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FINAL

CONTROL TECHNOLOGY ASSESSMENT
FOR
COAL GASIFICATION AND LIQUEFACTION PROCESSES

Coal Gasification Facility
Pennsylvania

Report for the Site Visit of
May 1981

Contract No. 210-78-0084

April 1982

Submitted to:

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FOREWORD

On August 18, 1980 and May 7, 1981 visits were made to the gasification facility at the Caterpillar Tractor Company in York, Pennsylvania. The purpose of these visits was to study the technology used to control occupational exposure to chemical and physical hazards at the gasification facility. On August 18, 1980 the study was conducted in conjunction with an industrial hygiene characterization study of the facility. The following people were in attendance at the initial meeting of the August 1980 visit:

For Caterpillar Tractor Company

Mr. K. Thompson, Corporate Manger, Industrial Hygiene
Mr. C. Williams, Industrial Hygienist, Corporate Office Peoria, Illinois
Mr. R. Julian, Manager, Plant Services, York, Pennsylvania
Mr. W. Glass, Safety Supervisor, York, Pennsylvania
Dr. G. Sprague, M.D., Medical Department, York, Pennsylvania
Mr. W. Norton, Plant Engineer, York, Pennsylvania
Mr. J. Misiolek, Supervising Engineer, York, Pennsylvania
Mr. J. King, Staff Engineer, York, Pennsylvania

For Enviro Control, Inc.

Mr. D. Telesca, Program Manager
Mr. J. Scopel, Chemical Engineer
Mr. R. Tanita, Industrial Hygienist

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 used to prevent occupational exposure to hazardous agents in coal conversion plants. This information is gathered during site visits to engineering firms, gasification facilities, and liquefaction facilities. Of particular importance is the industrial use of low-Btu coal gasification processes because of their potential for replacing more expensive and scarce fuels such as natural gas and oil. The low-Btu gasifier used by the Pennsylvania manufacturing plant is a two-stage gasifier. This report discusses the control technologies and work practices in use at the coal gasification facility in Pennsylvania during the site visits of August 18, 1980 and May 7, 1981. This facility is one of the first privately financed low-Btu coal gasification operations in the United States, and represents the first commercial operation designed to gasify a high sulfur coal to produce a clean fuel gas.

B. Project History

The gasification project at the Pennsylvania manufacturing plant represents one of the first privately financed low-Btu gasification operations in the United States. The objective of the project is to provide a supply of fuel gas to the plant carburizer furnaces at a price linked to the supply and cost of coal rather than natural gas. Gilbert Associates in Reading, Pennsylvania, designed the 150 ton-per-day facility. The impetus to proceed with the project was the natural gas curtailments in 1973 and continuing during following years which forced production cutbacks at the manufacturing plant. Two gasifiers were purchased from Black, Sivalls, & Bryson (BS&B), an engineering firm that designed and sold the Wellman-Incandescent gasifier under license from Wellman of England. Each gasifier consumes 67.5 tons of coal per day to produce approximately 14 million cubic feet of low-Btu gas per day. The gas is produced for onsite use in the carburizer furnaces of the manufacturing plant.

A six week test run of the facility in the fall of 1979 pointed out numerous problems with the system, including minor problems with the coal preparation screens, improper coal bed distribution, and a few gas leaks. These problems were corrected and the unit was restarted during April 1980. In subsequent test runs in May and June 1980, critical temperature rises in the carburizer furnaces using the coal derived gas were identical to those when using natural gas.

The gasifiers are designed for a specific bituminous coal to produce gas, but startup and shutdown are accomplished using low-sulfur anthracite. The reason for this is that during startup and shutdown the gas produced must be flared. Gas produced from anthracite is sufficiently free of sulfur and other impurities to permit flaring without cleanup. Bituminous coal produces a raw gas containing tars and sulfur compounds which must be removed before use or flaring.

