was screened again to assess the extent of decrepetation. This limestone showed only minor breakdown upon calcination and about 5 percent of the calcine passed a 20 mesh screen.

d. Test Results

Many of the issues to be resolved by the pilot plant test burn required extended periods of exposure, concentration of species or development of equilibrium conditions. To meet these varied needs, a 100-hour continuous test was opted for instead of several shorter duration tests. The first 24 hours of the run were used for stabilization of the unit, while the final 76 hours were used for performance evaluation. Conditions selected for initial operation were chosen on the basis of experience gained from other fuels. During the course of the run, the primary operating parameters of temperature and air split were varied to document their effect on unit performance and operation.

Data collection for the run was performed periodically according to the following schedule. Solids samples of fuel, bed and baghouse ash were taken hourly and coincided with the manually determined baghouse ash flow rate. Limestone sorbent samples were taken at four-hour intervals. Feed rate, flow, temperature, pressure and flue gas composition data were logged at one-minute intervals by the data-acquisition system. Hourly operator log sheets supplemented the data acquisition system and provided an independent check.

At the conclusion of the run, all test data were reviewed and analyzed for stability. Representative test periods were then selected for performance evaluation. Following chemical analysis of the solids samples from these periods, mass balance and efficiency calculations were made. The hourly quart fuel samples taken from the coal silo were found to be consistent in both carbon and sulfur content (average 76.2 and 1.37 percent, respectively).

The coal rate for this test was held between 300 and 340 lb/h, corresponding to a heat input of up to 4.5 x 10^6 Btu/h. The bed temperature was varied from 1,550°F to 1,650°F in order to assess its effect on unit performance. Primary air stoichiometry was maintained at between 60 and 75 percent for the test run. The total air rate (coal feed air, primary air and secondary air) was set to achieve a superficial gas velocity in the freeboard of about 20 ft/s. The target sulfur capture was 92 percent for the entire test run.

Combustion Efficiency

Carbon combustion efficiency data values were computed using a carbon balance which excluded carbon monoxide in the flue gas. The carbon content of the coal was very consistent throughout the test run (75.2 to 77.3 percent) and an average value of 76.2 percent was used for efficiency calculations. The carbon loss from the system was computed from the organic carbon content in the hourly baghouse ash samples and a baghouse ash rate averaged for an eight-hour period around the set point.

The carbon combustion efficiencies ranged from about 88 to 93 percent. Combustor temperature was found to have a significant effect on carbon conversion. The average combustor temperature was obtained from thermocouples placed at about 10-ft intervals along the height of the combustor. A maximum combustion efficiency of about 92 to 93 percent was obtained at an average combustor temperature of between 1,600°F and 1,625°F. A significant increasing carbon conversion should be obtained in a commercial-scale CFB compared to the pilot unit due to the longer gas residence time (5 vs. 2 seconds). For example, 5 to 6 percent higher combustion efficiencies have been obtained in commercial-scale units compared to the pilot plant when firing the same bituminous coals.

Gaseous Emissions

Average CO, NOx, N_2O and SO_2 emissions for the test intervals in both the molar concentrations and their equivalent emissions in lb/10^6 Btu have been corrected back to 39 percent O_2. This correction corresponds to 22 percent excess air (excluding unburned carbon) and was made to compensate for significant in-leakage which occurred during the test.

Carbon monoxide emissions ranged from about 0.12 to 0.26 lb/10^6 Btu and were strongly dependent upon combustor temperature. The CO emissions were reduced by about 50 percent as the combustor temperature was increased from 1,525°F and 1,625°F. The relatively low carbon monoxide emissions (at higher temperatures) tend to indicate that carbon loss was not a result of combustion-related problems such as poor mixing within the combustor. Instead, the carbon loss was probably a result of fine char which could not be completely burned in the relatively short residence time and elutriated from the cyclone.

The target sulfur capture for the test run was 92 percent. The sulfur capture ranged from 89 to 95 percent at Ca/S ratios ranging from 2.5 to 3.8. An average coal sulfur content of 1.37 percent was used in these calculations. At bed temperatures greater than 1,625°F, a Ca/S ratio in excess of 3.5 was required to obtain sulfur capture levels greater than 90 percent. Significantly lower Ca/S ratios were required at lower bed temperatures to obtain in excess of 90 percent sulfur capture. For bed temperatures between 1,600°F and 1,625°F a Ca/S ratio of about 2.8 was required to obtain sulfur capture levels between 91 and 93 percent. This relatively high Ca/S ratio was probably due to the moderate reactivity of the limestone, coupled with the relative low sulfur content of the coal (1.37 percent).

Nitrogen oxide emissions (NOx) ranged from 0.10 to 0.21 lb/10^6 Btu and were strongly dependent upon combustor temperature. The NOx emissions increased substantially as the average combustor temperature was increased from about 1,525°F and 1,625°F. Nitrous oxide emissions (N_2O) were observed to decrease by almost a factor of two over the same temperature range. The conversion of fuel nitrogen to nitrogen oxide and nitrous oxide as a function of combustor temperature is consistent with previous pilot plant data obtained with bituminous coals. The nitrogen and nitrous oxide emissions are for set point periods with primary air stoichiometries ranging from 60 to 74 percent. Over this primary stoichiometry range, NOx emissions increase with higher stoichiometries, while N_2O emissions remain essentially constant.

Ash Analysis and Control of Bed Inventory

No bed drains were required during the test run to maintain solids inventory, although several bed samples were taken for analysis. Essentially all of the carbon loss from the system occurred from carbon elutriated from the cyclone.

Although no bed drains were required to maintain solids inventory, substantial build-up of bed was observed during certain portions of the test run. However, the bed level fluctuated considerably due to changes in set point temperatures and primary air flows. The bed level was observed to decrease considerably as the bed temperature was increased to 1,650°F due to the decomposition of sulfated sorbent. Extended operation at lower bed temperatures and primary air flows would probably have required continual bed drains to maintain a specified bed level.

Analyses were performed on bed and baghouse samples to determine leachable components by the Toxic Characteristics Leaching Procedures (TCLP). This procedure is used to simulate the leacing which a waste would undergo if disposed in a sanitary landfill. The procedure involved extracting the ground ash samples with dilute acetic acid (0.5N) for 24 hours. The extract from the ash was then analyzed by inductively coupled plasma (ICP) analysis for the following elements: As, Se, Hg, Cr, Cd, Pb, Ag and Ba. None of these elements were observed in the extract from the bed and baghouse ash samples.

The pH of the bed and baghouse ash samples in deionized water (5 percent ash/95 percent water) was also measured. The baghouse ash had a slightly higher pH than the bed ash (12.3 vs. 11.3). Based on the carbon-free compositions of the bed and baghouse ash samples analyses, the bed and baghouse ash samples contained 39.2 and 32.1 percent free CaO, respectively.

c. Conclusions

The pilot plant test program has demonstrated the feasibility of using certain coals and limestones. The following conclusions are provided to summarize the findings of the test program:

- Carbon combustion efficiencies of 89-93 percent were attained at operating temperatures between 1,520 and 1,620°F. Higher efficiencies can be expected in the commercial plant because of its increased furnace residence time.

- Bed inventory was maintained using limestone alone, however, little or no bed drain was required over the course of the test. Trends observed during the test suggest that the commercial unit will require some bed drain during operation.

- The sulfur capture target of 92 percent is readily achievable as evidenced by SO_2 captures in excess of 93 percent in eight of the fifteen test set points. Ca/S ratios of 2.4 to almost 4 were required due primarily to the less than average stone reactivity and the friable nature of the stone.

- NOx and CO emissions should not present any permitting problems.

- No operational problems were encountered, i.e., bed agglomeration back and fouling.

3. Coal Handling and Storage

Washed coal would be delivered to the proposed facility via rail car. The rail cars would be unloaded inside the coal unloading building (a completely enclosed structure) where the coal would then be conveyed to storage silos. All coal transfer would occur via enclosed conveyors to minimize noise, dust, and exposure to rainfall. A 30,000-ton (approximately 12-day) supply of coal would be maintained in five 56 ft diameter enclosed storage silos. From the storage silos, the coal would be transferred by enclosed conveyance to the boiler house. Use of an enclosed conveyance and storage system would minimize the potential for fugitive dust emissions and solids discharge in stormwater runoff. Refer to Figure 9 for a fuel handling process flow diagram.

<u>Fuel and Sorbent Preparation and Feed System</u>

Bituminous coal is delivered to the site by rail and is stored in five 56 ft diameter coal storage silos with a 14 day storage capacity. The 2" x 0 size raw coal is then conveyed to crushers to be crushed to 1/2" x 0 size and stored in 4 in-plant coal silos. The crushed coal is extracted from the silos at variable rates, as required by the ACFB boiler, by gravimetric feeders and fed to both front and rear walls of the boiler.

Rotary Car Dumper System consists of:

a. One rotary car dumper complete with platen, platen hooks, and rings, car clamps and tower, spill truss, rear truss, trunnions, trunnion support beams, drive motor, drive chains, speed reducer, gear boxes, and car position sensors.

b. One traveling hammermill complete with drive motors, shafts, and couplings, coupling guards, speed reducers, traversing rails, steel support frame, hammer shaft, and hammers.

c. Limit switches, clamp position sensing and/or indicting devices, solenoids, speed switches, slow down switches, over-travel switches, stop switches, equipment space heaters, etc., necessary for the operation of the rotary car dumper and traveling hammermill.

d. Proximity detectors or other devices required to sense, detect, or indicate the position and presence of cars on or in proximity to the rotary car dumper.

e. A minimum of four mushroom-head pushbutton emergency stop switches.

f. Electrically operated brakes as an integral part of motor.

g. An alarm horn and flashing beacon lights.

Locomotive and Railcar Data:

Coal will be delivered to the site via unit trains which consist of 80-100 open top, rotary-coupled railcars. The unit train will be separated into 20-car sections which will be maneuvered onto the rotary car dumper with a main line locomotive.

High Angle Conveyors

a. Two sandwich-type, high angle, silo feed conveyors C-2 and C-4, including a local control panel, and a steel frame structure for support and enclosure. The steel support structure shall include stairs and access platforms.

b. One externally mounted, 4-person capacity elevator with open rack and pinion drive arrangement, support steel, and controls. The elevator shall have two entry doors on adjacent sides and will be installed next to conveyor C-2.

c. Head chute, transition chutework, flop gage, support steel, stirs, and access platforms at the discharge end of conveyor C-2.

d. All locally mounted control and safety devices such as belt misalignment switches, emergency pull cord switches, underspeed switches, plugged chute detectors, limit switches, etc.

Fuel Handling Area

a. One car dumper hopper with grizzly and dumper enclosure with control room.

b. Two drag chain type feeders (DCF-1 and 2).

c. One car dumper reclaim conveyor (C-1) with belt scale and magnetic separator.

d. One tripper conveyor (C-3) including a local control panel, support steel, and controls. The support steel shall include stairs and access platforms.

e. One self propelled traveling tripper with dual side discharge, including a local control panel, traversing rails, and chutework.

f. Five slide gates under the fuel storage silos.

g. Five belt feeder sunder the fuel storage silos.

h. Magnetic separator at the discharge of HAC collection conveyor (C-4).

i. One 50-ton capacity surge bin with two slide gates.

j. Two vibrating feeders.

k. Two coal crushers.

l. One 66 inch wide cleated belt conveyor (C-5).

m. One drag chain conveyor (C-6) with discharge gates.

n. Dust collection systems equipped with pulse jet type fabric filter(s) at car dumper and conveyor transfer points. Vent filters for fuel storage silos and a insertable dust collector at discharge of conveyor C-5

o. Hoists and trolleys for maintenance purposes at all required locations of the fuel handling system.

p. Central vacuum cleaning header system for various structures and enclosures located at higher elevations.

q. Heating and ventilation system.

r. Heating pads to the outer walls of the rotary car dumper hoppers and storage silos.

The Fuel Handling System shall be designed to meet the following design capacities requirements.

a. Coal unloading and storage system - 2,000 TPH.

b. Coal crushing and reclaiming system - 250 TPH.

Storage Area

a. Five (5) reinforced concrete fuel storage silos complete with concrete roof steel discharge hopper.

b. A reinforced concrete common mat foundation for support of the five silos including a topping slab with curb and al required excavation, subsurface preparation, and backfill work.

