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FINAL

CONTROL TECHNOLOGY ASSESSMENT

FOR

COAL GASIFICATION AND LIQUEFACTION PROCESSES

Westinghouse Fluidized-Bed Coal Gasification
Process Development Unit
Waltz Mill, Pennsylvania

Report for the Site Visit of
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Submitted to:

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FOREWORD

The Enviro Control, Inc. Control Technology Assessment (CTA) team met with representatives of the Westinghouse Fluidized-Bed Coal Gasification Process Development Unit at Waltz Mill, Pennsylvania on June 24-25, 1981. At our initial meeting Mr. Donato Telesca of Enviro Control explained the purpose of our visit and outlined the type of information Enviro wanted to collect. Based on this discussion, Mr. Edwin Vandergrift of Westinghouse scheduled Enviro to interview appropriate personnel. Those attending this initial meeting were:

<u>WESTINGHOUSE</u>

E. F. Vandergrift	Safety Coordinator, Advanced Coal Conversion Department
G. B. Haldipur	Manager, PDU Facility
K. J. Smith	Engineer, PDU Development Engineering

<u>ENVIRO CONTROL DIVISION</u>

D. R. Telesca	Program Manager
J. S. Scopel	Chemical Engineer

Mr. R. K. Tanita, an industrial hygienist at Enviro Control conducted a comprehensive industrial hygiene survey of the PDU facility in May, 1981. The information collected by Mr. Tanita is summarized in this report.

This report was made possible by the excellent cooperation of Messrs. Vandergrift, Haldipur and Smith.

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I. INTRODUCTION

A. Background

The objective of the "Control Technology Assessment for Coal Gasification and Liquefaction Processes" program is to study the control technologies that are currently in use for preventing occupational exposure to hazardous agents in the various coal conversion plants. For the purposes of this study the term "control technology" has a very broad meaning. It includes equipment whose specific function is the control of potentially harmful emissions, such as baghouses, dust collection hoods, and thermal oxidizers. It also includes any equipment design or process design change that increases the reliability of the process. Fewer equipment failures result in less worker exposure due to accidental releases and less exposure of the maintenance personnel who must make the repairs. Controls in this category include better metallurgy and improved equipment designs. We also considered the plant's work practices and industrial hygiene program to be part of their control technology.

This report details the control technology and industrial hygiene information gathered at the Westinghouse Fluidized-Bed Process Development Unit at the Waltz Mill, Pennsylvania, site during the site visit of June 24-25, 1981.

B. Project History

Westinghouse Electric Corporation has been engaged in the development of a pressurized, fluidized bed gasification process for converting coal to low- or medium-Btu gas for use as an industrial or utility fuel; as a synthesis gas for further processing to synthetic natural gas (SNG), synfuels or chemical raw materials; or as a fuel for electrical power generation by gas turbines or combined-cycle systems. The performance criteria guiding the development of the Westinghouse gasification system were that it have the ability:

- to operate with any type of washed or run-of-mine coal regardless of sulfur or ash content, caking tendency or reactivity;

- to convert coal to useful forms of energy with minimal environmental impact;
- to operate in a utility or industrial application at an economically competitive cost;
- to operate safely, reliably and controllably at full or part load and with air or oxygen as required by the application.

In the early years of the development program, the emphasis was directed primarily to the two-stage, air-blown system for direct integration with Westinghouse combined-cycle plants based on the W501D combustion turbine. This program was an Office of Coal Research program that was intended ultimately to result in the construction and operation of a nominal 130 Mw coal gasification combined-cycle facility in Indiana.

This initial development of the advanced coal gasification system involved laboratory research, including the design and construction of a process development unit (PDU). The 15-ton-per-day PDU was mechanically completed in 1974, and a test program was initiated in 1975 to establish the operating characteristics of the system and provide data for developing scale-up factors for a pilot plant.

In 1975, the Energy Research and Development Administration redirected the program, deferring the pilot plant portion of the work and emphasizing the process development aspects.

The experimental program on the PDU has been in progress since January 1975, when the plant was first commissioned. Experimental runs are carried out in "campaigns," the first was the devolatilizer campaign. The devolatilizer is part of the original two-stage process design. In this version of the process, coal is fed to a devolatilizer reactor where it is heated to 1600^{O}F to remove volatiles and to produce char particles that are non-caking. These char particles are then gasified in a second reactor using air and steam to produce the raw product gas which passes through the devolatilizer, heating and fluidizing the coal char bed. A recirculating draft tube is used to prevent the fresh coal from caking.

During the devolatilizer campaign, the basic technical feasibility of this recirculating bed concept was demonstrated. Caking coals were continuously processed in the unit without oxidative pretreatment. The char produced in these experimental runs was successfully gasified and ash agglomeration and removal was demonstrated in the subsequent air-blown gasifier campaign. These two test campaigns demonstrated that, individually, the two reactors used in the two-stage process were operable. It remained to be demonstrated that they could be successfully integrated. Toward the end of the air-blown campaign, an attempt was made to feed caking coal directly to the gasifier without pretreatment or prior devolatilization. These initial attempts, as well as long-duration runs conducted with caking coals, successfully demonstrated that a single-stage process was feasible. This breakthrough greatly simplified the process since only one, not two, reactors would be required and no interstage solid char transfer would be necessary.

The flexibility of the single-stage fludized bed process was further demonstrated in the oxygen-blown gasifier campaign that followed. In this series of tests, a variety of coals were processed in the unit using oxygen and steam to produce a medium-Btu gas, and most of the previously established criteria for gasifier performance were met. At this point in the program, it appeared that the single-stage process would be ideal for certain applications because of its simplicity and potentially low cost. These applications would include industrial fuel gas and synthesis gas production and integrated coal gasification, combined-cycled power generation. It appeared that the two-stage process might have application in the production of SNG because of its potential for higher thermal efficiency and greater methane yield. To evaluate these potential advantages, a brief integrated two-stage campaign was run in 1979. The results were extremely successful from an operability point of view, particularly with respect to the demonstration of the controllability of the two-stage process, but the results did not substantiate the potential advantages.

Consequently, the PDU test program has, since that time, concentrated on optimizing the oxygen-blown single-stage process. In 13 separate test runs, over 1500 hours of operation at design conditions were achieved. During this period, an oxidant injection nozzle was developed that permits operation of the gasifier with low steam-to-coal ratios. The ability of the process to handle a variety of coals was shown in tests with Appalachian coals (Pittsburgh #9, and #8, and Ohio #9), Mid-Continent coals (Indiana #7 and Western Kentucky) and Western coals (Rosebud, Wyoming Sub-bituminous and Texas lignite). Significantly, a method of mixing recycled fines with the coal resulted in more effective fines consumption. Finally, models required for scale-up were corroborated by these tests. These included models required for gasification kinetics, jet behavior, agglomeration and ash separation, fines elutriation, methane formation, and ash deposit prevention.

The technology development program is now being directed toward the enhancement of the data base for the design of commercial-scale hardware. Reactor scale-up is being studied by integrating the results of laboratory modeling with PDU results and with the results from a commercial-scale, semicircular, cold flow model.

The effect of pressure on single-stage operation has been investigated through tests with the PDU oxygen-blown system at 230 psig. A second fines cyclone has been included to increase fines capture and recycle, and heat recovery experiments were conducted on the raw product gas from the reactor. Laboratory work on the fundamental behavior of coal and ash, and new experiments with the PDU have been run to evaluate turndown and transient behavior of the process.

C. Process Description

A flow diagram of the Westinghouse Process Development Unit is shown in Figure 1. The major operations are coal storage and preparation, coal feeding, gasification, gas cleanup, gas compression, and waste incineration.