NIOSH Industrial Hygiene Characterization Programs were conducted by Enviro Control, Inc. at the gasification facility during both anthracite and bituminous coal gasification. Description and results of the programs are presented in Section VI of this report. Appendix A presents the sampling and analytical protocols used in obtaining the data. Results from these surveys aided in identifying the hazards present at the gasification facility.

During the site survey in August 1980, one gasifier was operated on anthracite coal to enable a NIOSH sampling program to be conducted. The gas was flared as described in Section II-D. A similar program was conducted during the May 1981 visit with the gasifier operating as designed on Ohio bituminous coal.

C. Bituminous Coal

1. Process Description

A simplified process flow diagram of the gasification facility is shown in Figure 1. The major process operations include Coal Storage and Handling, Gasification, Ash Removal, Product Gas Cleaning/By-Product Recovery, and

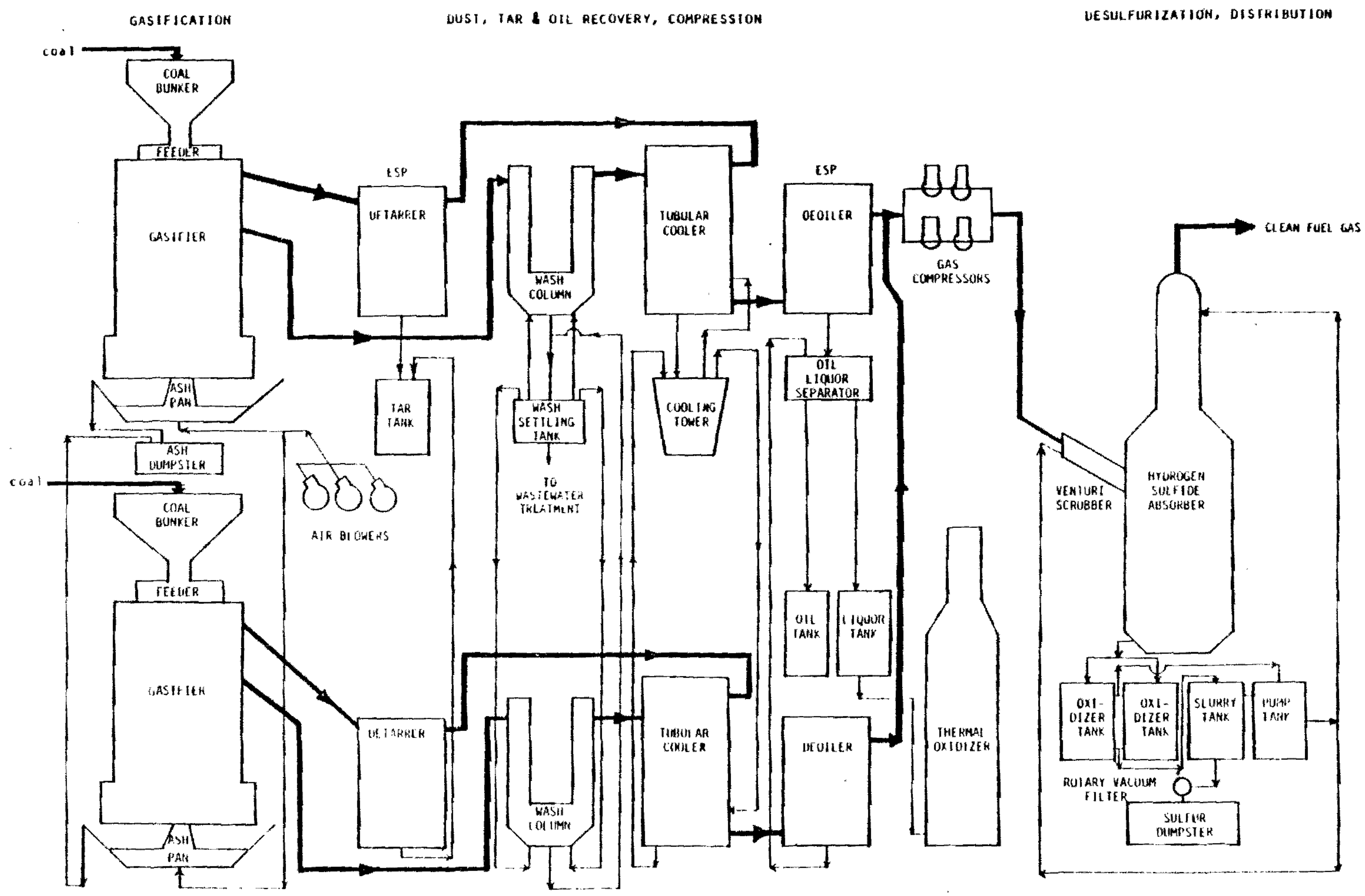

Figure 1. Simplified Process Flow Diagram, Bituminous Coal Gasification

Desulfurization. Each gasifier train includes dust, tar, and oil recovery equipment. Common facilities are used for coal and ash handling, by-product storage, desulfurization, and waste treatment.

Coal reclaimed from storage, or delivered by truck is dumped through a grate outside the gasification facility building into an underground bin. A vibrating feeder transfers the coal to a belt conveyor which discharges into a bucket elevator. The bucket elevator feeds a vibrating screen which in turn feeds a screw conveyor. The screw conveyor transfers the coal to a storage bin on top of the gasifier. A rotary valve feeds the coal through a knife valve into the top of the gasifier. Off gas from the feeding operation is vented through a baghouse to the atmosphere.

In the gasifier, coal flows countercurrently to air and steam introduced through a grate at the bottom of the gasifier. In moving from the top to the bottom of the gasifier, the coal passes through three reaction zones; devolatilization, gasification, and combustion. Ash from the combustion zone exits the bottom of the gasifier to a water-filled ash pan and is conveyed to an ash dumpster for disposal. The operating temperature of the gasifier ranges from 1800-2100 F (982-1149 C) in the combustion zone to 200-300 F (93-149 C) at the top of the gasifier. The gasifier operating pressure is approximately 20 inches of water.