Construction Features:

a. The silos shall be designed for a fuel storage capacity of 240,000 cubic feet per silo and shall be of cast-in-place concrete construction. A clear space shall be maintained between each silo to allow for independent wall construction by either the slipform or jumpform methods.

b. Each silo shall be equipped with a combination carbon and stainless steel discharge hopper.

c. The steel discharge hoppers shall be attached to and supported by a reinforced concrete ring beam at the wall/hopper transition elevation. The concrete ring beam shall be supported independent of the silo walls by reinforced concrete columns extending down to the top of the foundation.

4. Ash Handling and Storage

The CFB combustion process utilizes coal and limestone in the boiler. After combustion, the resulting limestone ash by-product material comes from two areas: bottom ash material from the CFB boiler and fly ash material from the pollution control equipment (boiler baghouse). The bottom ash and fly ash material would be conveyed separately to on-site enclosed storage silos with a total capacity of approximately 3,100 tons. The ash handling system would include ash conditioning equipment located in the ash silo area. The ash conditioning equipment would be used to dampen the ash with water prior to loading it into totally enclosed 25 ton net capacity trucks in order to minimize the potential for fugitive dust emissions during ash handling. The trucks would be used to haul the ash material from the site to a surface mine reclamation site in Schuylkill County.

Baghouse

A multi-compartment baghouse filter system will be used to clean the flue gas exiting the primary and secondary air heaters. The baghouse filter system is designed to remove particulates in the flue gas and maintain particulate emissions below 0.011 lbs/MMBtu. A design air-to-cloth ratio of two is specified with one compartment isolated for cleaning and one compartment out for maintenance. Each baghouse compartment has a hopper which is heat traced and has an 4 to 8-hour storage capacity. The ash collected in the hopper will be discharged to the fly ash removal system.

Ash Disposal System

The cooled bed ash will be conveyed to a bed ash storage silo via a pneumatic transport system. The bed ash collected during the pilot plant tests will be used to test different ash transport systems to determine the most reliable and cost effective transport system for the bed ash. The fly ash is conveyed from air heaters, economizer, and baghouse hoppers by dilute-phase pneumatic transport system to a fly ash storage silo.

5. Chemical Handling and Storage

As part of the proposed cogeneration facility operation, chemicals (for water treatment) and lubricants (for mechanical equipment upkeep) would be used and stored on-site. These materials would include oil and grease, diesel fuel, solvents (for degreasing equipment), caustics and sulfuric acid, water treatment chemicals, and aqueous ammonia.

Aqueous ammonia (29 percent solution) would arrive at the facility by truck at an estimated frequency of one delivery per week. The ammonia storage tank would be located within a fully contained and diked concrete area providing sufficient secondary containment of the storage tank to prevent a release.

6. **Limestone Handling and Storage**

Pulverized limestone would be delivered to the facility in 20-ton capacity enclosed trucks. YCEP is currently determining the necessary limestone specifications. Suppliers are expected to be generally located within a 50-mile radius of the proposed site, with one potential source located approximately 100 miles from the site. The limestone material would be pneumatically (air blown) transferred from the trucks into a storage silo. The silos would be sized to provide an approximately five-day supply of limestone (1,870 tons). The limestone material would then be pneumatically transferred from the storage silo to the day bins in the boiler house. From the day bins, the material would be fed directly into the CFB boiler for use in SO_2 emissions control. By transferring the material via enclosed systems the potential for fugitive dust emissions would be minimized.

Depending on the source of the raw limestone and dolomite, the sorbent would be either delivered by pneumatic truck or crushed at an adjacent site and pneumatically conveyed to two sorbent storage silos. Each silo discharges to on (1) 100% capacity gravimetric belt feeder. From the feeders, the sorbent is dropped into a bifurcated discharge hopper where the sorbent is divided into two streams. Four (4) 50% capacity sorbent blowers convey the sorbent to the ACFB boiler pneumatically and inject it to the boiler at the vicinity of coal feed points. The rate of sorbent feed is automatically adjusted if the SO_2 concentration measured at the stack exceeds a predetermined set point.

7. **Turbine**

The YCEP facility will generate electric power by extracting shaft work from the high pressure superheated steam flow produced by the ACFB steam generation circuits. The turbine generator system includes high, intermediate and low pressure steam turbines connected to a generator. The turbine will be equipped with 8 extraction points to service the feedwater heaters, reheat system, and export steam. Export steam (up to 400,000 lb/hr) at 575 psig and 670°F will be sent to PHG where it will be integrated with their existing steam system.

The steam turbine includes:

Steam Turbine:

Combined HP-IP steam turbine, solid-coupled to LP turbine

Double flow LP steam turbine with bottom down exhaust, solid-coupled to generator

One set of cross-over piping between IP and LP

Electro-pneumatic power-assisted non-return check valves for all extractions, including two parallel NR check valves in the extraction to the first LP heater and two series NR check valves in the extractions to both the 5th and 6th heaters.

Electric motor or electro-pneumatic actuated non-return stop valves for all extractions, including two parallel NR stop valves in the extraction from the first LP heater

Blowdown covers for throttle and reheat stop valves

Protection and control valve systems including:

DCS-based emergency trip system

High pressure (~2,000 psig) hydraulic fluid supply system

Lubricating oil system, supplies oil to turbine and generator bearings

Bypass oil purification/filtration system

Gland sealing system

Motor operated automatic/manual engage/disengage rotor turning gear

Bently Nevada series 3300 proximity probes and proximitors

Duplex thermocouples or RTD's:

Acoustic and appearance enclosure over HP-IP turbine, valving and piping, made of freestanding sections.

Block heat insulating material for upper and lower, HP-IP turbine casings, steam valve bodies and exhaust casing.

Rotor grounding device

Generator:

285 MVA @ 0.90 PF, 22,000 volt hydrogen inner-cooled generator with gas cooled stator winding

Hydrogen coolers include 70-30 CuNi tubes and Muntz metal tube sheets

Six high voltage bushings

Fifteen bushing current transformers with provisions for three additional transformers

Hydrogen seal oil system with required pumps, coolers and instrumentation

Hydrogen and carbon dioxide gas control system

Generator auxiliaries logic control system

Duplex RTD's

Neutral grounding transformer and resistor assembly

Brushless Excitation System:

Permanent magnet pilot exciter

AC exciter with rotating armature and stationary field

Rotating rectifier assembly with silicon diodes, indicating fuses and other required components

Necessary electrical interconnections

Fabricated steel baseplate

Air/water heat exchangers with 70-30 CuNi tubes

Bearing pedestal with terminal for testing insulation

Temperature measuring elements:

TEWAC enclosure mounted on the exciter base

Exciter base ground connection

WTA-300B Voltage Regulator:

Fully assembled low voltage metal enclosed excitation switchgear structures

Section number 1 enclosure with:

One ac isolation transducer module
One ac voltage error detector and reactive
Droop compensation module
One excitation system stabilizer module
One signal mixer module
One dc voltage error detector module
Two +/- 24 volt power supply modules with auctioneering circuit
Two transformer modules
Two firing circuit modules
One minimum excitation limiter (MEL) module
One maximum excitation limiter (MXL) module
One volts/hertz limiter module
One volts/hertz protection module
One over excitation protection (OXP) module
One forcing alarm module
One loss of sensing module
One power system stabilizer (with option to delete)

One digital manual dc regulator adjuster with follower

One digital ac regulator adjuster with follower

Section number 2 enclosure with:

Two draw-out thyristor power amplifier drawers of suitable rating, three-phase full converter bridge assemblies including one operating spare unit. Power drawer protection RC snubber circuits, thermal sensor and blown fuse detector included
Two set of exciter field shunts
Two dc-dc isolation transducers
One type DS breaker 600V, three-pole electrically operated with suitable auxiliary interlocks One set of fuses for control power
One starting resistor assembly
One set three-phase voltraps for thyristor protection

Site Specific Data

Site location:	York Co., Pennsylvania		
Site altitude:	461 feet above mean sea level		
Ambient temperature:			
Average Daily Mean	53°F		
Ambient relative humidity:			
Average	65%		
Electrical Characteristics:			
Transmission Line	115KV, 3 phase, 60 Hz		
Generator Rating	22,000V, 0.90 PF		
Motors >500 HP	4 KV		
Motors <300 HP	460 V		
(Voltage of 300 to 500 HP motors to be defined later as function of site loading requirements)			
Miscellaneous	460 V and 120 V/1 phase		
Cooling water characteristics:			
Source	Cooling tower		
	Winter	Average	Summer
Supply	64°F	78°F	93°F
Return	86°F	100°F	115°F
Condenser characteristics:			
	Winter	Average	Summer
Pressure, inHgA	1.47	2.24	3.45
(Minimum achievable concurrent with above cooling water temperatures)			
Seismic Zone	1		

Steam Turbine-Generator Performance Requirements

The steam turbine-generator performance shall be optimized around the average conditions listed below and it shall be guaranteed to deliver 248 MW within the variations (and any combinations) as shown as well as within the variations of site design conditions listed above.

Main Throttle Steam:

Psia	2415
°F	1000

Reheat Steam:

Turbine Outlet Psia	555
Turbine Return Psia	500
Turbine Return °F	1000

HP Process Extraction Steam:

psia	690
°F	725
lb/hr	average - 340,000 minimum - zero maximum - 400,000
Condensate return	100% @ 200°F

Turbine Exhaust Pressure:

psia	1.10 (average)	1.69 (summer)
InHgA	2.24 (average)	3.45 (summer)

Deaerator psia — 134.3 psi

Leaving Feedwater:

Temp. °F — 539

Attemporating Spray Water — Flow from the BFW pump discharge to the primary and secondary HP superheaters shall be scaled from the following data:

main steam flow lb/hr	attemporating flow lb/hr
1,725,000	78,223
1,293,750	42,010
862,500	0

Boiler Blowdown — 0.50% of main steam flow directed to 200 psia flash drum; 0.29 % of main steam flow returns to deaerator saturated and 0.21% is drained.

Feedwater Heater TTD's:

Top heaters,°F	- 3
LP heaters,°F	+ 5

Drain Cooler Approaches:

All FW Heaters,°F	+10
Pressure drop to°FW heaters	6%
No. of closed FW heaters	7

8. Draft System

The ACFB boiler is equipped with one (1) 100% capacity centrifugal primary air fan, one (1) 100% capacity centrifugal secondary air fan, two (2) 100% capacity centrifugal INTREX™ heat exchanger blowers, two (2) 100% capacity positive displacement J-valve blowers, four (4) 50% capacity positive displacement sorbent blowers. The primary air and the secondary air are heated by the flue gas in two heaters arranged in parallel with multiple air and flue gas passes. With flue gas flowing on the inside of the vertical tube, the gas side cleanliness is maintained without steam soot blowing. Balance furnace draft is maintained by one (1) 100% capacity centrifugal induced draft fan. Part of the primary air bypasses the primary air heater and is used to fluidize the stripper/coolers and provide seal and sweep air for the fuel feeders part of the high pressure air from the J-valve blowers is injected into the transfer lines from the combustor to the stripper/coolers to assist solids movement into the stripper/cooler.

H. Pollution Control

The proposed facility includes a single coal-fired CFB boiler equipped with state-of-the-art air pollution control equipment. Since the facility would be subject to Prevention of Significant Deterioration (PSD) regulations, the regulated level for these air pollution controls would be determined through a Best Available Control technology (BACT) analysis. In addition, the YCEP site is located in the Northeast Ozone Transport Region established by the CAAA and would therefore be required to offset any NOx emissions at a ratio of 1.15 to 1. The facility also would be required to complete a Lowest Achievable Emission Rate (LAER) performance test to demonstrate whether the proposed facility can meet a lower NOx emission level. Both the BACT analysis and the NOx offset plan approvals would be conducted as part of the facility's PSD air quality permit application process with the Pennsylvania Department of Environmental Resources (PADER).

The proposed air pollution control equipment would include the following:

- A minimum of 92 percent SO_2 emissions control would be achieved through the design of the CFB boiler system. The inert limestone in the boiler combustion chamber would interact with the SO_2 emitted in the coal burning process to control the SO_2 emissions level.

- Aqueous ammonia injection technology known as selective non-catalytic reduction (SNCR) would be employed to minimize NOx emissions. In this process, aqueous ammonia or urea is injected into the boiler exhaust gas to convert NOx into nitrogen and water. The NOx emissions reduction level being proposed would be guaranteed by the boiler manufacturer to achieve a 50 percent or greater reduction in NOx emissions.