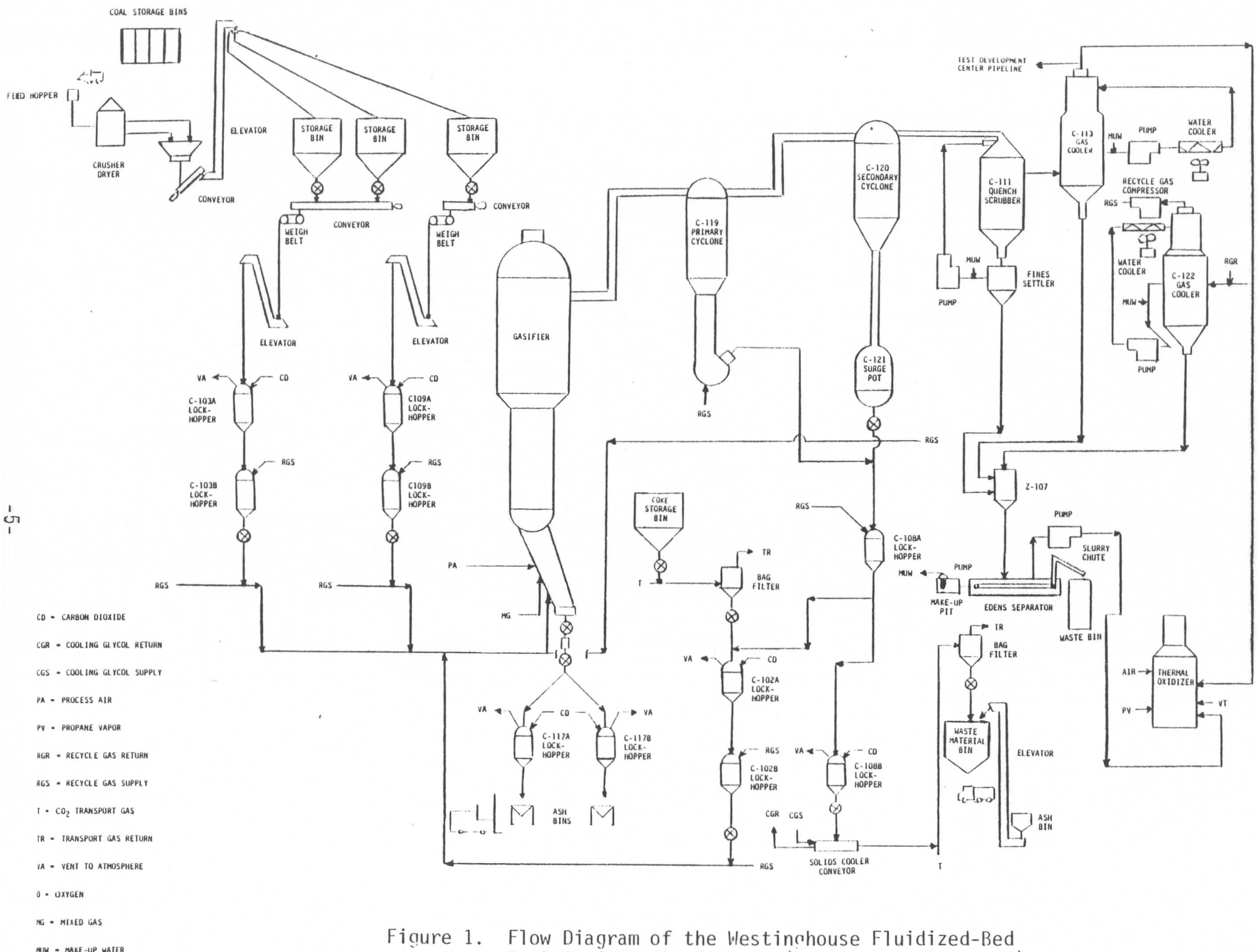

Figure 1. Flow Diagram of the Westinghouse Fluidized-Bed Coal Gasification Process (source: Westinghouse)

A front end loader moves coal from on-site storage bays to a feed hopper. The coal is ground to 1/4 inch by 0, dried to less than 10% moisture, and then conveyed to storage bins.

The coal is pressurized and fed pneumatically to the gasifier. Recycled product gas is used as the conveying gas. Coal is combusted and gasified in a stream of oxygen and steam fed through a central feed tube in the gasifier. The combustion of the coal provides the heat for the gasification reaction. Steam reacts with the coal and char to form hydrogen and carbon monoxide. Some methane is also formed. The ash particles agglomerate, defluidize, and are continuously removed from the gasifier by a rotary feeder to a lock hopper.

The raw product gas containing methane, hydrogen, carbon monoxide, carbon dioxide, hydrogen sulfide, ammonia and entrained char fines, exits the gasifier at approximately 1800 F (982 C). Two refractory-lined cyclones are used in series to remove char particles from the raw gas before it is scrubbed and cooled in a quench scrubber. The scrubber removes most of the remaining particulates. Following the quench scrubber is a gas cooler. Here the gas is cooled further and the remaining particulates removed.

The char fines from the cyclones are transported pneumatically to the feed lock hopper and are reinjected into the gasifier along with fresh coal.

Particulate laden water from the quench scrubber and gas coolers is collected and sent to an Eden separator. Dewatered material is conveyed to a waste bin for disposal. The water from the separator is recycled to the scrubber and coolers. Off-gas from the separator is burned in a thermal oxidizer.

D. Plant Layout

Figure 2 is a plot plan of the PDU facility showing the locations of the process buildings and outside equipment. The gasification system is completely enclosed in the PDU structure. The coal storage area and coal preparation area are also enclosed. All buildings except the coal preparation building

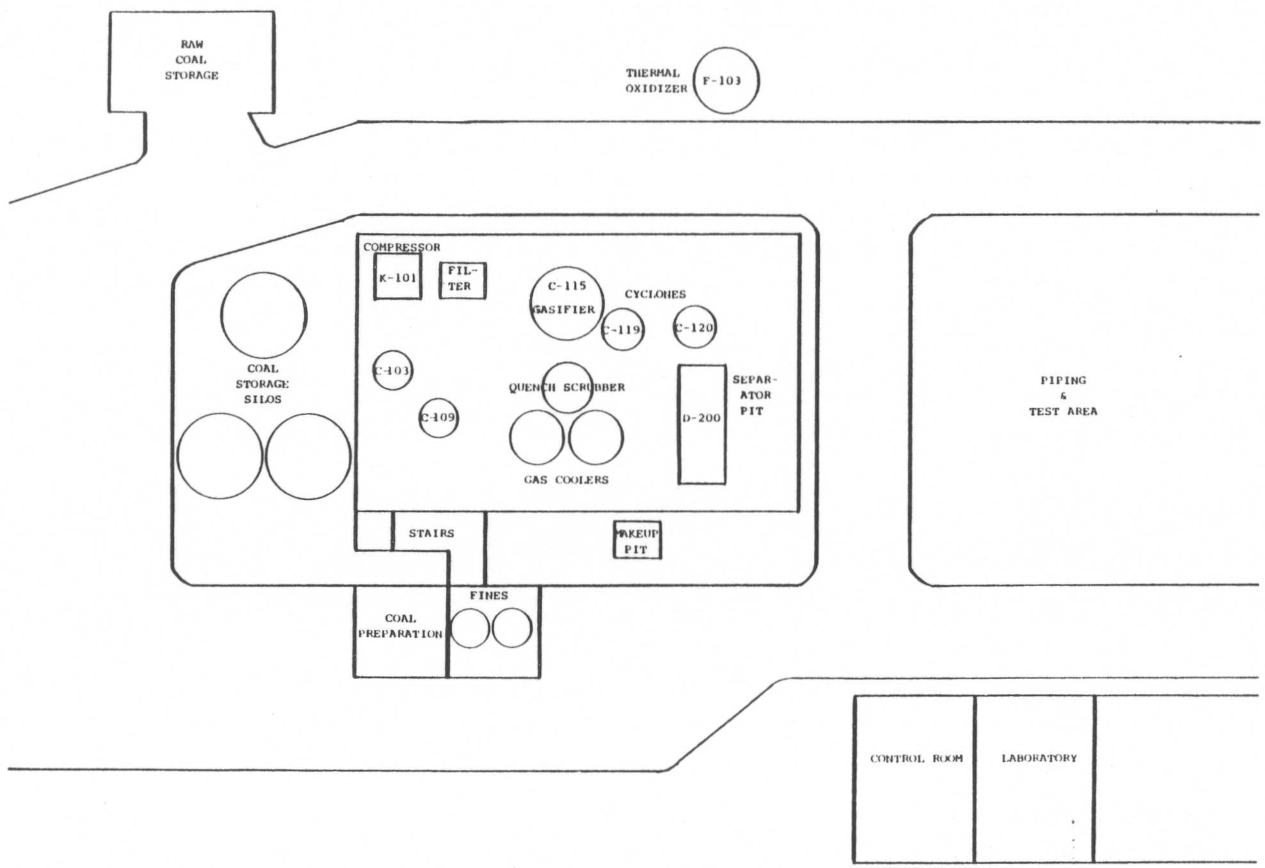

Figure 2. Layout of the Westinghouse Fluidized-Bed Coal Gasification PDU Facility

are at approximately the same elevation (101 feet). The coal preparation building is located slightly uphill of the PDU structure at an elevation of 114 feet. Grade level in the PDU structure is called the "pit" area.

The coal storage area is enclosed in a three sided structure. Four 300-ton bays are housed by the structure. A coal pile located in front of the coal storage structure (not shown) provides additional storage.

The coal preparation building is an enclosed metal sided structure located on the southeast side of the PDU structure. A large door on the north end of the coal preparation building provides access by truck. Propane, carbon dioxide, and oxygen tankage is located outside the PDU structure, as is the thermal oxidizer. The PDU control room is located in an enclosed building north of the PDU structure.

The equipment in the PDU structure includes units which were used in previous tests of the two stage process. An addition to the building houses a second hot gas cyclone. Equipment for future testing will also be located in the addition. The other equipment in the PDU structure is that used for single stage tests. The building is roofed but open on the sides.

E. Potential Hazards

1. Identification of Potential Hazards

Based on the operating parameters of the PDU and on information obtained during its operation, Westinghouse has identifed a number of potential hazards at this facility. The materials and operating conditions that Westinghouse considers to be the major potential hazards are:

- flammable and explosive nature of fine coal dust,
- flammability and explosiveness of product gas,
- high temperature/high pressure operating parameters of the PDU,
- hydrogen sulfide and carbon monoxide, and
- polynuclear aromatics (PNAs) that are found in coal-derived liquid products.

Hydrogen sulfide and CO are labeled as major hazards because of their acute toxicity and high concentrations in the product gas. The concentration of these gases in the product stream is dependent upon the operating conditions and on the type of coal being used; however, concentrations range from 21% to 50% for CO and trace to 2.5% for hydrogen sulfide. With the high operating pressures a process leak could readily lead to high concentrations of these gases in the workplace and the development of an acute health hazard. Although the risk of developing adverse health effects is not known for long-term exposures to PNAs at the levels anticipated for the PDU, the PNAs are included as a major hazard because of the reported carcinogenic properties of certain compounds in this group. Table 1 is a list, by process area, of the potential hazards associated with the operation of the PDU that were identified by Westinghouse and by the Enviro CTA team.