Two gas streams are removed as product: a top gas which exits at 200-300 F (93-149 C), and a bottom gas which exits at 800-1000 F (427-538 C). The top gas is sent through an electrostatic precipitator ("detarrer") for tar removal. The tar is collected in a "day tank" before being pumped to the tar storage tank. The bottom gas is scrubbed in a wash water column for dust removal. The bottom gas and top gas streams are combined and cooled in the tubular cooler. The mixed product gas flows through a second electrostatic precipitator (the "deoiler") to remove oil and phenolic liquor. The oil is separated from the liquor in a settling tank, and is pumped to storage. The liquor is first pumped to a liquor storage tank, and then to the thermal oxidizer.

The mixed product gas is compressed and fed to a Stretford desulfurization unit. Elemental sulfur is collected as a salable by-product. The clean, low-Btu gas is piped out of the gas plant to the carburizer furnaces in the manufacturing plant.

2. Physical Description of Facility

The gasification facility is enclosed in a multi-level steel structure. Figure 2 is a plot plan showing the location of the major equipment. Figure 3 is an elevation drawing of the plant showing the location of major equipment by building level. The coal handling equipment, gasifiers, and the tar, dust, and oil removal and recovery units are located on the upper levels. The Stretford oxidizer slurry tank and pump tanks, the gas compressors, and the ash handling equipment are located on the lower levels. The delay tank and plate tower, wash settling tank, cooling tower, thermal oxidizer, coal storage piles, and the main tar and oil storage tanks are located outside the structure.

3. Potential Hazards

Many of the process streams associated with this gasification operation contain potentially hazardous chemical and physical agents. Those agents that are of concern due to their toxic and/or flammable nature are presented by process area in Table 1. Work practices, including administrative controls, personal protective equipment, personal hygiene, and workplace monitoring supplement the engineering controls used to control exposure to these agents.

Low-sulfur anthracite coal, when gasified during startup and shutdown, produces a gas that is essentially free of sulfur, tars, and oils. The gas, after passing through a cyclone/condensor to remove particulates, is flared.