- A fabric filter collection system (baghouse) would be used to control particulate emissions to 0.011 pounds per million Btu (lbs/MMBtu). The baghouse would remove the fine particles in the boiler exhaust stream prior to release of the exhaust gas into the atmosphere.

- The facility would also be equipped with a continuous emissions monitoring (CEM) system located in the stack, downstream of the pollution control equipment. The CEM would monitor exhaust gas flow, SO_2, NOx, opacity, and either carbon dioxide (CO_2) or oxygen (O_2). This CEM system would be used to assure that the facility is in constant compliance with the air quality permit approval.

In addition, the facility would be designed to minimize fugitive emissions associated with coal, ash by-product, and limestone materials handling through the maximum use of enclosures.

I. Facility Water Usage

The proposed cogeneration facility would have several different uses for water within the facility. During facility construction, the projected water use is expected to range from 5,000 to 15,000 gallons per day (gpd). The facility water balance shown on Figure 10 provides a breakdown of water usage during normal facility operation. It is proposed that YCEP's external water needs would be satisfied primarily from the P. H. Glatfelter Company and Spring Grove Water Company. Further details with regard to facility water supply are provided below.

Process Water

The proposed YCEP facility would supply up to 400,000 pounds per hour of high pressure steam to the P. H. Glatfelter Company; therefore, the process water make-up for the steam system (i.e., boiler water make-up) would be provided from the P. H. Glatfelter Company's boiler feed water or condensate systems which would be returned to the proposed cogeneration facility. For every pound of steam supplied to the P. H. Glatfelter Company, one pound of condensate and/or boiler feed water would be returned to the YCEP facility. Since the returned condensate and boiler feed water would be of lower quality (i.e., higher in dissolved minerals and impurities) than is required for make-up into the cogeneration facility steam system, the returned stream would require treatment through a demineralization treatment process to remove the impurities prior to reuse in the CFB boiler system. Process water losses from the steam system, water treatment and boiler blowdown (i.e., discharge) would be compensated for by using water supplied from the P. H. Glatfelter process water system. Periodic blowdown of the boiler would be required to control and minimize the potential for scale formation. The average flow would be approximately 200,000 gpd of additional water transferred from the P. H. Glatfelter Company's process water system to make up for these operating losses.

Cooling Water

Cooling water system make-up requirements for the proposed YCEP facility would be supplied from the P. H. Glatfelter wastewater treatment plant secondary effluent discharge located on the eastern side of the paper mill's property. Consumption of this water would vary based upon ambient conditions, plant production levels and cooling water quality. The average consumption would be approximately 2.5 mgd; the maximum consumption would be approximately 2.9 mgd. The P. H. Glatfelter wastewater treatment system currently discharges an average of 12.6 mgd of secondary effluent to Codorus Creek.

A pilot plant program was used to determine the water treatment program which would be needed to allow for the reuse of the P. H. Glatfelter secondary treatment plant effluent stream in the cooling tower. Based on the pilot plant operation, as well as-available data and information on other similar water treatment programs, the proposed YCEP water treatment program would be limited to a disinfectant, a chemical dispersant, and sulfuric acid. A material such as bromine, chlorine gas, or hypochlorite (liquid bleach) would be used as a disinfectant to prevent build-up of algae in the recirculation water; the chemical dispersant would be used to limit scale formation on the cooling water system components (heat exchangers, piping, pumps); and sulfuric acid would be added to assist in controlling corrosion and scaling on cooling water system components and maintain the water pH within acceptable limits for discharge to the P. H. Glatfelter secondary treatment plant. This water treatment program would be placed directly in the cooling tower recirculation water system.

As shown on Figure 10, the expected usage of secondary treatment plant effluent for cooling tower incoming water would be 4.1 mgd. This expected usage is during the periods when maximum evaporation is taking place in the YCEP cooling tower. Of this incoming water, 2.5 mgd would be evaporated in the cooling tower operation and 1.6 mgd would be returned to the P. H. Glatfelter secondary treatment plant as cooling tower blowdown. This blowdown stream would be at a cooler temperature than the secondary effluent incoming water stream due to the cooling effect in the cooling tower operation. This cooler would be discharged back into the P. H. Glatfelter secondary treatment plant.

J. Facility Wastewater

The proposed facility would be designed to minimize wastewater discharge facility through the efficient recirculation and reuse of water within the facility. Average discharge from all sources, including cooling tower blowdown, would be approximately 1.7 mgd. Facility wastewater not reused would be discharged to the P. H. Glatfelter Company's wastewater treatment system equalization basin via a 10-inch pipeline (force main). Flows to be discharged in this manner include utility and process streams such as cooling tower blowdown, and facility sanitary wastewater after treatment in the on-site package treatment facility. Water quality constituents in this discharge would consist primarily of naturally occurring minerals (e.g., calcium, magnesium, sulfate) contained in the makeup water which have been concentrated due to evaporation of water in the steam and cooling water systems.

The P. H. Glatfelter wastewater treatment system currently operates under an NPDES Industrial Wastewater Discharge Permit. This existing permit would be modified as required by the regulatory agency.

Stormwater runoff from potential high-dust areas (i.e., suspended solids from on-site materials such as coal, ash by-products or limestone) would, after a residence period in an on-site collection basin to remove some of the suspended solids, be directed to the cooling water pretreatment system, or used as ash quench. Stormwater runoff from clean areas of the facility would be discharged to the existing on-site detention basin. A NPDES Stormwater General or Individual Permit would be required for the YCEP facility stormwater management arrangements.

Wastewater Treatment

Process wastewater from the proposed facility would originate from three primary sources: cooling tower blowdown, stormwater runoff, and sanitary wastes. Process waste stream characteristics and proposed disposal methods are outlined below. Stormwater management for the proposed facility is discussed later in this section.

Cooling Tower Blowdown

A conventional wet cooling tower system would be used to dissipate process heat. The system would operate on a continuous basis using mechanical draft cooling units. Water would serve as the heat transfer medium.

While cooling tower blowdown would be minimized, some blowdown is required to prevent excessive build-up of dissolved solids. The blowdown volume would vary depending on the allowable cycles of concentration, i.e. the factor by which influent constituent concentrations are increased due to evaporative effects. Based on available makeup water quality characteristics, the system will operate at approximately 2.5 cycles of concentration.

Based on available data and information, routine cooling water treatment chemical additives would be limited to bromine, chlorine gas or hypochlorite (liquid bleach) to prevent biofouling, a chemical dispersant to limit scale formation, and sulfuric acid to maintain pH within acceptable limits for discharge and to assist in controlling corrosion and scaling rates for system components. Periodic maintenance may also require the addition of a commercially available biocide or slimicide to control fouling of the condenser and cooling tower.

Sanitary Waste

Sanitary wastes from the facility would be combined with sanitary wastewater from P. H. Glatfelter's Roundwood facility, and treated in an on-site package treatment system. Following treatment, the discharge would be combined with the other industrial water and pumped to the P. H. Glatfelter waste equalization basin.

K. Air Emissions

Regulatory requirements and topographic features in the general vicinity of the project site were evaluated in order to select the appropriate air quality dispersion models to perform the impact analysis. In addition, existing air quality background data were reviewed and compared to applicable federal and state air quality standards. These background levels, as measured at a network of air quality monitoring sites, were evaluated with respect to the attainment status for each of the regulated pollutants. With the exception of ozone, the concentrations of all regulated pollutants are in attainment with their respective standards. The area in which the York County Energy Partners, L.P., cogeneration facility is proposed to be located has been designated as a marginal non-attainment area for ozone, due to its inclusion in the Northeast Ozone Transport Region.

The air emissions control technology which would be demonstrated by the project would result in the generation of significantly less air pollutant emissions as compared to a conventional coal fired facility of comparable power rating. Application of stringent combustion and post-combustion control technologies, and a fully enclosed fuel handling system would minimize emissions of pollutants at this facility. The project would comply with all applicable standards to protect the ambient air quality of the region. By providing steam to the P. H. Glatfelter Company, the operation of their existing Power Boiler #4 would be curtailed resulting in a net reduction in sulfur dioxide, nitrogen oxide, and particulate emissions.

The chart below shows that, based on estimated actual emissions, the project results in a net reduction of 4.5 million pounds per year of SO_2, NOx, and PM.

York County Energy Partners, L.P.
Emission Reductions Summary

Based on PHG Actual and
YCEP Expected Actual Emissions
(pounds per year)

	SO_2	NOx	Part.
PHG No. 4 Boiler	(7,436,000)	(2,028,000)	(286,222)
No. 4 Boiler - 15 Days	310,696	84,735	11,959
Other NOx Reductions		(1,226,000)	
YCEP	3,820,163	1,995,840	219,240
Net Change	(3,305,141)	(1,173,425)	(55,023)

Total Emissions Reduction	(4,533,589)

Figures in "( )" indicate reductions

Notes:

1. PHG data is from 1992 PEDS submitted to PaDER.
2. YCEP data is based on the YCEP air permit application and operating factors.
3. Other NOx reductions will occur in York County in conjunction with this project.

V. CLOSURE

This report has documented the progress of the York County Energy Partners 250 MW circulating fluidized bed project over the past year. The facility site was moved 5 miles to facilitate a reduction in net emissions. Moving the facility increased the boiler steaming rate by approximately 20%. In addition, YCEP has performed extensive boiler pilot tests which has confirmed scale-up issues and fuel and limestone selection. YCEP has defined the scope of the boiler, turbine and fuel handling areas in detail, as documented in this report. Further, YCEP is developing a strategy for reusing wastewater from the steam host which may provide additional environmental benefits.

In the time since the Cooperative Agreement has been signed, YCEP has made significant progress in both understanding the technical issues of a new technology as well as in moving toward successful project development. In the next year, YCEP anticipates initiating detailed engineering with site construction occurring by mid 1995.