2. Workers at Risk

The workers most likely to be exposed to process constituents are those stationed within the process area or with duties involving contact with process constituents. Generally these workers include:

- field operators with responsibility for in-the-field inspection, monitoring, and adjusting of operating parameters,
- maintenance workers who maintain and repair process equipment, and
- laboratory technicians who prepare and analyze process stream samples.

At the Westinghouse PDU, field operators are responsible for maintenance as well as normal process monitoring duties. As a result, the field operators are the group of workers having the greatest potential for exposure. The field operators are referred to as upper and lower level technicians at the PDU.

Because the maintenance of process equipment has been delegated to the field operators, the primary function of the maintenance department staff is new construction and retrofitting activities. Since these workers do not work

TABLE 1

POTENTIAL HAZARDS BY PROCESS AREA

AREA	POTENTIAL HAZARD
Coal Storage and Preparation	Flammable/Explosive Coal Dust Carbon Dioxide Respirable Coal Dust Noise
Coal and Char Fines Feeding	Flammable/Explosive Recycle Gas Carbon Dioxide High Temperature High Pressure Respirable Coal Dust Carbon Monoxide Hydrogen Sulfide
Gasification	Flammable/Explosive Product Gas High Temperature High Pressure Carbon Monoxide Hydrogen Sulfide Nickel Carbonyl Respirable Ash Dust
Gas Clean-up	Flammable/Explosive Product Gas High Temperature High Pressure Respirable Char Fines Dust Carbon Monoxide Hydrogen Sulfide Nickel Carbonyl Polynuclear Aromatic Hydrocarbons Ammonia
Waste Disposal	Carbon Monoxide Hydrogen Sulfide/Sulfur Dioxide Polynuclear Aromatic Hydrocarbons Nickel Carbonyl Ammonia

on operating equipment and are not present during test runs, their exposure to the major hazards is expected to be minimal. Similarly the laboratory technicians are also expected to be minimally exposed because they deal only with the analysis of coal and char samples. A detailed description of these job categories is given in Appendix A.

II. Engineering Control Technology

A. Introduction

A two part discussion of each process area in the Westinghouse Gasification Process Development Unit is presented. The first part consists of an area process description. The second part is a discussion of the potential hazards associated with that process area, and the engineering controls used to mitigate those hazards. The term engineering control is defined by NIOSH to mean the use of add-on control equipment (e.g., ventilation systems); the modification of existing equipment (e.g., the substitution of mechanical seals for packing, or the use of special metallurgy); or changes in the process design (e.g., recycling a stream that was formerly discharged) to eliminate or reduce an occupational safety or health hazard. Work practices, protective equipment, monitoring programs, and health and safety programs as a means of mitigating occupational safety and health hazards are discussed later in the report.

B. Coal Storage and Preparation

1. Process Description

The coal storage and preparation area covers operations from coal receiving to coal storage ahead of the feed lock hoppers. Coal or lignite is brought to the site by truck and is unloaded into the coal storage bays. Each bay has an approximate capacity of 300 tons. A coal pile outside the storage bays is used for additional storage. Tarpaulins are used to keep the coal pile dry.

From the outside storage or from the storage bays, coal is brought by front-end loader to the coal feed hopper located on the south side of the coal preparation building. Coal from the hopper feeds into a screw conveyor which carries the coal into the coal preparation building for crushing and drying.

A Williams impact mill and dryer system crushes and dries the coal. The system includes a coal storage bin, crusher/dryer, hot air furnace, blowers, baghouse, and classifying screens. The system has a capacity of 10,000 pounds of coal per hour. Coal is crushed to minus 1/4 inch and dried to less than 10% moisture. Oversized coal is recycled. The system is designed to generate less than 10% fines. Hot air from the crusher/dryer is vented to a baghouse, then to the atmosphere.

Properly sized coal from the classifying screen is transfered by screw conveyor to a bucket elevator. The bucket elevator carries the coal to a diverter valve that directs coal to any of three 20-ton storage bins.

Metallurgical coke breeze is stored for use during start-up and shutdown of the gasifier. The size of the coke is similar to that of the coal.

2. Control Technology

The potential hazards associated with the coal storage and preparation area are fires and/or explosions from coal dust, asphyxiation from carbon dioxide, respirable coal dust, and noise.

The following engineering controls are used to mitigate these potential hazards.

- The coal storage bays and the auxiliary coal pile are covered to prevent weathering, to keep moisture out, and to prevent coal dust from becoming airborne.
- The coal preparation building coal receiving hopper is located outside to minimize exposure to coal dust during the loading operation.
- High-sulfur bituminous coals will auto-ignite after 2 to 6 months of exposure to normal weather. Thermometers three feet long, are inserted into the coal piles to monitor temperature.
- A thermocouple is installed in the bottom of the storage bin above the Williams mill to detect fire in the bin. The thermocouple is located in the bottom of the bin because fines, which are more combustible than larger coal particles, accumulate at the bottom.
- The operating temperature of the baghouse (normally 180 F (82 C) is monitored. A high temperature alarm, set at 325 F (163 C) indicates a fire in the baghouse.

- All electrical equipment in the mill area is explosion-proof.

- The crusher/dryer system is interlocked to stop the coal feed when any major component shuts down.

- Emergency stop buttons for the crusher/dryer system are installed at four locations in the facility.

- The gas heater shed exhaust fan is interlocked with entrance doors to provide ventilation prior to entry.

- The crusher/dryer system is equipped with a rupture disk set at 3 psig.

- The concentration of oxygen (O_2) in the Williams mill is monitored with an oxygen analyzer. The oxygen analyzer is set at 12% O_2. This provides a safety factor for the worst case maximum allowable O_2 level of 15% for processing lignite. The plant maintains a level of less than 10% O_2 during operation by using furnace exhaust gas for drying. If the 12% set point is reached or exceeded, water is automatically injected into the furnace. At the same time the firing rate of the furnace is increased in order to vaporize the water as it is injected. The water valve stays open until the diluent steam reduces the O_2 level below 12%. In addition, a carbon dioxide purge system is activated automatically to flood the system with inert gas.

- The tramp metal collector to the Williams mill is sized to trap at least eight hours of tramp metal, which is the maximum continuous operating time for the mill. This eliminates the need to check the collector while the mill is operating, avoiding the potential for exposure to coal dust and hot drying gases.

- The classifiying screen is covered with sheet plastic to minimize dust emissions.

C. Coal Feeding and Char Recycle

1. Process Description

There are two parallel coal feed systems. Because the two systems are similar the following description applies to both trains. Coal from a storage bin is fed by a starwheel feeder to a screw conveyor. The screw conveyor moves coal to a weigh belt conveyor that transfers the coal to a bucket elevator. Coal is dropped from the elevator through a ball valve into a lockhopper. The ball valve is closed and the lockhopper is pressurized with carbon dioxide from atmospheric pressure to approximately 240 psig.

A ball valve in the discharge line of the lockhopper is opened and the coal drops into a second lockhopper. The second ball valve is then closed. Pressure in the second lockhopper is maintained at approximately 230 psig with recycle gas.

On demand from the gasifier bed level controller, a starwheel feeder on the discharge of the second lockhopper feeds coal into a 1-inch Incoloy 825 feed-line. The coal is conveyed pneumatically by recycle product gas into the gasifier. The transport gas is preheated in electric heaters. When additional coal is required in the second lockhopper, the first lockhopper is depressurized, the CO_2 being vented through a baghouse. The upper ball valve is opened and the lockhopper is ready to receive another charge of coal. Approximately 2300 lbs/hr of recycle gas is required for coal and char transport. Coal is transported in the feedline at 35 feet per second (fps) to prevent plugging. Char fines may be transported at rates as low as 15 fps.

The raw product gas stream from the gasifier contains approximately 30% of the feed coal as entrained char fines. Because the fines contain about 45% carbon, the fines are recycled to the gasifier to increase carbon conversion. Approximately 99% of the char ellutriated from the gasifier is recycled. Fines recovery is accomplished in primary and secondary cyclones. The char fines collected by each cyclone are returned to the gasifier.

Char fines removed by the primary cyclone collect in a catch pot at the end of the cyclone downleg. The fines are conveyed pneumatically with recycle gas to a "mini" cyclone where the carrier gas is separated and sent to the recycle gas cooler for cleaning and cooling.

Product gas exiting the primary cyclone is directed to the secondary cyclone where additional char fines are separated from the gas. The gas is sent to the quench scrubber while the fines fall by gravity through four glycol cooled exchangers to a glycol cooled surge pot. The cooling loop is designed to control the amount of cooling. The fines leaving the surge pot are maintained below 450 F to protect the teflon seals in the fines rotary feeder and above 350 F to avoid moisture condensation.

Fines from the secondary cyclone can be combined with the fines from the primary cyclone in alockhopper for recycle to the gasifier or removal from the system. Alternatively they can be fed from the secondary cyclone surge pot into a recycle line with a starwheel feeder for reinjection directly into the gasifier with recycle product gas.

2. Control Technology

The potential hazards associated with the coal feeding and char recycle operations include: fires, explosions, asphyxiation, high temperatures, respirable coal dust, and the toxicants carbon monoxide and hydrogen sulfide.

The following engineering controls are used to mitigate these hazards.

- The lockhopper pressurization valves are ball valves with stellite seats. They have given satisfactory service. However the pressurization and feeding lockhoppers at times fill above the inlet ball valve. If these ball valves are closed on coal or char, scoring and the loss of pressure occur. The recycle gas, used as a transport, can then leak back through the valves and contaminate the workplace. Therefore the level of coal or char in the lockhopper is allowed to drop below the ball valve and then the valve is closed.

- All lockhoppers that cycle between atmospheric pressure and gasifier system pressure are pressurized with CO_2 rather than with recycle product gas. Thus when the lockhopper is depressurized, CO_2 rather than toxic and flammable gases are vented.

- CO_2 pressure is maintained in the pressurizing lockhopper at about 240 psig except when it is receiving a load of coal. The feed lockhopper is pressurized with recycle gas to only 230 psig. Therefore if the valve between the lockhoppers leaks, CO_2 will leak into the feed lockhopper instead of recycle gas leaking into the pressurizing lockhopper where it can escape into the workplace when the lockhopper is depressurized.

- The CO_2 used in pressurizing the lockhoppers is vented through a baghouse. This reduces exposure to coal and char dust.

- CO_2, an inert gas, prevents fires or explosions in the lockhoppers.

- The coal and char pneumatic feedlines had erosion and weld cracking problems with the original material of construction Incoloy 800. The lines are now Incoloy 825, have long radius elbows, and proprietary ceramic-type liners. This has resulted in a much longer service life.

The liners are tested periodically with a sonic wall thickness meter. This allows detection of a corrosion/erosion problem before there is a materials failure resulting in the release of toxic and flammable product gases.

- The valve located on the line from the mini cyclone to the gas cooler has a plasma sprayed coating. This coating has reduced erosive wear on the valve, resulting in less valve maintenance and less exposure of maintenance personnel to toxic process constituents.

- Char fines generate a dust problem when they are dumped from the waste material bin into trucks for disposal. The operator wets the dust after it is in the truck, however, the generation of dust is uncontrolled during the dumping operation.

- The char fines lockhopper is vented through a baghouse to reduce exposure to char dust.

- The secondary fines recovery cyclone was installed to increase carbon conversion by increasing the amount of carbon-laden char returned to the gasifier. It has also reduced the fines loading downstream in the gas cleaning and waste disposal equipment.

D. Gasification

1. Process Description

The Westinghouse gasifier is a pressurized, single-stage, fluidized-bed, agglomerating ash unit. It can be air and/or oxygen blown. The gasifier has demonstrated in test runs its ability to handle a variety of coals. Operation at a higher pressure, 600 psig, results in a greater methane yield.

The feedstock used during start-up and shutdown of the gasifier is minus 6 mesh metallurgical coke breeze. Coke breeze is fed to the gasifier until the temperature and pressure in the gasifier is proper for coal ignition and gasification. Coal feed to the gasifier is then initiated.

Coal and char are conveyed pneumatically with recycle gas into the gasifier. The coal and char are gasified in a stream of oxygen or air and steam. The steam fed with the oxygen or air reacts with coal and recycled char fines in the bed section of the gasifier to form hydrogen and carbon monoxide.

The temperature in the freeboard section of the gasifier is dependent on the type of coal used, but is typically in the 1600 to 1950 F (970 to 1065 C) range. At these temperatures tars and oils are not formed. The raw product gas exiting the gasifier contains CO, H_2, CO_2, CH_4, H_2S, and char fines. Approximately 30% of the coal feed is elutriated in the product gas as char fines. The char fines contain up to 20% carbon. The fines are collected in two cyclones and recycled back to the gasifier to gasify the remaining carbon. The temperature of the fluidized-bed is maintained so that the ash particles agglomerate. The agglomerated ash particles which are larger and denser than the particles of char in the bed, defluidized. The settled particles are continuously removed by a starwheel rotary feeder to the gasifier surge pot. Recycle product gas or steam is used to partially fludized the ash and cool it as it is withdrawn from the gasifier. From the surge pot, ash is fed by a starwheel feeder into a CO_2 pressurized lockhopper. The lockhopper is depressurized and the ash is dumped into ash bins. The ash bins are moved by forklift to a bucket elevator. The ash is dumped into the bucket elevator which transfers the ash into the waste material bin. The ash is removed to landfill by a truck.

2. Control Technology

The potential hazards associated with the gasification area include: fires and explosions resulting from product gas leaks; burns from contact with hot equipment; and adverse health effects from the inhalation of carbon monoxide, hydrogen sulfide, and ash dust.

The engineering controls used to mitigate these hazards are discussed below.

- The gasifier is painted with a gray-blue paint that turns olive green at 400 F (200 C) and brown at 650 F (340 C). The heat sensitive paint warns the operators of a breakdown of the refractory lining of the gasifier. Early detection of a lining failure can prevent a catastrophic failure of the gasifier pressure vessel shell.

- During steady-state operation, the production of hydrocarbons heavier than methane is negligible due to the high operating temperature. Tar and oils would be produced during the heat up and cool down phases of start up and shutdown if the gasifier was fed coal during these periods. To minimize the production of tars and oils during start up and shutdown, coke breeze is fed to the gasifier. This helps prevent plugging of downstream equipment with condensing tars, and the potential exposure of maintenance personnel assigned to clean the equipment.

- The gasifier is pressure tested before each test run for leaks at the body flanges. If a leak develops, then the pressure and temperature are lowered and the flange bolts are retorqued. The seals between the body flanges are flexitallic compacted asbestos gaskets.

- The ash produced by the Westinghouse gasifier agglomerates, therefore there are few problems with gasifier ash dust.

- The ash lockhoppers are pressurized above the operating pressure of the gasifier with CO_2 in order to prevent gasifier gases from entering the lockhoppers while ash is being withdrawn from the gasifier. The ash lockhoppers are vented to the atmosphere away from the work area when they are depressurized. These operating procedures prevent the release of toxic and flammable gasifier gases during the ash removal operation.

E. Product Gas Clean-up

1. Process Description

Approximately 99% of the entrained char fines in the product gas stream exiting the gasifier are removed by the primary and secondary cyclones. The essentially particulate free product gas then enters the quench scrubber at approximately 1100 F (593 C). The gas is cooled to approximately 500 F (260 C) by passing it through a water spray. Additional particulates and some of the acid gases and condensible vapors are removed from the product gas by the water spray. The quench water collects in the bottom of the scrubber vessel. This water drains into the fines settler vessel. The slurry from the settler is sent to the tar water flash drum where flocculating agents are added. This mixture passes to an Edens separator. Clarified water from the fines settler and from the Edens separator make-up pit is recycled to the quench scrubber. The product gas flows from the quench scrubber to the gas cooler for further scrubbing and cooling. The cooler is a column with two packed beds of 2-1/2 inch stainless steel Pall rings. The gas enters the bottom of the cooler and passes up through the packed sections countercurrent to the flow of water. The wash water which is laden with particulates collects in the bottom of the column and is drained to the tar water flash drum.

The temperature of the gas exiting the gas cooler is about 120 F (49 C). The major portion of the gas exiting the cooler is sent to the propane-fired thermal oxidizer. A portion of the gas is used for study at the Test Development Center. The remaining portion of the gas is recycled as a carrier gas for coal and char fines feeding, lockhopper pressurization and gasifier bed fluidization. This portion of the gas requires further cooling and cleaning before being sent to the recycle gas compresser.

2. Control Technology

The hazardous agents associated with the product gas clean-up area are: flammable/explosive product gases, carbon monoxide, hydrogen sulfide, polynuclear aromatic hydrocarbons, ammonia, high temperatures and pressures, and respirable char fines.

The primary source of exposure to carbon monoxide and hydrogen sulfide containing product gas is the recycle gas compressor. The product gas escapes past leaking filter and strainer housing gaskets, during compressor filter and strainer changes, and during gasket replacement. The lower level technicians, are responsible for equipment on the grade level, including changing the compressor filters and strainer. CO concentrations in this area are in the range of 5 ppm to 200 ppm near the compressor during normal operation. During the industrial hygiene survey performed by Enviro, a CO level of 180 ppm was recorded. The strainer and filters are replaced approximately twice per day. It takes an hour to complete the task. This task has been associated with one incident of worker overexposure. This was prior to the required use of a supplied-air system. The lower level technicians have reported CO levels in excess of 1500 ppm while changing the filter and strainer. Enviro, in its survey of this facility, measured a high of 1745 ppm CO and 160 ppm hydrogen sulfide while the filters and strainer were being changed.

When CO levels near the compressor are continuously in the 100-200 ppm range, both the filter and strainer housing gaskets and the filters and strainer are replaced. Worn gaskets are considered to be the major cause of the frequently high CO and H_2S levels in this area. Gaskets are generally replaced once per week. Another potential source of exposure to product gases is equipment inspections during shutdowns. For example, the recycle gas compressor is inspected for wear 8 times per year.

The engineering controls used to lessen the potential for worker exposure to CO, H_2S, and the other hazardous agents in this process area are discussed below.