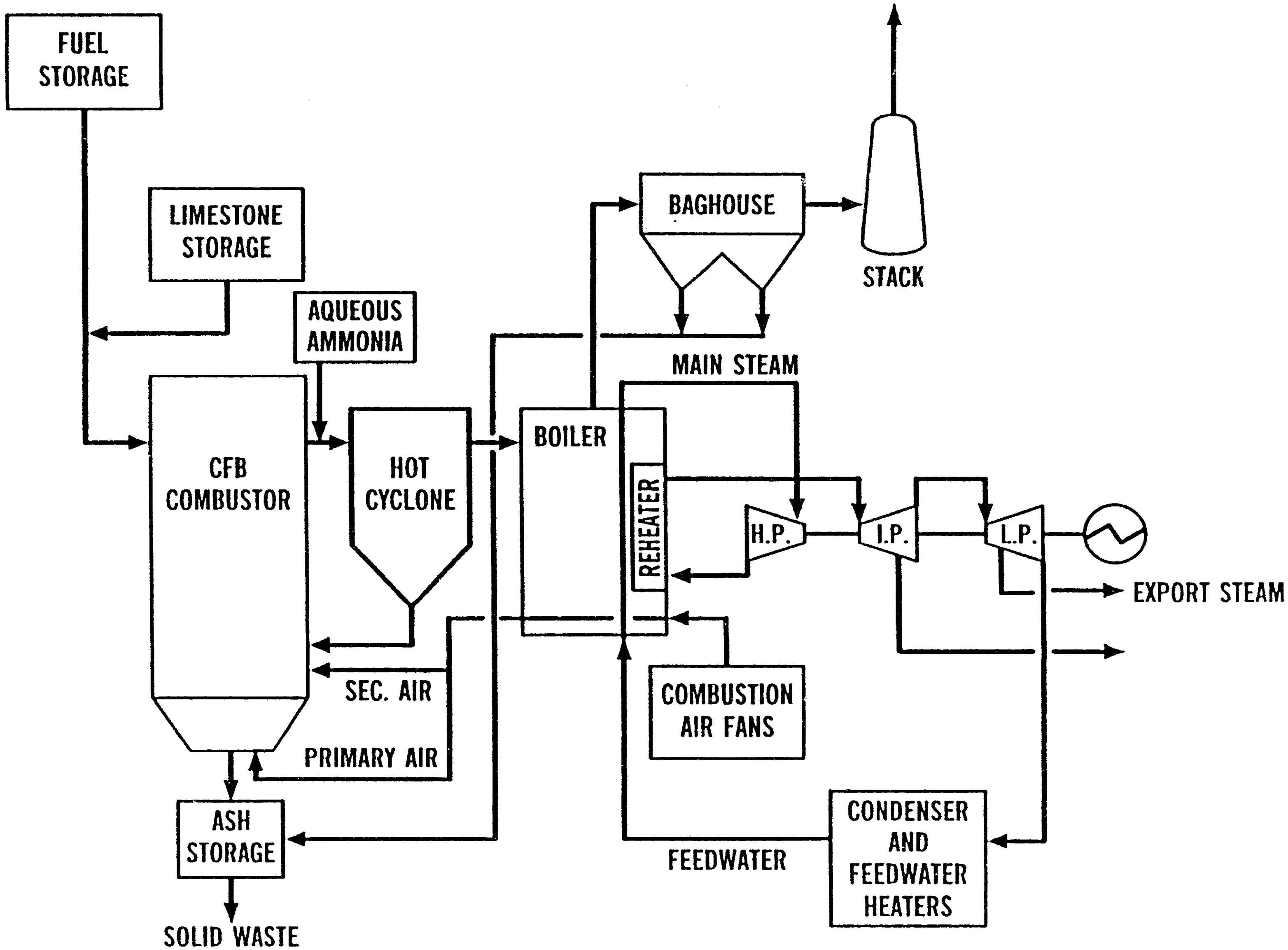
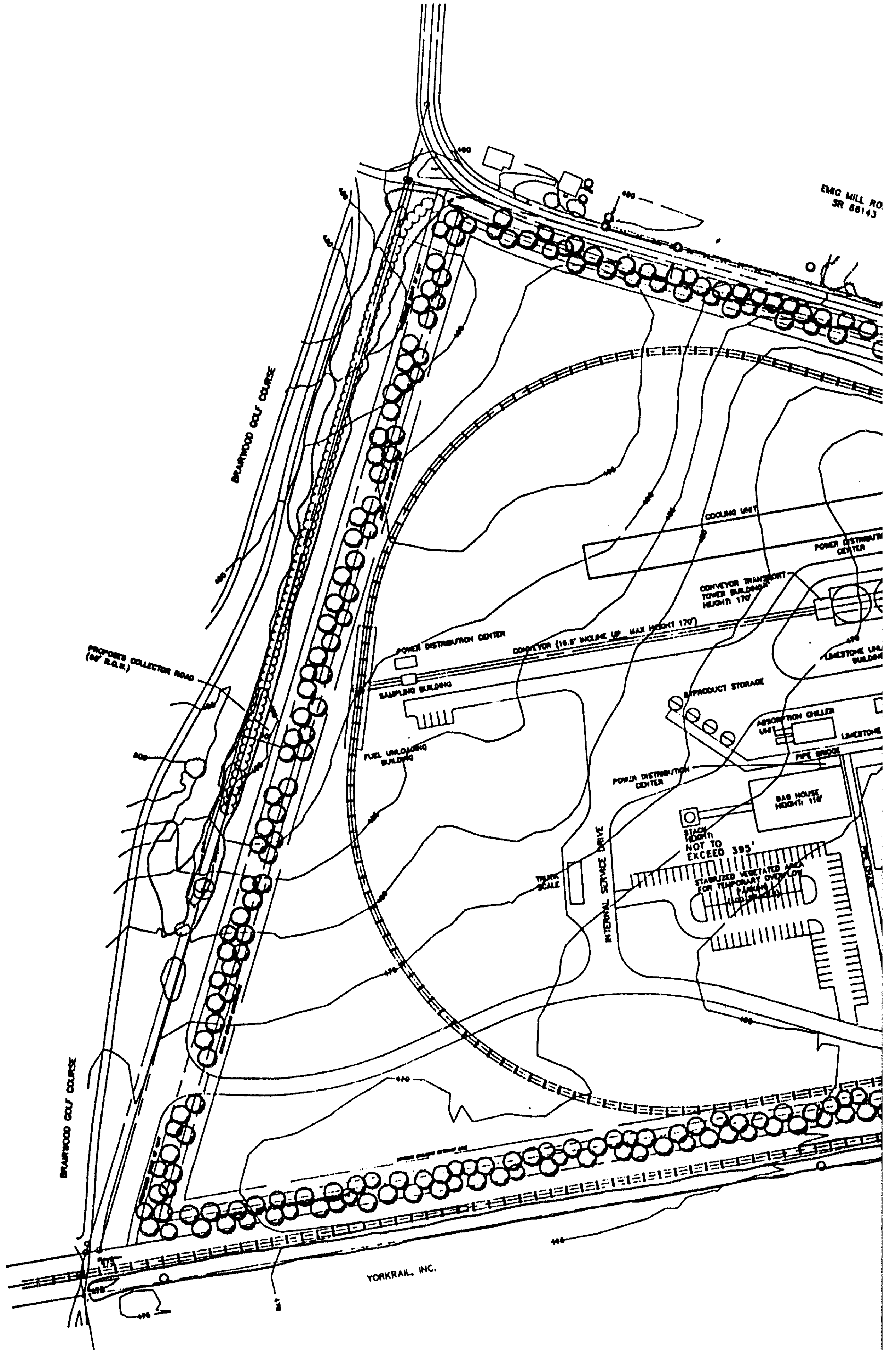


FIGURE 1 . Process Flow Digram for YCEP Cogen Facility.


BRIARWOOD GOLF COURSE
PROPOSED COLLECTOR ROAD
POWER DISTRIBUTION CENTER
SAMPLING BUILDING
FUEL UNLOADING BUILDING
COOLING UNIT
BYPRODUCT STORAGE
PIPE BRIDGE
BAG HOUSE
STACK
NOT TO
EXCEED 395'
STABILIZED VEGETATED AREA
FOR TEMPORARY OVERFLOW
INTERNAL SERVICE DRIVE
BRIARWOOD GOLF COURSE
YORKRAIL, INC.

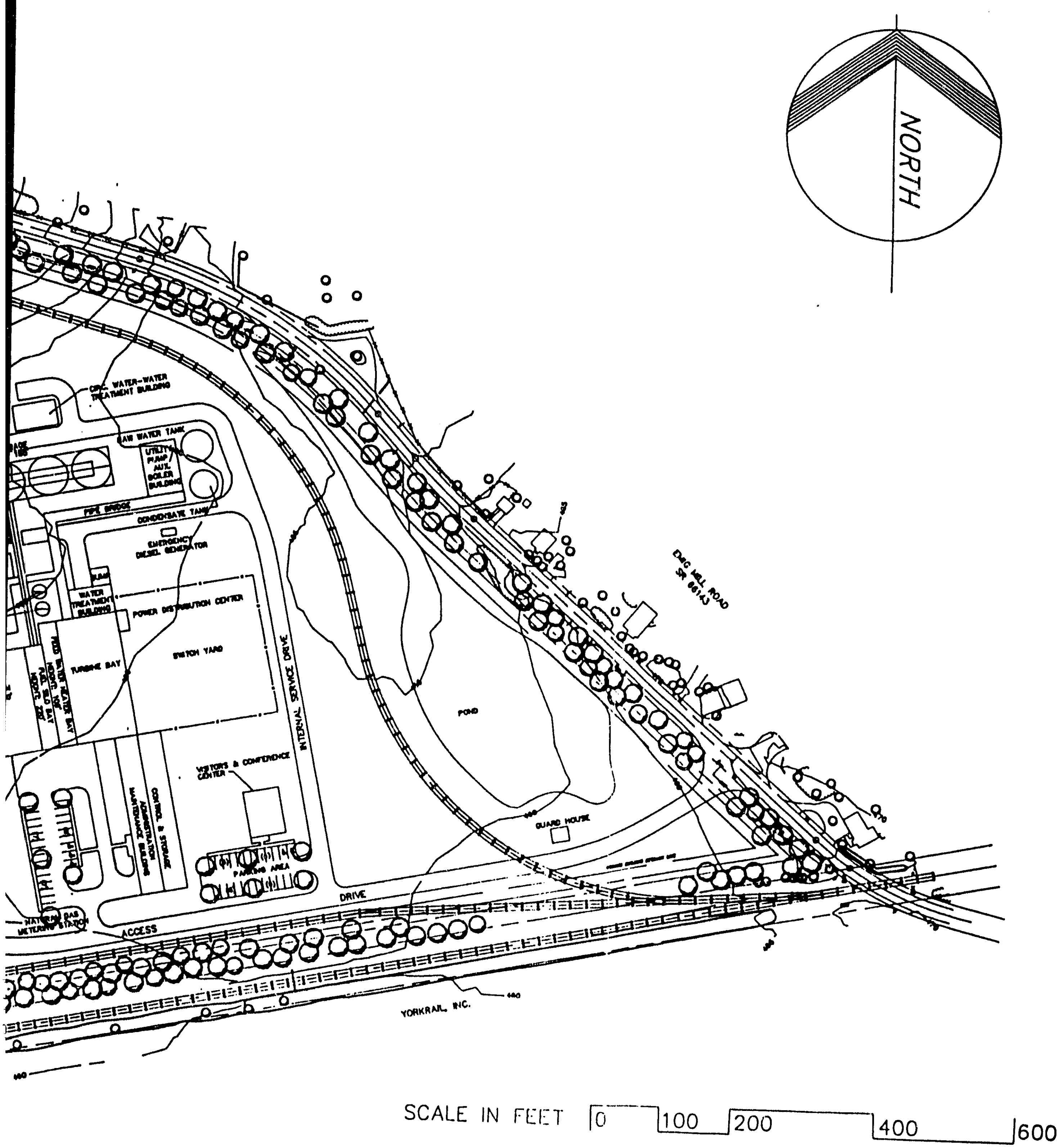
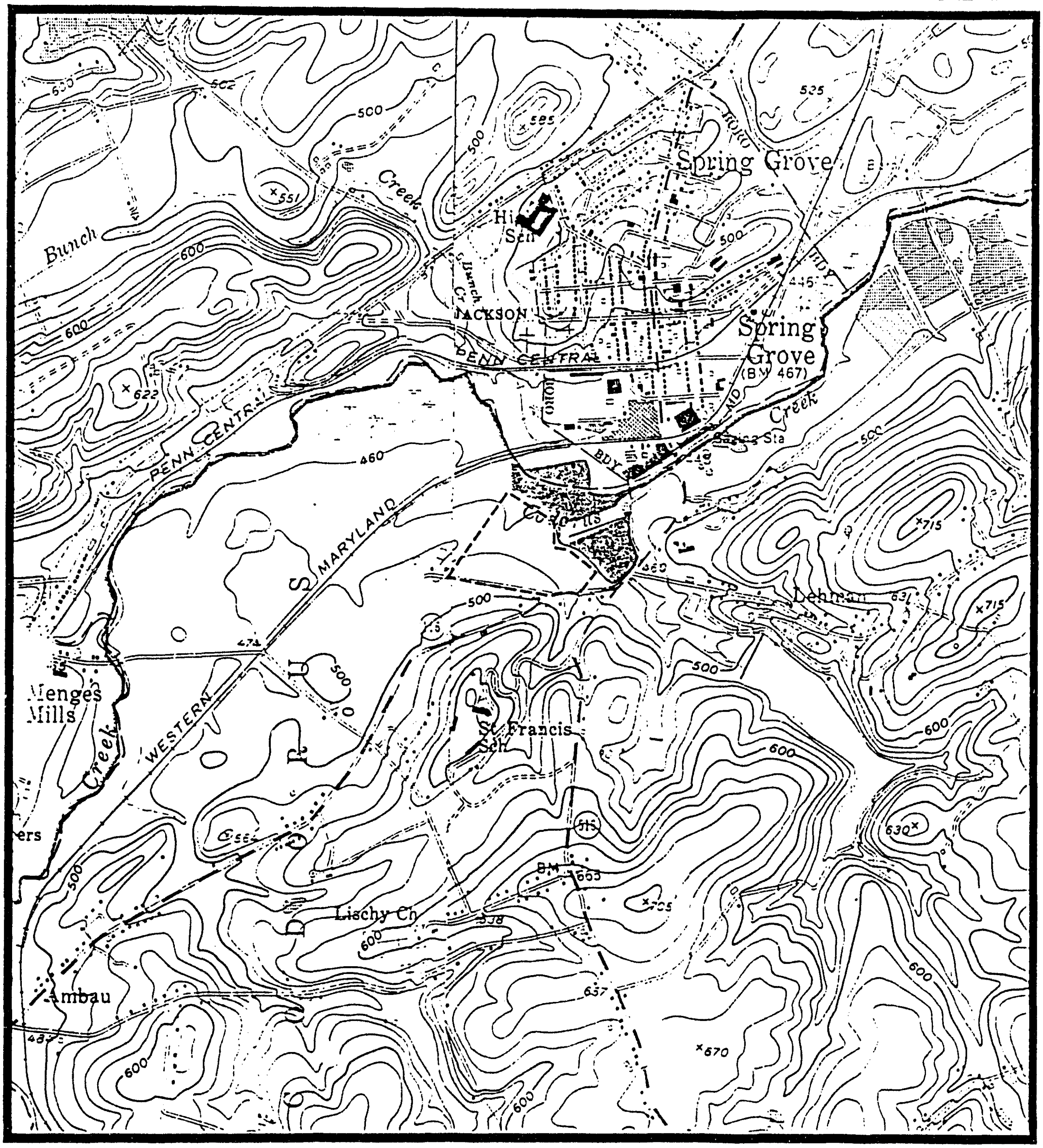


FIGURE 2 PROPOSED COGENERATION FACILITY SITE PLAN

WEST MANCHESTER SITE

ENSR



SOURCE:
U.S.G.S. 7.5 minute series topographic quads of
West York, Seven Valleys, Hanover and Abbottstown Pennsylvania

N

Site Boundary

0 .5 1

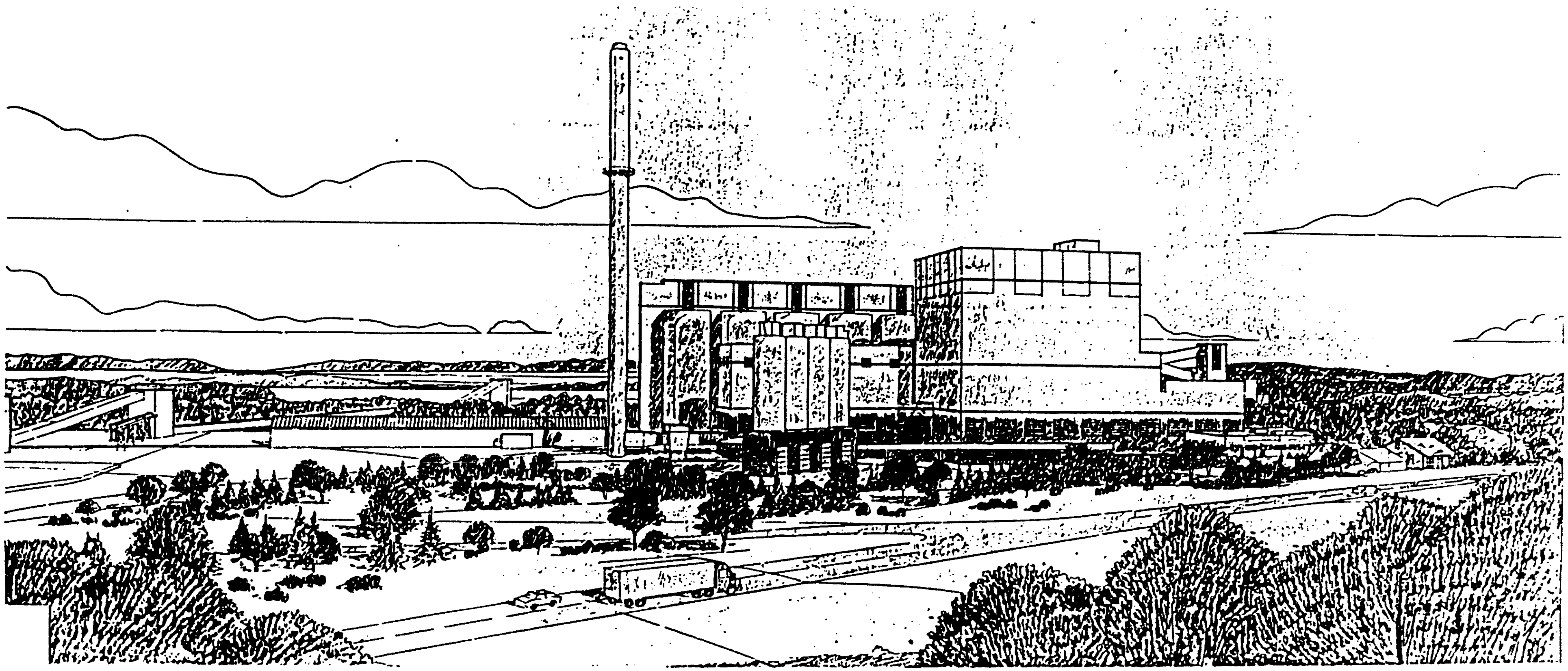
Scale in Miles

0 .5 1

Scale in Kilometers

FIGURE 3

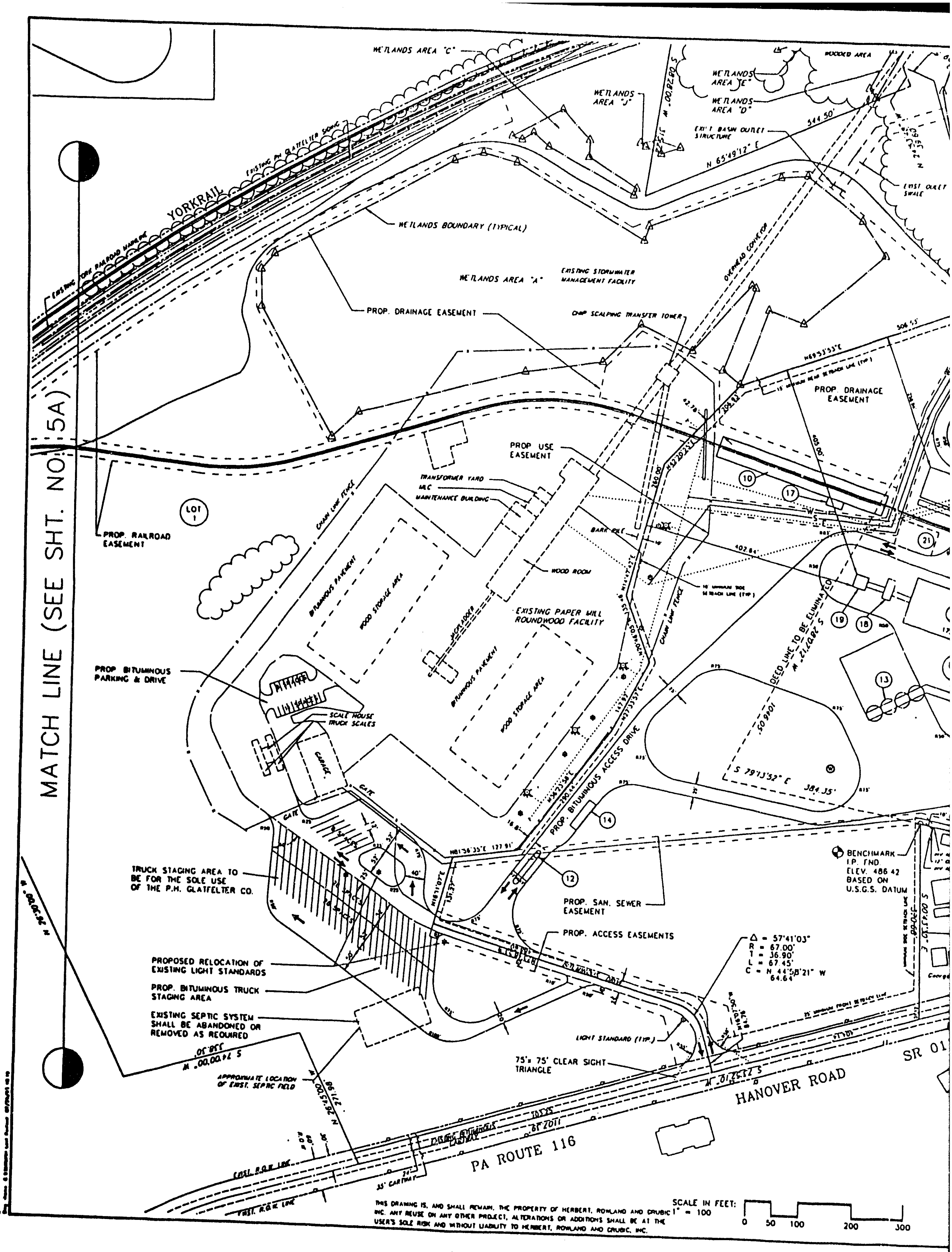
Site Location Map



York County Energy Partners
Proposed Cogeneration Facility

NORTH CODORUS TOWNSHIP SITE

FIGURE 4
Artist's Rendering of
YCEP Facility


MATCH LINE (SEE SHT. NO. 5A)
YORKRAIL
EXISTING YORK RAILROAD MAINLINE
EXISTING P.H. GLATFELTER SIDING
WETLANDS AREA "C"
WETLANDS AREA "J"
WETLANDS AREA "E"
WETLANDS AREA "D"
WOODED AREA
EXIT BASIN OUTLET STRUCTURE
EXIST OUTLET SWALE
WETLANDS BOUNDARY (TYPICAL)
WETLANDS AREA "A"
EXISTING STORMWATER MANAGEMENT FACILITY
OVERHEAD CONVEYOR
PROP. DRAINAGE EASEMENT
CHIP SCALPING TRANSFER TOWER
PROP. DRAINAGE EASEMENT
PROP USE EASEMENT
TRANSFORMER YARD
MAINTENANCE BUILDING
LOT 1
PROP. RAILROAD EASEMENT
CHAIN LINK FENCE
BITUMINOUS PAVEMENT
WOOD STORAGE AREA
BARK PILE
WOOD ROOM
EXISTING PAPER MILL ROUNDHOOD FACILITY
DEED LINE TO BE ELIMINATED
PROP BITUMINOUS PARKING & DRIVE
SCALE HOUSE
TRUCK SCALES
GARAGE
GATE
PROP. BITUMINOUS ACCESS DRIVE
S 79°13'52" E 384.35'
TRUCK STAGING AREA TO BE FOR THE SOLE USE OF THE P.H. GLATFELTER CO.
BENCHMARK I.P. FND. ELEV. 486.42 BASED ON U.S.G.S. DATUM
PROP. SAN. SEWER EASEMENT
PROP. ACCESS EASEMENTS
Δ = 57°41'03"
R = 67.00'
T = 36.90'
L = 67.45'
C = N 44°58'21" W 64.64'
PROPOSED RELOCATION OF EXISTING LIGHT STANDARDS
PROP. BITUMINOUS TRUCK STAGING AREA
EXISTING SEPTIC SYSTEM SHALL BE ABANDONED OR REMOVED AS REQUIRED
LIGHT STANDARD (TYP.)
75'x 75' CLEAR SIGHT TRIANGLE
APPROXIMATE LOCATION OF EXIST. SEPTIC FIELD
HANOVER ROAD
SR 0116
PA ROUTE 116
EXIST. R.O.W. LINE
35' CARTWAY
THIS DRAWING IS, AND SHALL REMAIN, THE PROPERTY OF HERBERT, ROWLAND AND GRUBIC INC. ANY REUSE ON ANY OTHER PROJECT, ALTERATIONS OR ADDITIONS SHALL BE AT THE USER'S SOLE RISK AND WITHOUT LIABILITY TO HERBERT, ROWLAND AND GRUBIC, INC.
SCALE IN FEET: 1" = 100
0 50 100 200 300