- The original circulating scrubbing water level controller used in the gas cooler was a "float and tube" type. When the primary and secondary cyclones were not working properly, excessive solids carryover would foul the float-and-tube controller. This caused a loss of scrubbing water in the cooler allowing particulates into the next gas cooler. Thus, an excessive amount of fines reached the compressor strainer and filter necessitating frequent replacment. More frequent replacement results in a greater potential for worker exposure to hazardous concentrations of CO and H_2S. The float-and-tube controller was replaced with a diaphram-type level controller which is not as prone to fouling from the particulates in the scrubbing water. In addition, the "mini" cyclone located between the surge pot and lockhopper does not separate the char fines from the transport gas efficiently, allowing excessive dust carryover into the gas cooler.

- Problems occurring with the recycle gas compressors are caused by moisture and erosion from particulate fines. Both filters and strainers are employed to keep particulates from reaching the recycle gas compressor. The filters are used to supplement the basket-type strainer. At present 10 m Cuno "Micro-Wynd II" fiber element filter cartridges are used. Five m cartridges were used but they plugged too quickly. Two parallel systems enable strainer and filter changes to be performed while the plant is operating. At present, filters are changed about two times per day. Pressure drop across the filter indicates the need to change the filters.

- The original block valves on the recycle gas compressor were carbon steel Stockholm Standard gate valves. These valves were replaced with rubber-lined pinch valves. These valves leaked product gas into the workplace, so they were replaced with one stainless steel, and one carbon steel gate valve.

- Originally, carbon/asbestos packings were used on the pumps that circulated water to the quench scrubber and gas cooling equipment. These packings provided only 400 hours of service before repacking was necessary. Repacking these pumps was a potential means of exposure to tars containing PNA and particulates in the scrubbing water. Westinghouse has since gone to a mechanical seal with water flush.

- Corrosion/erosion failures of pipe sections from the surge pot, fines settler and gas cooler resulted in releases of product gas into the workplace. As each carbon steel line failed, it was replaced with either 304 or 316 type stainless steel.

F. Waste Disposal

1. Process Description

Waste disposal operations include tar-water incineration, ash and char fines disposal, and sludge separation and disposal.

The plant water system is a closed system. Wash water from the quench scrubber and the gas coolers is sent to the tar-water flash drum where floccutating agents are added. This mixture passes to a covered Edens separator where the sludge settles to the bottom. A scraper moves the sludge to a waste bin. Water overflow from the Edens separator is directed to a make-up pit and is then pumped back to the quench and cooler vessels. Off-gases from the separator include H_2S, NH_3, and CO. These gases are vented to the thermal oxidizer. Tar-water skimmed from the top of the Edens separator is pumped to the thermal oxidizer.

Ash from the gasifier is transferred into the waste material bin. Char recycle fines from the solids cooler conveyor are also sent to the waste material bin. The accumulated waste is disposed of in a landfill by a contractor.

2. Control Technology

The hazardous agents associated with the waste disposal area are: phenols, polynuclear aromatic hydrocarbons, CO, H_2S and NH_3. The engineering controls used to lessen the potential for worker exposure to these agents are discussed below.

- The original wash water recycle system employed an open top settling vessel to separate the solids from the scrubbing water. An Edens separator is now used. The separator has an automatic sludge removal system. A cover has been added to contain emissions of H_2S, CO, and NH_3-containing off-gases. Rather than venting these off-gases to the atmosphere, an exhaust ventilation fan sends them to the thermal oxidizer for incineration. Tar-water from the separator is also sent to the thermal oxidizer.

- After dumping the char fines from the waste material bin into a truck, workers spray the fines with water to suppress dust.

- The second through the sixth levels of the PDU structure are the responsibility of the upper level technicians. These technicians have reported that concentrations of CO are generally in the range of 1 ppm to 10 ppm, with occasional excursions up to 500 ppm. The source of the CO has not been established. The major worker complaint is not related to the CO levels, but to a disagreeable odor associted with hydrogen sulfide. As of the date of the site visit this problem had not been corrected.

- Char particles are removed from the raw product gas by the hot gas cyclone, the quench scrubber, and the two gas coolers. The char collected in the cyclone is removed from the system via a lockhopper and a char cooler conveyor. The particulate laden wash water from the scrubber and the coolers goes to the Edens separator where the solids settle and are removed for disposal. Dermal contact with the char may occur during maintenance and cleaning of the Edens separator and the char cooler conveyor.

III. WORK PRACTICES

The work practice guidelines developed under the health and safety program are designed to supplement engineering controls by providing additional protection in situations where the potential for exposure to hazardous agents exists. These situations generally relate to conditions in which the closed-system mode of operation is broken and these include:

- entry points for feed materials
- discharge points for products, by-products, and waste streams,
- maintenance of on-line equipment, including changing the recycle gas compressor filters and strainers, and
- process stream sampling.

The work practice guidelines were modeled whenever possible after the appropriate OSHA requirements, such as the elements of a respirator program and NIOSH recommended procedures for entering confined spaces. Workers are informed of these guidelines through on-the-job training, safety meetings held every 4 to 6 weeks, and individual training.

A. Administrative Controls

1. Inspections and Surveys

Inspections and surveys are held on a periodic basis to insure that plant guidelines are being followed. These internal checks are conducted by the shift supervisors and an inspection team. A report documenting any unsafe practices, incidents of workers not following recommended guidelines, and the corrective measures to be taken are distributed to the appropriate in-plant personnel. Incidents of overexposure are discussed with the sampled worker.

2. Limited Access to PDU Structure

Flashing colored lights are located at the entrance to the PDU. A green light signifies that the plant is not in operation and no hazardous activities are being conducted on the structure. A yellow light indicates that activities are being conducted which could lead to injury if caution is not taken while in the PDU. Conditions warranting a yellow caution signal include welding, the use of cranes or hoists, and temporary removal of safety railing. A red light indicates that the PDU is in operation or hazardous activities are in progress. The safety status of the PDU is determined by the shift supervisor.

Process operators have unlimited access to the structure under the three operating conditions provided they are properly equipped with hard hat, safety glasses, and coveralls. Coveralls are required only under danger conditions. Other PDU personnel require shift supervisor permission prior to entering the PDU under "caution" and "danger" conditions.

Outside personnel associated with the PDU project require the shift supervisor's permission to enter the PDU under "clear" conditions, and must be escorted in order to enter under other operating conditions. Visitors not associated with the PDU project must be escorted under "clear" and "caution" conditions and are not permitted in the structure under "danger" situations. All outside personnel are required to sign-in at the control room, don the proper protective equipment and clothing, and obtain the necessary permission prior to entering the facility.

In order to contain the contaminants within the process area, any person wearing work coveralls is restricted to the PDU structure, support facilities, control room, laboratory, and maintenance facility. Coveralls must be removed prior to leaving these areas.

3. Job Performance Protocols

A few activities conducted by the field technicians are considered high risk duties because of the possibility that the worker may encounter process contaminants at levels high enough to produce adverse health effects. Many of these activities involve vessel entry, especially the gasifier. In these situations protocols following NIOSH recommendations are used to maximize worker safety. Elements of this program include:

- employment of the buddy system,
- use of supplied-air respirators with full facemask,
- lockout of valves and electrical systems, and
- pre-entry check of oxygen, carbon monoxide, and hydrogen sulfide levels.

An activity that is not related to vessel entry but is considered high risk involves changing the recycle gas compressor filters and strainer. Changing the filters and strainer is associated with CO levels in excess of 1500 ppm and hydrogen sulfide levels up to 160 ppm. The buddy system is employed in this activity to provide assistance in the event of an emergency. Each person is equipped with a supplied-air respirator to provide protection against the high CO and hydrogen sulfide concentrations.

As an added safeguard, one of the two workers carries a portable CO meter to provide a continuous readout of ambient concentrations to keep the workers informed of prevailing levels. The meter is also equipped with an audible alarm set at 50 ppm to serve as a secondary warning system for hazardous levels. However, the major concern in this activity is the development of an acute hazard situation involving CO levels exceeding 200 ppm, the NIOSH recommended ceiling for this gas. The Enviro CTA team observed that when set at 50 ppm, the CO alarm is on continuously and becomes a source of irritation rather than a warning system. The CO meter may be a more effective warning device if the alarm trigger level is set at a higher CO concentration.

Because the PDU operates at elevated pressure, the compressor filters or strainers must be isolated from the system with block valves and the pressure reduced to atmospheric with bleed valves prior to replacement. A pressure gauge is used to check the pressure at the filters and strainers before opening the system. This is standard procedure for breaking into any on-stream line which is operating at elevated pressure.

B. Housekeeping

Housekeeping is stressed at the PDU to keep contamination of equipment and tools at a minimum. The contaminant of concern is PNAs. A mixture of an industrial detergent and water is used to clean the facility during plant downtime. Wastewater is collected and treated in a wastewater treatment pond prior to discharge.

IV. PROTECTIVE CLOTHING AND EQUIPMENT

Plant safety guidelines include the use of protective clothing and equipment to supplement controls provided by existing engineering measures. The basic policy requires that workers entering the PDU structure wear flame-retardant coveralls, hard hat, and safety glasses. The boundaries of the structure are outlined in yellow. Visitors may substitute flame-retardant laboratory coats for the coveralls.