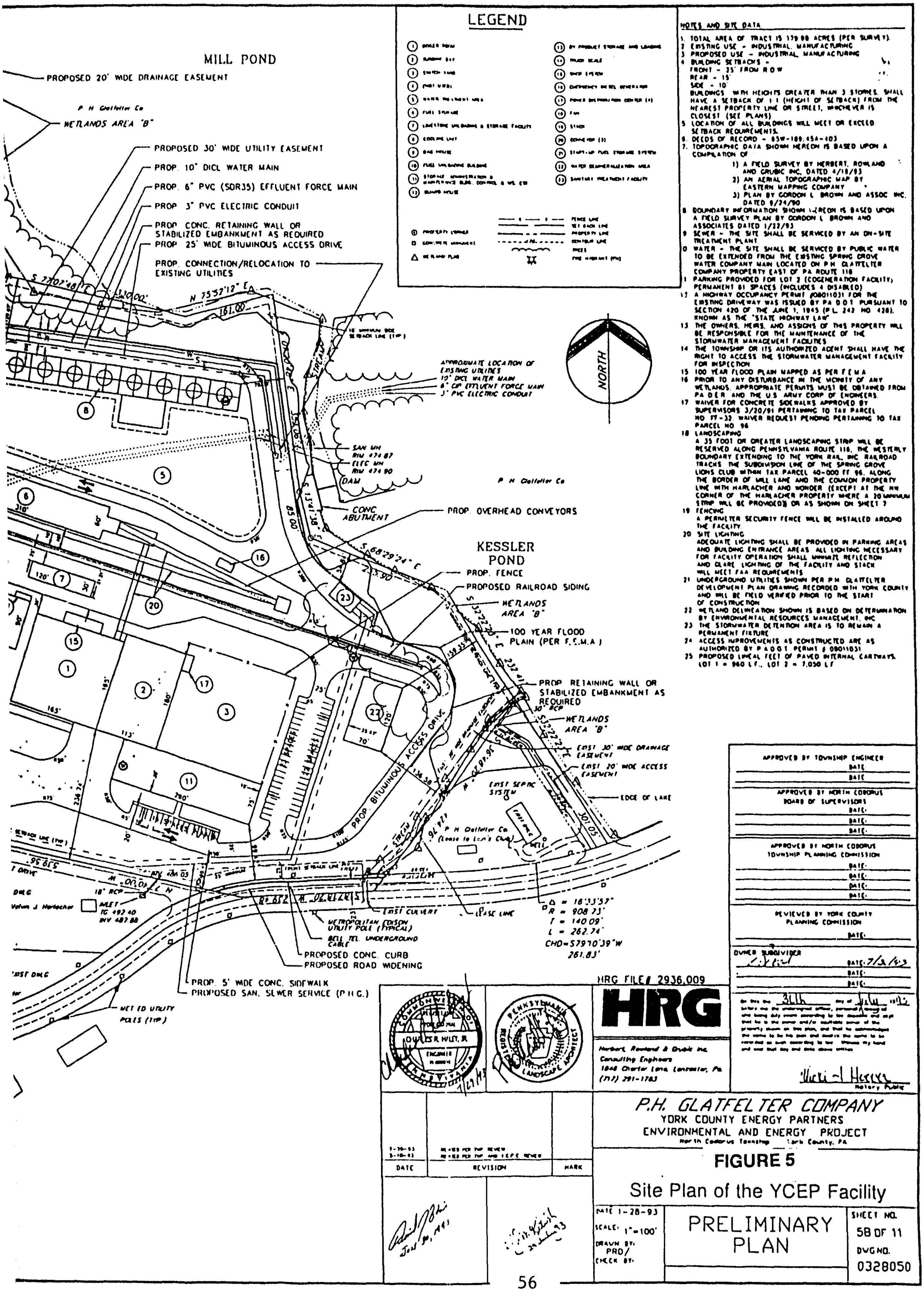


FIGURE 5

Site Plan of the YCEP Facility

YORK COUNTY ENERGY PARTNERS PROJECT

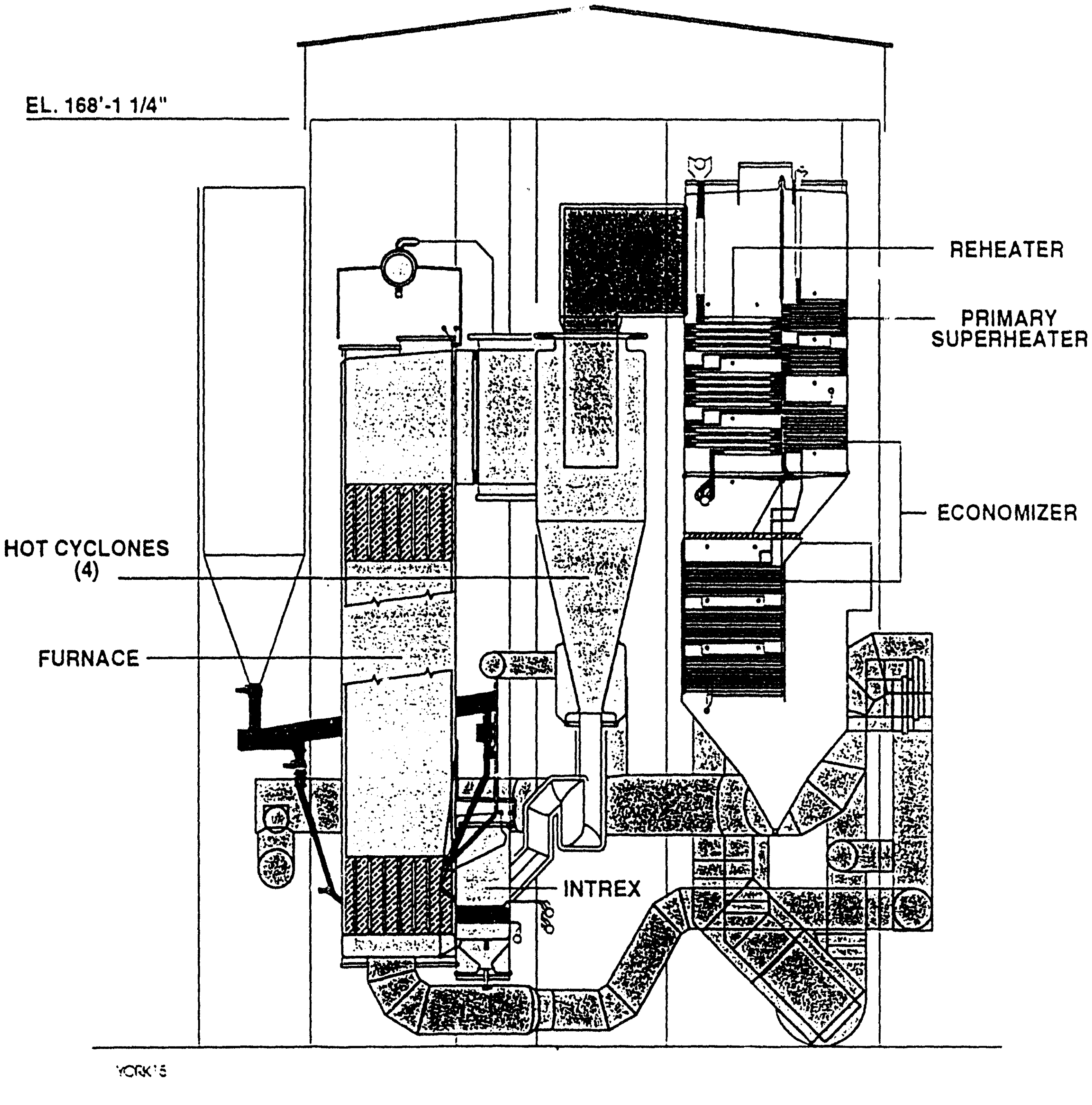


FIGURE 6A

YORK COUNTY ENERGY PARTNERS PROJECT

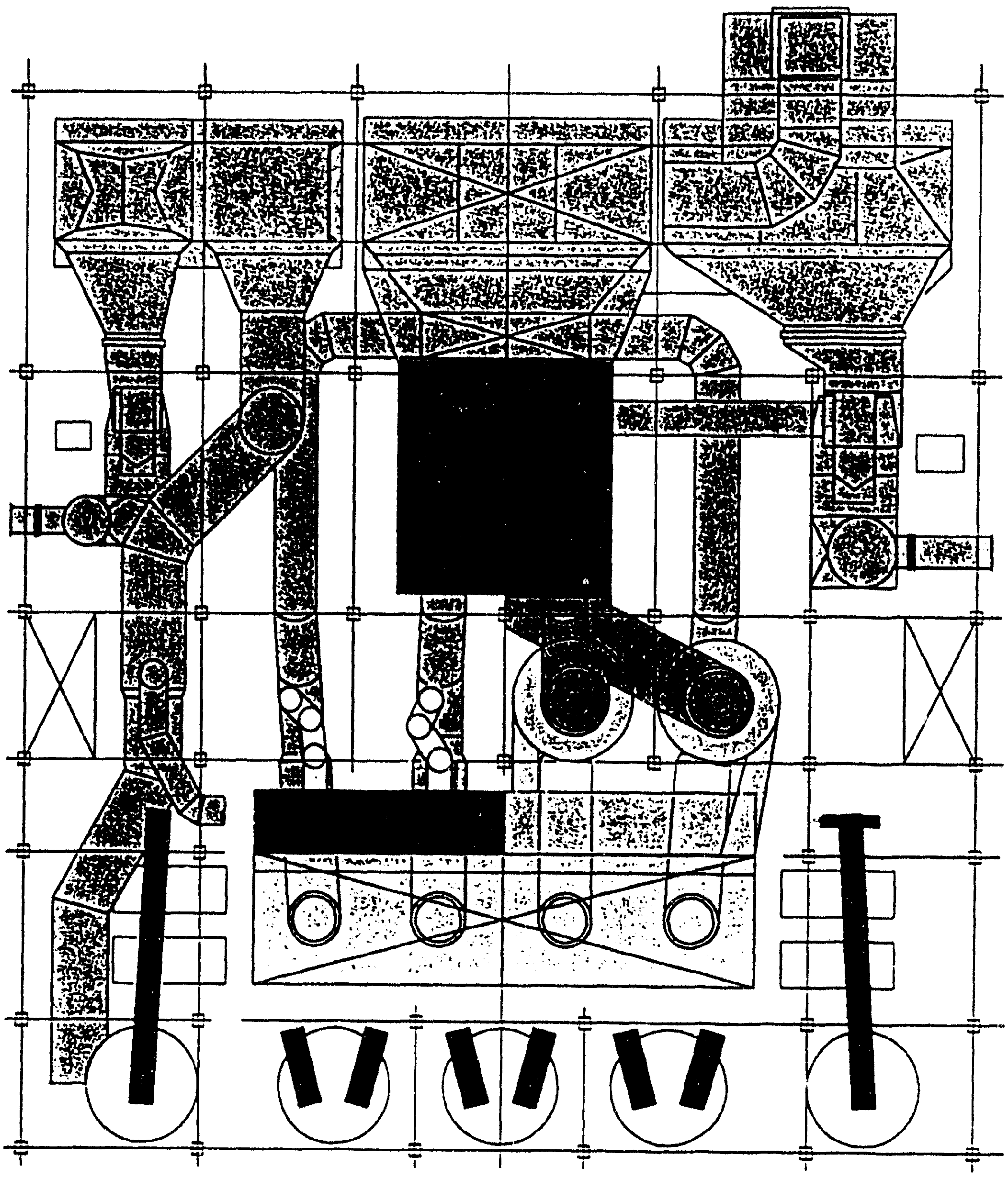


FIGURE 6B

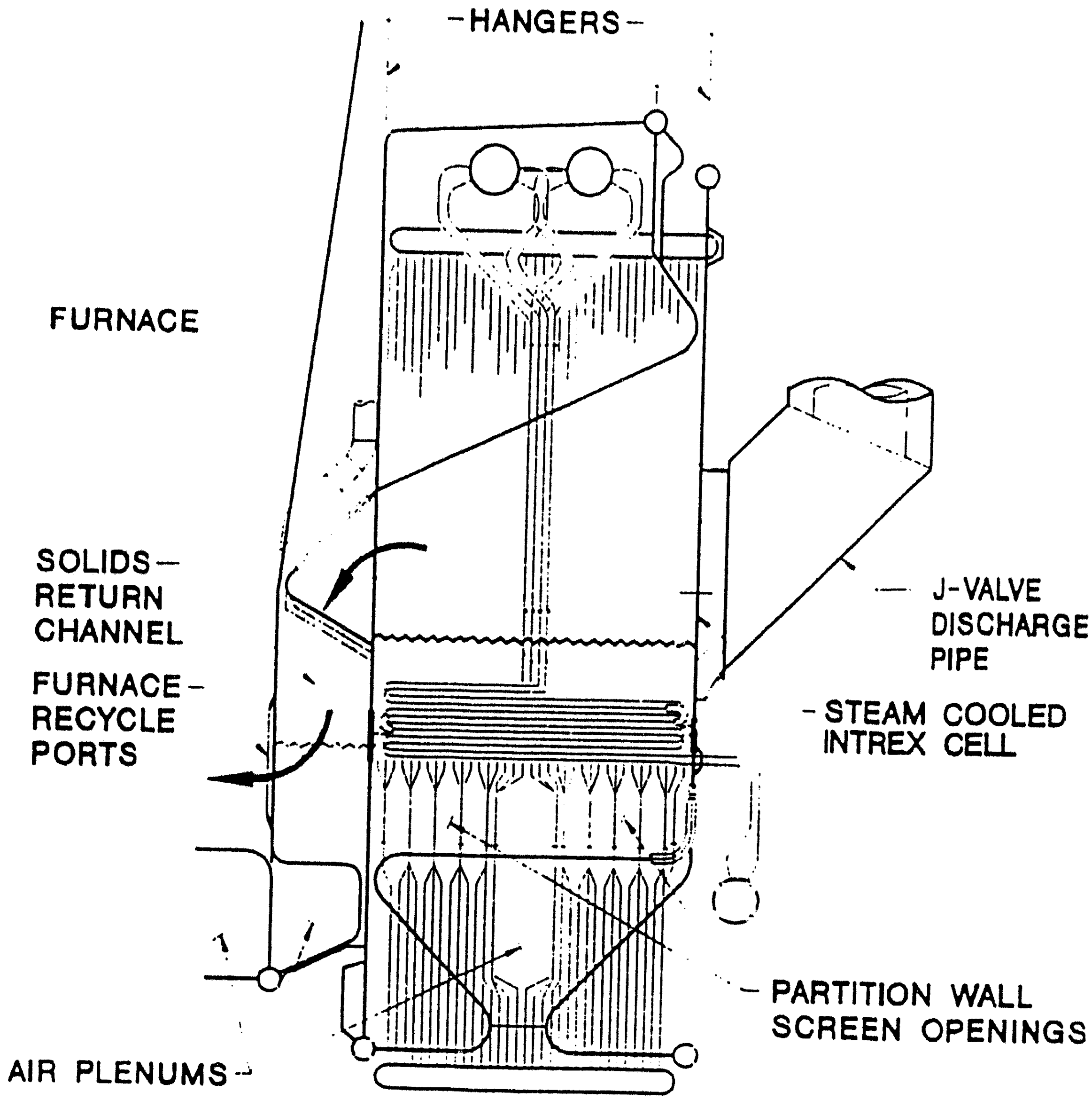


FIGURE 7 INTREX.

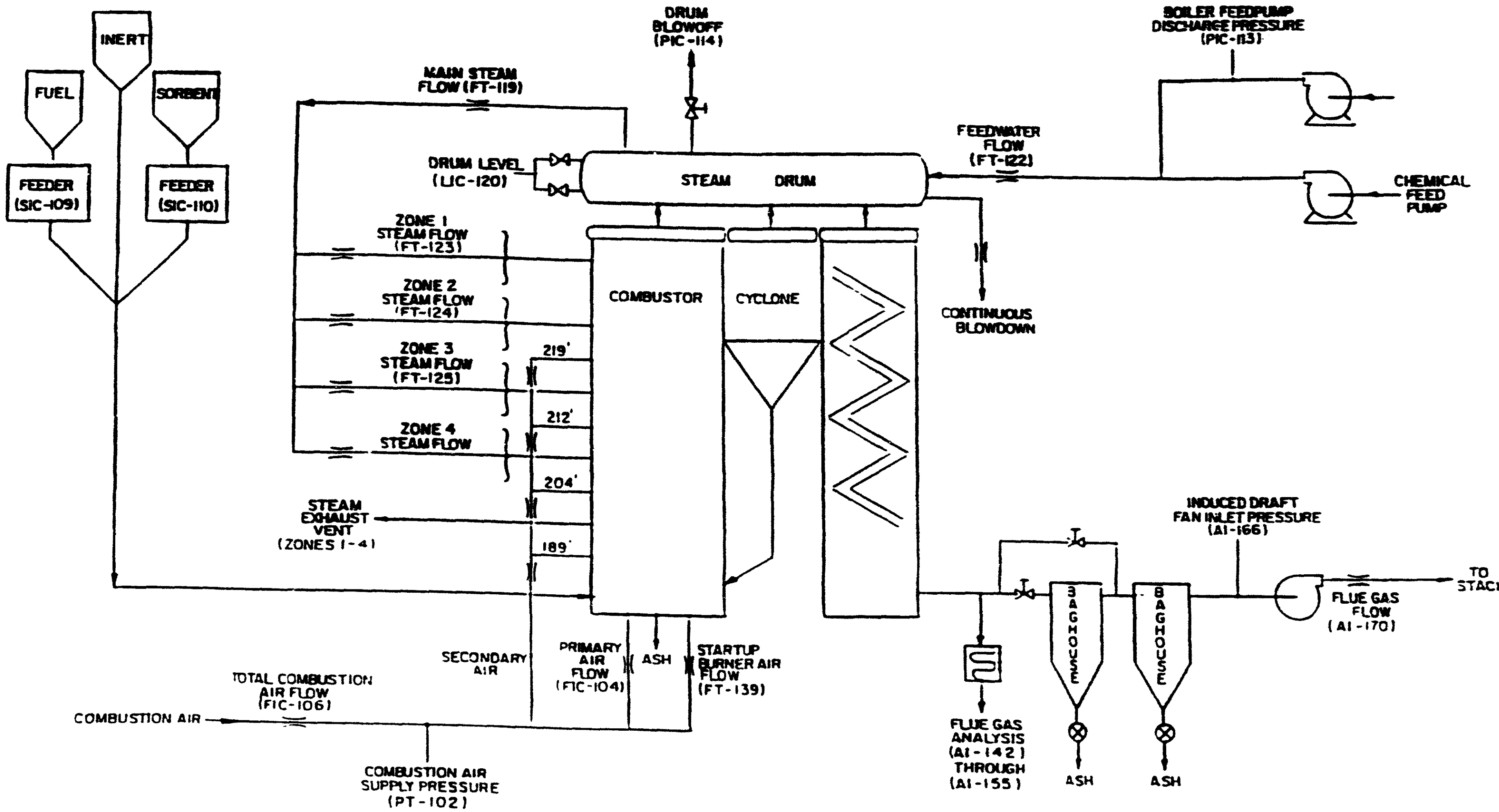


FIGURE 8

Process Diagram for CPFC Pilot Plant