Workers with assigned responsibilities in the PDU are provided with seven sets of flame-retardant cotton coveralls to insure that a clean set is available each work day. The seven sets include spares for emergencies in which gross contamination has occurred. A two-locker system is also provided to keep clean coveralls and street clothing separated from personal work equipment and used coveralls. Coveralls ready for cleaning are kept in special containers for pick-up by an outside laundry firm.

Other protective equipment available to the PDU workers includes:

- cotton gloves
- full-face shields
- hearing muffs
- respirators
- portable carbon monoxide meters

Use of this equipment is dependent upon the activities being performed.

In addition to the basic clothing requirements in activities involving the handling of coal-derived liquids and solids, face shields and surgeon-rubber gloves beneath cotton gloves are used to minimize skin contact with these process residues. These activities involve work on the separator pit and the char cooling conveyor. Rubber gloves may provide more skin protection than cotton gloves in these activities.

Disposable hoods are used with dust masks in any activity involving heavy dust areas. The hood is tucked under the collar of the coveralls; wrists and ankles of the coveralls are taped prior to wearing gloves and boots to minimize exposed skin surface.

Ear muffs are required for work within the coal shed where noise levels exceeding 90 dBA could potentially occur during operation of the crusher/dryer. Disposable single-use dust respirators are also used in the Coal Storage and Preparation area during operations such as filling the coal feed hopper with the front-end loader and collecting coal samples at the belt conveyor. Loading the feed hopper is conducted as needed. The duration of this activitiy is dependent upon plant needs for the test run. A coal dust sample is collected once each shift. The time required to take the sample is 15 minutes.

Other respiratory protection available to the workers include half-mask respirators with acid-gas cartridges, self-contained breathing apparatus (SCBA), and supplied-air respirators. These respirators are individually assigned to workers in the PDU structure. The assignments are made following quantitative fit testing that is repeated every three years. All workers undergo yearly training in the proper use of these respirators. The supervisors are responsible for insuring that respirators are cleaned and maintained.

The half-mask respirators provide protection against low concentrations of hydrogen sulfide. However, these masks are rarely used since hazardous levels of hydrogen sulfide generally occur simultaneously with hazardous levels of carbon monoxide. Under these conditions supplied-air respirators with full facemask are preferred and generally used. The SCBAs are used strictly for emergency situations.

Situations involving both high carbon monoxide and hydrogen sulfide levels include vessel entry, opening process lines, and changing the filters and strainers on the recycle gas compressor. Of these activities, only changing the filters and strainers are conducted on a periodic basis; filters are changed twice per day and strainers once per week minimum.

V. MONITORING PROGRAM

A. Westinghouse Surveys

The PDU utilizes a simple monitoring program to keep track of selected gases in the structure. Direct-reading instruments, including an MSA Model "D" CO monitor and a SENTEX oxygen-combustible gas detector, are used in this program. Readings are taken once per shift for combustible gas, carbon monoxide, and oxygen. Area locations are designated on ground level as well as levels 2,5,6, and 8. Because of high levels encountered in earlier tests of the PDU, detector tube measurements were taken once per shift for hydrogen sulfide and ammonia. Detector tubes are now used in non-routine situations only.

All results are documented in a log; actual measurements are recorded for levels exceeding 30 ppm CO, exceeding 10% of the lower explosive limit (LEL) for combustible gas, and all results for oxygen. If measured levels exceed 50 ppm for CO, and 20% of the LEL for combustible gas, or are less than 19.5% for oxygen, emergency action is required. This involves evacuating the affected area, seeking the cause of the unusual readings, and taking the appropriate corrective measures to reduce concentrations to acceptable levels. CO levels exceeding 500 ppm were recorded at these sites while changing the recycle gas compressor filters.

Concentrations of 1000 ppm were recorded for hydrogen sulfide and 10,000 ppm for ammonia at the separator pit during a test run in 1978. Covering the separator and makeup water pits, and venting the pits to the thermal oxidizer have effectively reduced the levels of these gases. Detector tube measurements taken at the separator and at the other three sites in the PDU by Enviro during May 1981 showed concentrations of less than 1 ppm.

High levels of hydrogen sulfide were recorded while changing the recycle gas compressor filters/strainer. Enviro recorded an H_2S concentration of 160 ppm with the filter housing opened.

A sample of the quench scrubber and gas cooler scrubbing water was taken at the tar water flash drum during a 1975 test run of the PDU and qualitatively analyzed. Results given in Table 2 show the presence of aromatic compounds, including PNAs. Benzene solubles were reported to be 29 ppm by weight.

Additional bulk samples were collected in 1976 in an expanded program that included air sampling. Liquid samples were taken at the tar water flash drum, the quench scrubber, and the gas coolers. Air samples were collected at the tar water flash drum and on the 5th level at the gas chromatograph apparatus. Samples were analyzed for benzo(a)pyrene (BaP) using gas chromatography on the liquid samples and a mass spectrometer on the air samples. Analytical interferences do exist for this procedure, especially by other substances of the same molecular weight. Results given in Table 3 indicate the presence of BaP in the scrubbing water at potentially high levels. Since this water is recycled, the possibility exists that significant concentrations of BaP may accumulate in the srubbing water.

B. Other Surveys

In 1978 and 1979 an outside consultant conducted three personal monitoring surveys to assess the exposure of workers to various contaminants, including benzene, phenolics, arsenic, lead, total and respirable dust, crystalline silica, and PNAs. Four technicians were sampled in each of these surveys and results are given in Tables 4 to 6. An area monitoring survey was also conducted, the results of which are presented in Table 7. The conclusion of the survey team was that for the contaminants measured, the level of exposure of these technicians was generally low relative to current federal standards. However, levels exceeding current standards were measured for some of the technicians sampled. Contaminants which exceeded the standards included total dust and benzene-solubles. These high levels could not be accounted for by the technicians observed activities. Levels of total dust and benzene-solubles were re-measured using high volume area sampling techniques. The results indicated data well below allowable levels of exposure.

TABLE 2

Compounds Present in Tar Water Flash Drum Bulk Sample,
1975 Westinghouse Survey

Aromatic Amines	Polynuclear Aromatics	Phenolics	Miscellaneous
Aniline	Indene	Phenol	Pyridine
Toluidine	Naphthalene	o-Ethyl Phenol	Methyl Pyridine
	Quinoline	Dimethyl Phenol	Dimethyl Pyridine
	Isoquinoline	Phenol Pyrolan	Benzonitrile
	Indole	o-Methyl Phenol	Nitrile
	Methyl Indole	m-Methyl Phenol	
	Carbazole	o-Cresol	
		m-Cresol	
		p-Cresol	

TABLE 3

Benzo(a)pyrene Present in Air and Scrubbing Water Samples,
1976 Westinghouse Survey

Location	Type Sample	Sample Volume(m^3)	BaP(%wt)	BaP(ug)
2107	Bulk	-	0.2	-
	Air	1.13	-	2
	Air	1.13	-	2
	Air	1.13	-	2
C-111	Bulk	-	0.3	-
C-113	Bulk	-	0.005	-
C-122	Bulk	-	0.15	-
5th Level	Air	4	-	2
	Air	0.6	-	2
	Air	0.68	-	2

TABLE 4

Survey 1: Personal Monitoring Data
Westinghouse Survey

Workshift / Process Technician	Benzene (ppm)	Total Dust (mg/m^3)	Benzene-Solubles (mg/m^3)
DAY		May 24, 1978	
PT - 1	0.09	2.8	0.2
PT - 2	0.1	2.9	0.03
PT - 3	0.2	3.1	void
PT - 4	0.3	1.2	0.06
		May 25, 1978	
PT - 1	0.04	1.2	<0.06
PT - 2	0.1	4.4	0.2
PT - 3	0.2	136.0	0.3
PT - 4	0.1	0.5	0.8
AFTERNOON		May 24, 1978	
PT - 5	0.1	4.0	0.2
PT - 6	0.2	0.3	<0.06
PT - 7	0.07	1.0	0.2
PT - 8	0.2	0.3	0.06
		May 25, 1978	
PT - 5	0.1	2.7	0.09
PT - 6	0.3	0.5	0.2
PT - 7	0.1	0.2	<0.06
PT - 8	0.5	0.5	<0.06
MIDNIGHT		May 24, 1978	
PT - 9	0.2	4.4	0.1
PT - 10	0.2	14.0	0.2
PT - 11	void	0.3	<0.07
PT - 12	void	1.5	0.2