*U.S. GOVERNMENT PRINTING OFFICE: 1994-550-168-00020

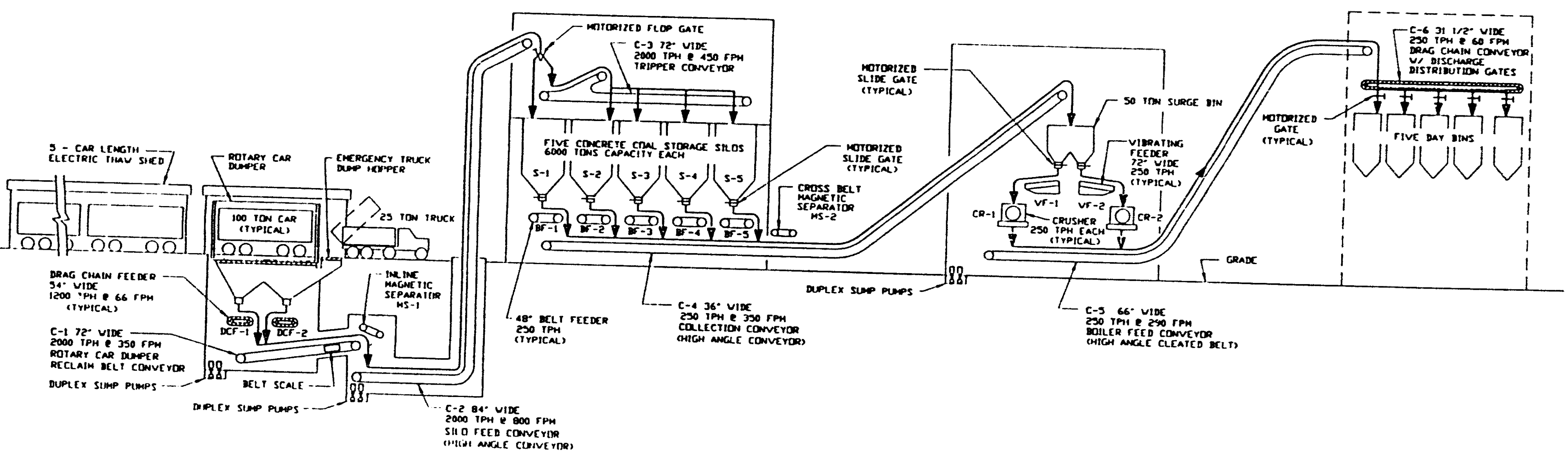


FIGURE 9

CONCEPTUAL
FOR BIDDING PURPOSE
ONLY

NOTES:

1 LOCATION OF THE DUST PICK-UP POINTS AND THE DUST COLLECTION ARE NOT SHOWN ON THIS FLOW DIAGRAM

2 THE CONTRACTOR SHALL PROVIDE A DUST COLLECTION AND VENTILATION SYSTEM AT ALL TRANSFER LOCATIONS CONFORMING TO THE PROJECT SPECIFICATION

YORK COUNTY ENERGY PARTNERS
250 MW COGENERATION FACILITY
FUEL HANDLING SYSTEM
FLOW DIAGRAM

03-2-8050

AIR PRODUCTS

INITIAL ISSUE

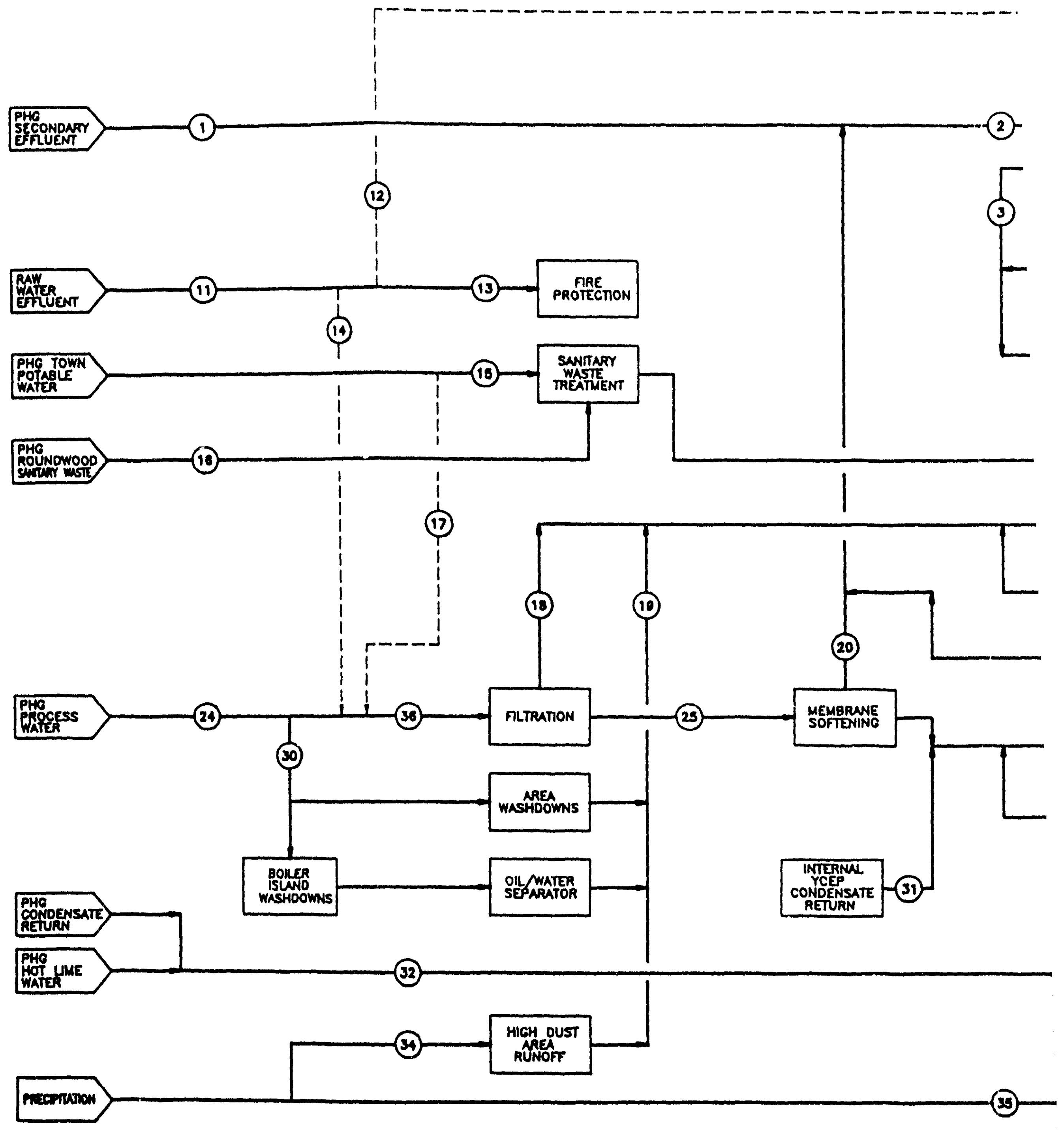
REVISIONS

17.40.10-1001 A

ACAD 1001.DWG

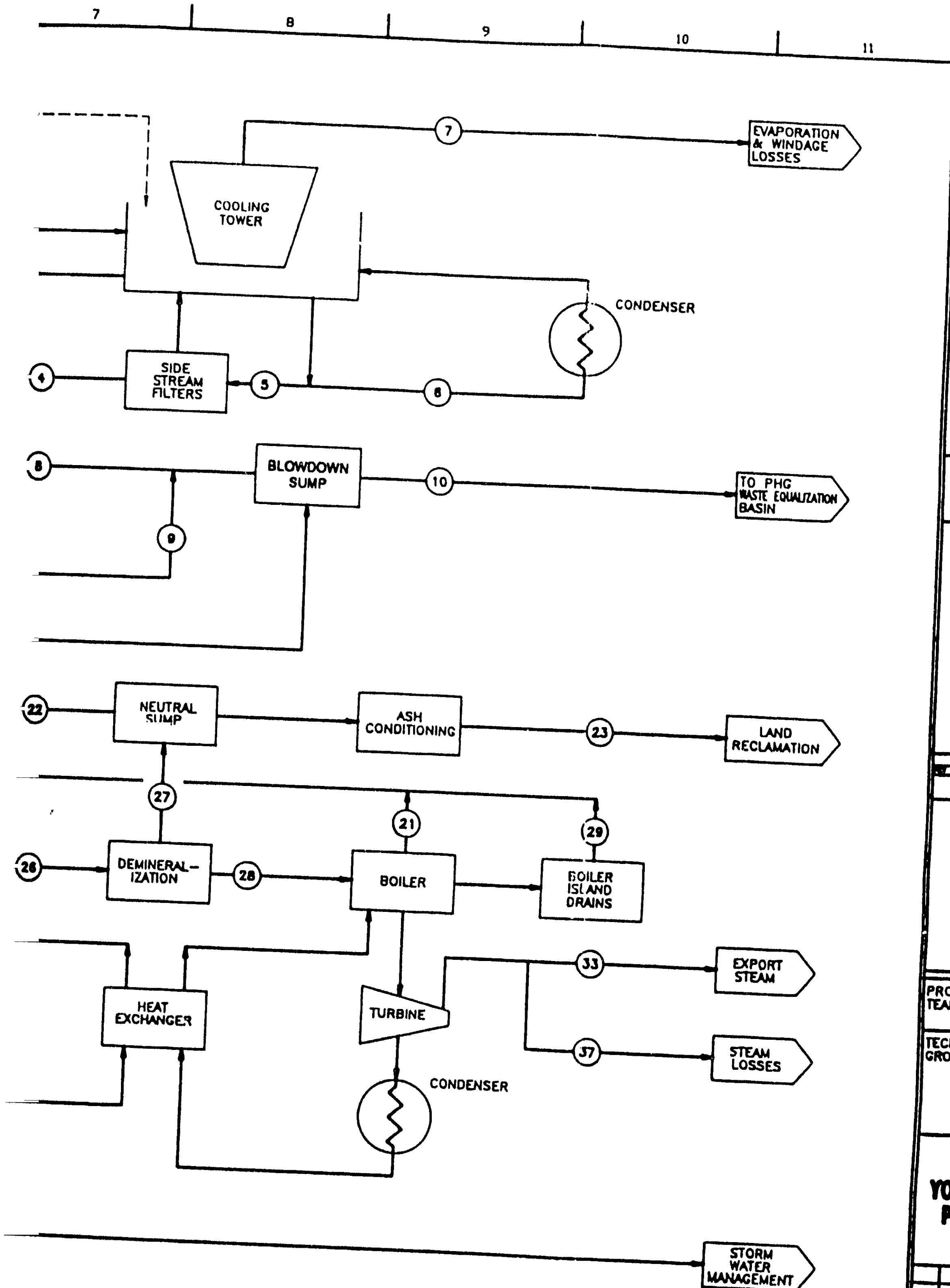
DD

PFD-WTR-01



STREAM	1	2	3	4	5	6	7	8	9	10	11	12
DAILY AVERAGE 000 GALS/DAY	4,081.4	4,164.8	1,837.6	57.6	1,440	151,200	2,469.6	1,695.2	3.4	1,718.8	0	0
DAILY MAXIMUM 000 GALS/DAY	5,433.2	5,688.1	2,796.8	57.6	1,440	151,200	2,833.7	2,854.4	6.0	2,906.2	0	0
MAX INSTANTANEOUS (GPM)	5,000.	5,000	3,000	3,000	1,000	105,000	1,960	3,000	40	3,000	5,000	5,00

STREAM	24	25	26	27	28	29	30	31	32	33	34	35
DAILY AVERAGE 000 GALS/DAY	199.9	186.1	1,118.8	33.6	1,085.2	7.2	6.0	0	979.2	979.2	0	0
DAILY MAXIMUM 000 GALS/DAY	384.0	357.1	1,535.0	46.1	1,489.0	14.4	12.0	106.5	1,152.0	1,152.0	0	0
MAX INSTANTANEOUS (GPM)	850	450	1,070	–	1,035	10	50	80	800	800	–	0



13	14	15	16	17	18	19	20	21	22	23
0	0	2.8	.6	0	7.8	6.0	46.5	29.7	6.4	27.2
0	0	4.5	1.5	0	14.9	12.0	89.3	151.2	18.9	52.6
1,500	800	20	20	400	–	–	115	110	20	400

36	37									
193.9	69.1									
372.0	178.5									
800	–									

DAILY MAXIMUM CASE:
- MAX STEAM EXPORT
- MAX BOILER BLOWDOWN
- MAX STEAM LOSSES
- MAX ASH SHIPMENTS
- MAX EVAPORATION LOSSES
- 2 CYCLES ON COOLING TOWER
- MAXIMUM FLOWS MAY NOT OCCUR AT THE SAME TIME

DAILY AVERAGE CASE:
- NORMAL STEAM EXPORT
- NORMAL BOILER BLOWDOWN
- NORMAL STEAM LOSSES
- NORMAL ASH SHIPMENTS
- NORMAL EVAPORATION LOSSES
- 2.5 CYCLES ON COOLING TOWER

---- EMERGENCY BACKUP

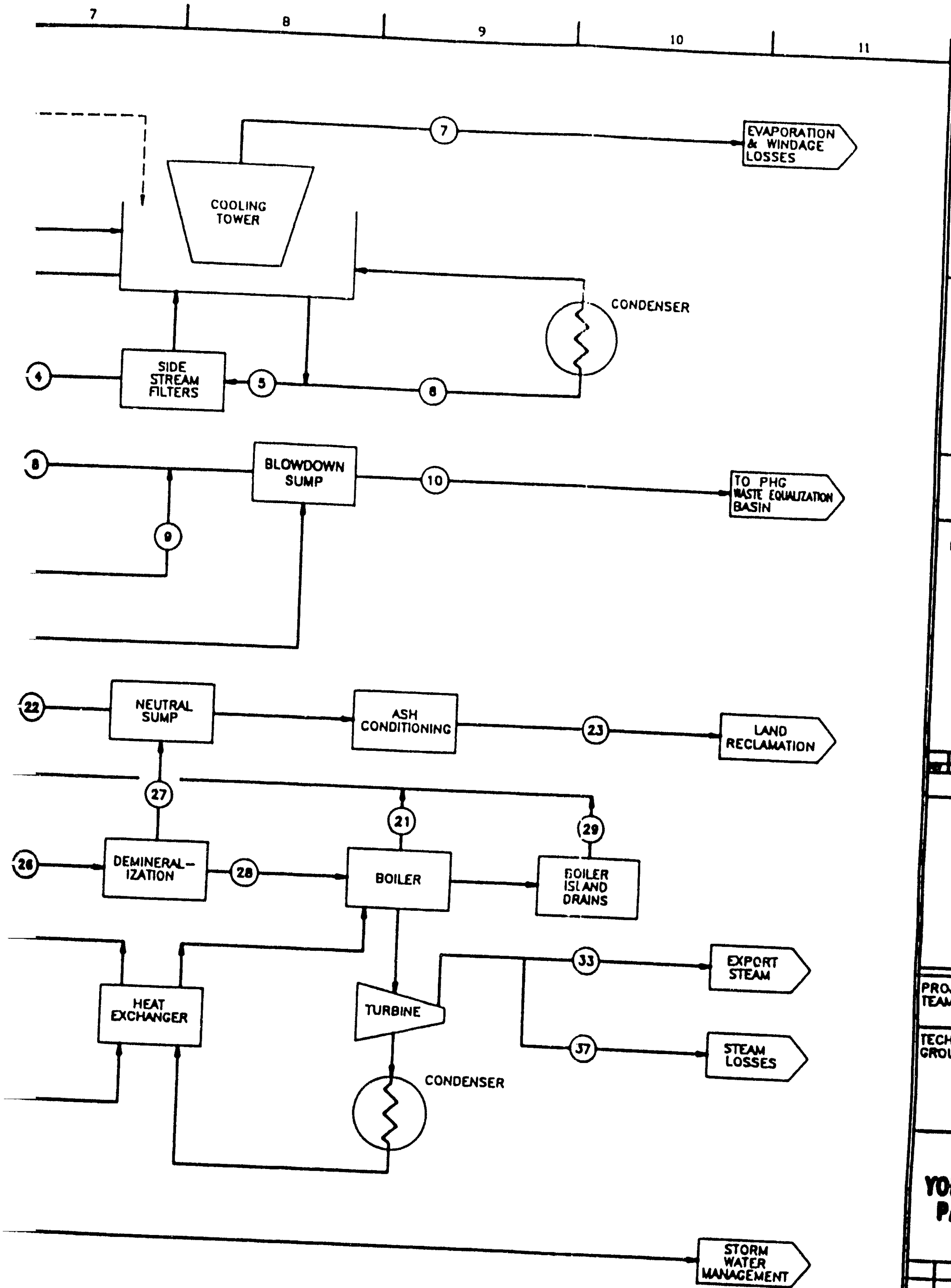
NOTE:
STORAGE LOCATIONS ARE NOT SHOWN ON DIAGRAM

PROJ. TEAM	APPR.	
	CHK.	
TECH. GROUP	APPR.	
	CHK.	
	CHK.	
	ISSUE	

YORK COUNTY ENERGY PARTNERS PROJECT

REV	DATE	DESC.	BY	CKD	APPD
P3	3/15/94	GENERAL REVISION	LG		
P2	9/8/93	REMOVE WASTE GLAR	MM		
P1	6/1/93	BLOWDOWN REV.	LLG		

FIGURE 10
YCEP Facility
Water Balance



13	14	15	16	17	18	19	20	21	22	23
0	0	2.8	.6	0	7.8	6.0	46.5	29.7	6.4	27.2
0	0	4.5	1.5	0	14.9	12.0	89.3	151.2	18.9	52.6
1,500	800	20	20	400	–	–	115	110	20	400

36	37									
193.9	69.1									
372.0	178.5									
800	–									

DAILY MAXIMUM CASE:
- MAX STEAM EXPORT
- MAX BOILER BLOWDOWN
- MAX STEAM LOSSES
- MAX ASH SHIPMENTS
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MAXIMUM FLOWS MAY NOT OCCUR AT THE SAME TIME

DAILY AVERAGE CASE:
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---- EMERGENCY BACKUP

NOTE:
STORAGE LOCATIONS ARE NOT SHOWN ON DIAGRAM

PROJ. TEAM	APPR.	
	CHK.	
TECH. GROUP	APPR.	
	CHK.	
	CHK.	
	ISSUE	

YORK COUNTY ENERGY PARTNERS PROJECT

REV	DATE	DESC.	BY	CKD	APPD
P3	[illegible]/15/94	GENERAL REVISION	LG		
P2	[illegible]/8/93	REMOVE WASTE [illegible]	MM		
P1	[illegible]/1/93	BLOWDOWN REV.	LLG		

FIGURE 10
YCEP Facility
Water Balance