TABLE 5

Survey 2: Personal Monitoring Data
Westinghouse Survey

Workshift / Process Technician	Benzene (ppm)	Total Dust (mg/m^3)	Benzene-Solubles (mg/m^3)	As (mg/m^3)	R.D. (mg/m^3)	SiO_2 (%)	OSHA Limit (mg/m^3)
DAY				October 25, 1978			
PT - 1	0.02	--	--	<0.0005	0.4	7.9	1.0
PT - 2	0.05	--	--	<0.0005	0.5	2.1	2.4
PT - 3	0.03	97.0	0.10<PPAH<0.14	<0.0005	--	--	--
PT - 4	0.03	1.1	0.13	<0.0005	--	--	--
				October 26, 1978			
PT - 1	0.04	0.72<TD<0.95	<0.14	<0.001	--	--	--
PT - 2	0.1	1.9	0.04	<0.0005	--	--	--
PT - 3	0.1	--	--	<0.0006	0.2	4.5	2.4
PT - 4	<0.02	--	--	<0.0005	0.1<RD<0.3	5<%<20	0.4<L<1.4
AFTERNOON				October 24, 1978			
PT - 5	0.06	--	--	<0.0004	0.5	8.3	1.0
PT - 6	0.06	--	--	<0.0004	0.2	21.4	0.4
PT - 7	<0.02	0.4	0.05	<0.0003	--	--	--
PT - 8	0.03	0.8	0.32	<0.0004	--	--	--
				October 25, 1978			
PT - 5	0.04	0.6	0.07	<0.0005	--	--	--
PT - 6	0.02	0.4	0.56	<0.0007	--	--	--
PT - 7	0.05	--	--	<0.0004	0.3	3.8	2.4
PT - 8	0.03	--	--	<0.0004	<0.1	>20.0	<0.5
MIDNIGHT				October 25, 1978			
PT - 9	0.04	--	--	<0.0006	0.4	3.6	2.4
PT - 10	<0.05	--	--	<0.001	0.5	20.0	0.5
PT - 11	<0.02	0.4	0.07	<0.0006	--	--	--
PT - 12	0.03	0.8	<0.06	<0.0005	--	--	--
				October 26, 1978			
PT - 9	0.06	4.0	0.04	<0.0007	--	--	--
PT - 10	0.02	0.09<TD<0.2	<0.03	<0.0005	--	--	--
PT - 11	0.02	--	--	<0.0005	0.3	<3.7	2.4
PT - 12	0.06	--	--	<0.0005	0.4	<3.6	2.4

TABLE 6

Survey 3: Personal Monitoring Data
Westinghouse Survey

Work Shift / Process Technician	Naph-thalene (ppm)	Total Dust (mg/m^3)	Lead (mg/m^3)	Respirable Dust (mg/m^3)	Crystalline Silica (%)	OSHA Limit (mg/m^3)
DAY				July 31, 1979		
PT - 1	<0.03	<0.4	<0.003	<0.1	--	--
PT - 2	<0.03	770.0	0.04	0.1	20.0	0.45
PT - 3	<0.01	6.8	<0.002	0.1	<10.0	>0.83
PT - 4	<0.04	0.5	<0.003	<0.1	--	--
				August 1, 1979		
PT - 1	<0.03	0.4	<0.002	<0.1	--	--
PT - 2	<0.02	0.9	<0.003	0.2	< 5.0	>1.4
PT - 3	<0.03	0.3	<0.003	<0.1	<10.0	>0.84
PT - 4	<0.04	0.3	<0.002	<0.1	--	--
AFTERNOON				July 31, 1979		
PT - 5	<0.03	6.1	<0.003	0.4	10.0	0.83
PT - 6	<0.03	0.8	<0.003	0.1	<10.0	>0.83
PT - 7	Void	0.8	<0.003	0.3	5.0	1.4
PT - 8	<0.03	1.3	<0.002	<0.1	--	--
				August 1, 1978		
PT - 5	<0.03	1.6	<0.002	1.3	< 1.0	>3.3
PT - 6	<0.03	3.9	<0.003	0.1	20.0	0.45
PT - 7	<0.03	1.0	<0.003	0.3	< 5.0	>1.4
PT - 8	<0.03	1.2	<0.003	<0.1	--	--
MIDNIGHT				July 31, 1979		
PT - 9	<0.01	0.6	<0.003	0.1	--	--
PT - 10	<0.01	0.5	<0.002	0.1	--	--
PT - 11	<0.01	0.6	<0.002	0.3	< 5.0	>1.4
PT - 12	<0.01	0.9	<0.003	0.3	< 5.0	>1.4
				August 1, 1979		
PT - 9	<0.01	11.0	<0.003	1.2	4.0	1.7
PT - 10	<0.01	5.9	<0.003	1.1	5.0	1.4
PT - 11	<0.01	<0.1	<0.003	<0.2	--	--
PT - 12	<0.01	35.5	0.006	1.5	4.0	1.7

TABLE 7

High-Volume Area Monitoring Data
Westinghouse Survey

Work Shift	Date 1979	SITES									
		1		2		3		4		5	
		TSP mg/m^3	BENZENE SOLUBLES mg/m^3	TSP mg/m^3	BENZENE SOLUBLES mg/m^3	TSP mg/m^3	BENZENE SOLUBLES mg/m^3	TSP mg/m^3	BENZENE SOLUBLES mg/m^3	TSP mg/m^3	BENZENE SOLUBLES mg/m^3
Midnight	7/30-7/31	0.071	0.002	0.070	0.005	0.075	0.004	0.28	0.004	0.21	0.003
	7/31-8/1	0.060	0.001	0.045	0.002	0.057	0.003	0.061	0.001	0.12	0.004
Day	7/31	0.11	0.003	0.12	0.004	0.24	0.005	0.67	0.008	0.40	0.002
	8/1	0.088	0.002	0.058	0.002	0.089	0.003	0.13	0.002	0.17	0.004
Afternoon	7/31	0.092	0.002	0.076	0.002	0.11	0.002	0.14	0.003	0.19	0.002
	8/1	0.17	0.003	0.070	0.001	0.088	0.003	0.088	0.002	0.10	0.008
Geometric Mean		0.093	0.002	0.070	0.002	0.096	0.003	0.16	0.003	0.18	0.003

Site 1 - North side of coal feed shed (ground level)

Site 2 - Northwest of tower structure, north of oxider (ground level)

Site 3 - West of tower structure (ground Level)

Site 4 - East of tower structure, between tower and coal feed shed (ground level)

Site 5 - North of water pit separator (ground level)

VI. HEALTH AND SAFETY PROGRAMS

A. Employee Education and Training

Worker training consists of on-the-job training and supplemental classroom sessions. On-the-job training includes working in the field with an experienced PDU employee. This training period is designed to safely familiarize the new worker with his assigned duties, the safe way of completing the tasks, and hazards within the structure.

The classroom sessions are divided into three courses and are taken in conjunction with the on-the-job training sessions. The Red Cross multi-media first-aid training course is given annually to one-third of the PDU workforce. The other two courses are scheduled as needed for new workers. One course covers the plant safety rules; safety equipment; emergency plan; the use of respirators; material, machinery, and equipment hazards; and fire protection including the use of fire extingushers. The last course is concerned with the causes of accidents and their prevention; job safety analysis; motivating workers to be safety concious; and the unsafe worker.

Individualized training is given to workers in operations requiring specialized skills. These operations include vehicle drivers, crane operators, and welders. Site licenses are awarded to those workers who successfully complete the training. Volunteers for the fire brigade are given monetary consideration to encourage them to attend local fire fighting schools.

B. Medical Program

The medical examination given a Westinghouse employee is dependent upon the worker's assignments. Four general groupings have been developed. They are:

- crane/vehicle operators,
- handlers of toxic materials, and radiation workers not assigned to the PDU,

- respirator users not assigned to the PDU and members of the fire brigade, and
- operators assigned to the PDU who may be exposed to toxic materials anywhere on site.

PDU workers are placed in a separate group as a precautionary measure because Westinghouse recognizes that unique problems may develop among workers in this new technology. The primary differences between the medical requirements of this group and the other three groups are the frequency of testing and the inclusion of skin examinations. For PDU workers, chest X-rays, blood work, urine analysis, pulmonary function tests, and a skin examination are given annually. An EKG, blood glucose, visual acuity, and audiometric examinations are provided every two years.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

- The major hazards of concern at the Westinghouse PDU are carbon monoxide, hydrogen sulfide, and PNAs. Carbon monoxide and hydrogen sulfide present an acute hazard because of their high concentrations in the process streams and the high operating pressure of the system. The PNAs are a major hazard because they are suspected carcinogens.

- The upper level and lower level technicians have the greatest potential for exposure to these hazards because their duties include in-the-field monitoring of the PDU, the maintenance of on-line equipment, and equipment cleaning and repair work during the shutdowns. Other workers are only minimally exposed to these hazards.

- Exposure to CO and hydrogen sulfide are most likely to occur on the 5th and 6th level and at grade level, above and adjacent to the recycle compressor. Concentrations of CO greater than 50 ppm are limited to the area immediately adjacent to the recycle gas compresor shaft seals and to the filter bank (during replacement). Concentrations of CO in these areas exceed 200 ppm, the NIOSH ceiling level for permissible exposure.

- Changing the recycle gas compressor filters and strainer is a major potential health hazard. During these activities CO levels have been found to exceed 1500 ppm, the level immediately dangerous to life and health.

- Skin contact with PNAs is most likely to occur during activities involving the wastewater treatment system that serves the quench scrubber, the gas coolers, and the char cooling conveyor. Skin contact may occur as a result of cleaning the separator pit, or entering process vessels.

B. Recommendations

- Rubber gloves should be used in place of cotton gloves for activities necessitating the handling of equipment, tools, or process materials contaminated with coal-derived liquids.

- While the compressor filter and strainer are being changed, people not equipped with respirator protection should be kept away from the vicinity of the filter.

- All personnel whose activities take them to the grade level of the PDU should be required to carry a portable CO meter with an audible alarm.

- Although the buddy system and the use of the supplied-air respirators have made changing the filters and strainer of the recycle gas compressor safer, an incident of worker passing out was reported. This incident was attributed to CO levels in excess of 1500 ppm and to the failure of the workers to adhere to the guidelines for safely performing this activity, especially with regard to wearing respirators. Stricter enforcement of these guidelines is necessary to prevent recurrences of this incident.

- The workers carry a CO meter with an audible alarm set at 50 ppm when changing the recycle gas compressor filters and strainer. When set at 50 ppm the alarm is on continuously and becomes a source of irritation. The CO meter may be a more effective warning device if the alarm is set for a higher concentration.

APPENDIX A
WESTINGHOUSE PROCESS DEVELOPMENT UNIT WORKFORCE

Workers who may be exposed to process constituents belong to one of three groups. These groups are: Operations, Laboratory, and Maintenance. Operations and Laboratory personnel work an 8-hour shift schedule using three crews. Some maintenance, specifically pipe insulating, is performed by outside contractors who work days and only during down-time.

Each operating shift is headed by a shift supervisor. Control room activities are handled by two operators; field activities are conducted by seven technicians. These seven technicians are: one utility man, two upper level technicians, two lower level technicians, and two instrument men. There are also positions for a sample coordinator, safety observer, and oxygen loop technician; positions generally filled by the upper and lower level technicians. The upper and lower level technicians are the workers with the greatest potential for exposure to process constituents. Two laboratory technicians are assigned to each shift to analyze process samples collected by the technicians in the Operations group. There are 14 maintenance personnel on the day shift including a supervisor, two electricians, two welders, three mechanics, two machine operators, and four store room/administrative personnel.

SHIFT SUPERVISOR

The shift supervisor is responsible for the overall performance of the PDU, and works closely with the Director of Operations and other management personnel to ensure that all test objectives are met. He spends his time in the control room and office area, and normally does not enter the PDU.

CONTROL ROOM OPERATORS

The board operators are responsible for the day-to-day operation of the PDU. They spend all of their time in the control room monitoring the process and ensuring that the selected test run set-point conditions are being maintained. Exposure to process constituents is considered to be negligible because the control room is outside the confines of the PDU structure.

UTILITY OPERATOR

The main responsibility of the utility operator is monitoring the support facilities including the PDU compressors, boiler, thermal oxidizer, carbon dioxide and oxygen storage tanks, propane tanks, liquid waste system, and glycol system. These facilities are located outside the confines of the PDU structure and except for the liquid waste system and glycol system, are not considered to be sources of exposure to the hazards of concern.

Exposure may occur during monitoring of the liquid waste and glycol systems. The liquid waste system includes the phenolic water transport system.. The utility operator is responsible for the pumps serving this system; these pumps are located at ground level, adjacent to and downwind of the process equipment. The glycol system used in the solids cooling conveyor has check points on the 5th and 6th level upwind of the process equipment.

The utility operator's duties in the liquid waste and glycol systems involve monitoring the two systems at designated check points and adjusting the systems as necessary to maintain set-point conditions. These tasks do not involve the maintenance of any on-line process equipment and take at a maximum, an hour to complete. Exposure to the measured process constituents is expected to be low. Area sampling in these areas reflect the maximum exposure for the utility operator.

The utility operator is also in charge of the coal feed system from the feed hopper to the storage bins. Duties in this area can potentially lead to coal dust exposure especially while loading the feed hopper and during collection of coal samples. Single-use dust respirators are used in these activities.

One coal sample is taken once per shift at each of the two bucket elevators transporting coal to the lockhoppers on the 8th level. Boiler feed water is supplied once every two days. Recycle gas bomb samples are taken as requested.

UPPER LEVEL TECHNICIAN

The upper level technicians are responsible for process equipment located on the second and higher levels of the PDU structure. Equipment includes:

- coal lockhopper system and feed lines,
- fines lockhopper system and feed line,
- Aerodyne system controlling the carbon dioxide blanket in the lockhoppers,
- solids cooler conveyor,
- bag filters,
- gas cyclone,
- gasifier, and
- quench scrubber and gas coolers.

When the plant is on-stream, responsibilities involve monitoring these systems for operational parameters such as temperature and pressure at selected check sites. Adjustments are made as necessary to maintain these operational parameters within the prescribed set-point conditions. About 75% of the check sites are located on the 5th and 6th levels which represent the major areas of technician activity.

The upper level technicians are also responsible for the collection of process samples. These samples include:

- char in the gasifier bed once every hour at ground level sample port,
- recycle fines once every four hours at 8th level,
- isokinetic sampling at the gas cyclones for fines once per shift at 6th level,
- product gas sample bombs as required at 5th level, and
- isokinetic sampling at the gasifier once per shift.

Sampling activities and process monitoring account for 5 to 6 hours of each of the two technicians' time. Most of the remaining time is spent in the control room. Plant down times are spent with the upper level technicians on general clean-up, inspection, and repair of plant equipment; the upper-level technicians are most likely to be exposed to process constituents during plant down-time when they are engaged in these activities. Industrial detergents and water are used for cleanup.

Inspection and repair involve disassembling process equipment, checking for mechanical defects, and performing necessary repairs. All equipment is inspected with emphasis on equipment exhibiting problems during the prior run. Equipment undergoing thorough inspection during each down-time include the gasifier and coal feed lines, the latter for erosion. Other equipment that is frequently checked include the thermal oxidizer and separtor pit system, the gas coolers, and the baghouse. Vessel entry procedures for inspecting the oxidizer, gas coolers, baghouse, and gasifier follow NIOSH recommendations.

The upper level technicians work closely with the lower level technicians during down-time to accomplish these tasks. Job classification distinctions are not recognized during down-time activities.

LOWER LEVEL TECHNICIANS

While the plant is on stream, the lower level technicians spend 5 to 6 hours at the grade level of the PDU monitoring process equipment and collecting process samples. Process equipment for which the technicians are responsible include:

- product gas cooling system,
- Edens separator for removal of foreign material from scrubbing water,
- recycle gas compressor and subsystem including strainer and filter,
- carbon dioxide purge system,
- Aerodyne system for carbon dioxide conveying and pressurizing gas,
- coal conveying system up to lockhoppers, and
- ash collection system.

These systems are monitored for operating parameters such as temperature and pressure and adjusted as necessary to maintain prescribed set-point conditions.

Samples taken include:

- ash from the ash lockhoppers every hour,
- water samples from the quench scrubber and gas coolers once per shift,
- recycle gas bomb sample as requested.

The technicians also collect direct-reading, grab samples once per shift using Gastel samplers and detector tubes. Readings are taken at the thermal oxidizer, recycle gas compressor filter, at the west end of the Edens separator pit, and at the north-east corner, grade level of the PDU. Gases being measured are hydrogen sulfide, carbon monoxide, and ammonia.

INSTRUMENT TECHNICIANS

The instrument technicians maintain and calibrate in-line continuous monitoring equipment used for measuring process operating parameters such as temperature, pressure, and flow rates, and for determining product component gas concentrations. Component gas analyzers include gas chromatographs, calorimeters, and infrared analyzers. Except for sensor probes, most of the monitoring equipment is located in the control room, the center of the technician's activities. Technician exposure to process constituents is therefore expected to be minimal.

LABORATORY TECHNICIANS

Laboratory personnel spend all of their time in the laboratory analyzing samples collected by field personnel. Samples handled include ash, char, and product gas cooling water. These samples and the type of analyses being performed are listed in Table A-1. Gas bomb samples collected by the upper and lower level technicians are analyzed by an outside laboratory for simple organics. Laboratory workers are expected to experience minimal exposure to process materials.

MAINTENANCE

The maintenance department has nine workers in the field, each belonging to a specific craft. However, these workers will cross craft lines and perform duties associated with other crafts. Therefore, work is generally assigned on an availability basis rather than by craft.

New construction, including welding and fabrication, accounts for 60% of the maintenance department activities. Remodeling in the PDU structure and support facilities and equipment upkeep in support facilities account for the remaining 40% of the department's time. The maintenance crew does not work on on-line process equipment. The responsibility for maintaining on-line equipment rests with the upper and lower level technicians.

Table A-1

Process Samples Analyzed by Laboratory

Westinghouse PDU

Sample	Frequency of Collection	Source	Analysis
C-117	one per hour	Ash from ash lockhoppers	% Ash
SC-22	one per hour	Char from fluidized bed	% Ash
SC-20	one every 4 hours	Fines from C-108A lockhopper	% Ash
Water balance	one per shift	Water from flocculant mixer (Z107)	% Solids
SC-5	one per shift	Coal from T-122 beltway transfer	% Ash Moisture Fixed carbons Volatiles
SC-9	one per shift	Coal from T-121 beltway transfer	
Williams Mill	one every 4 hours	Coal from crusher/dryer	Moisture
Isokinetic	one per shift	Stream sample at cyclones (C-119 and C-120)	% Fines
Makeup pit	one every 8 hours	Water sample from makeup pit	Trace elements Sulfur Ammonia pH
Separator pit	one every 8 hours	Water sample from separator pit	Trace elements Sulfur Ammonia pH
Miniscrubber	one per shift	Water sample at GC outlet on 6th level	Ammonia

When the plant is on-steam the maintenance personnel do not enter the PDU structure. Instead, work is scheduled for new construction, remodeling, and repair activities in the support facilities including administrative facilities. During plant down-time, maintenance workers perform remodeling activities, check and repair the compressors, grease the motors, and correct any electrical problems. Based on the responsibilities of the maintenance department, it is expected that these workers would have minimal exposures to process constituents. Tasks with a potential for exposure to process constituents, including vessel entry and equipment repair, have been delegated to the upper and lower level technicians.