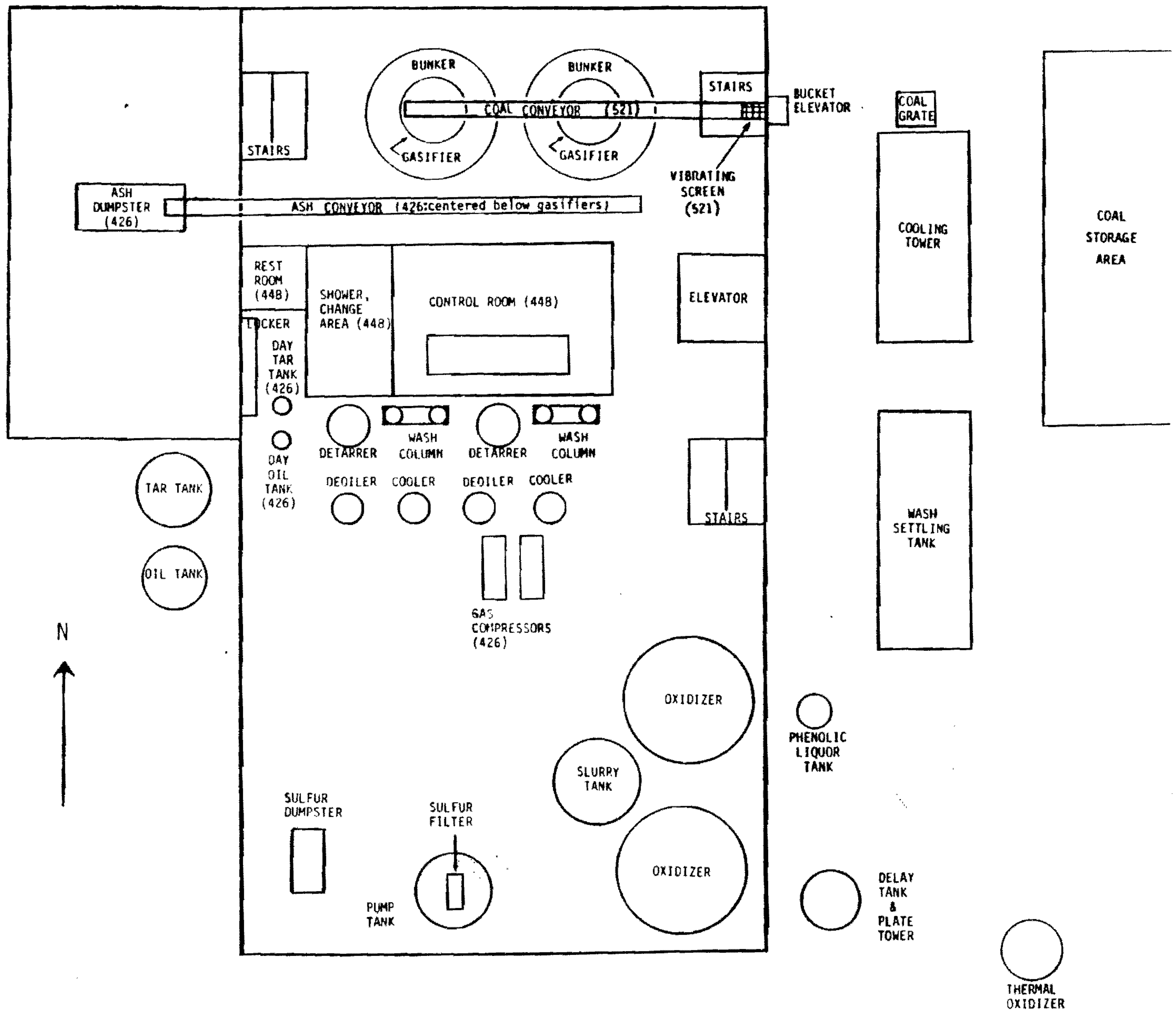

Figure 2. Plant Layout

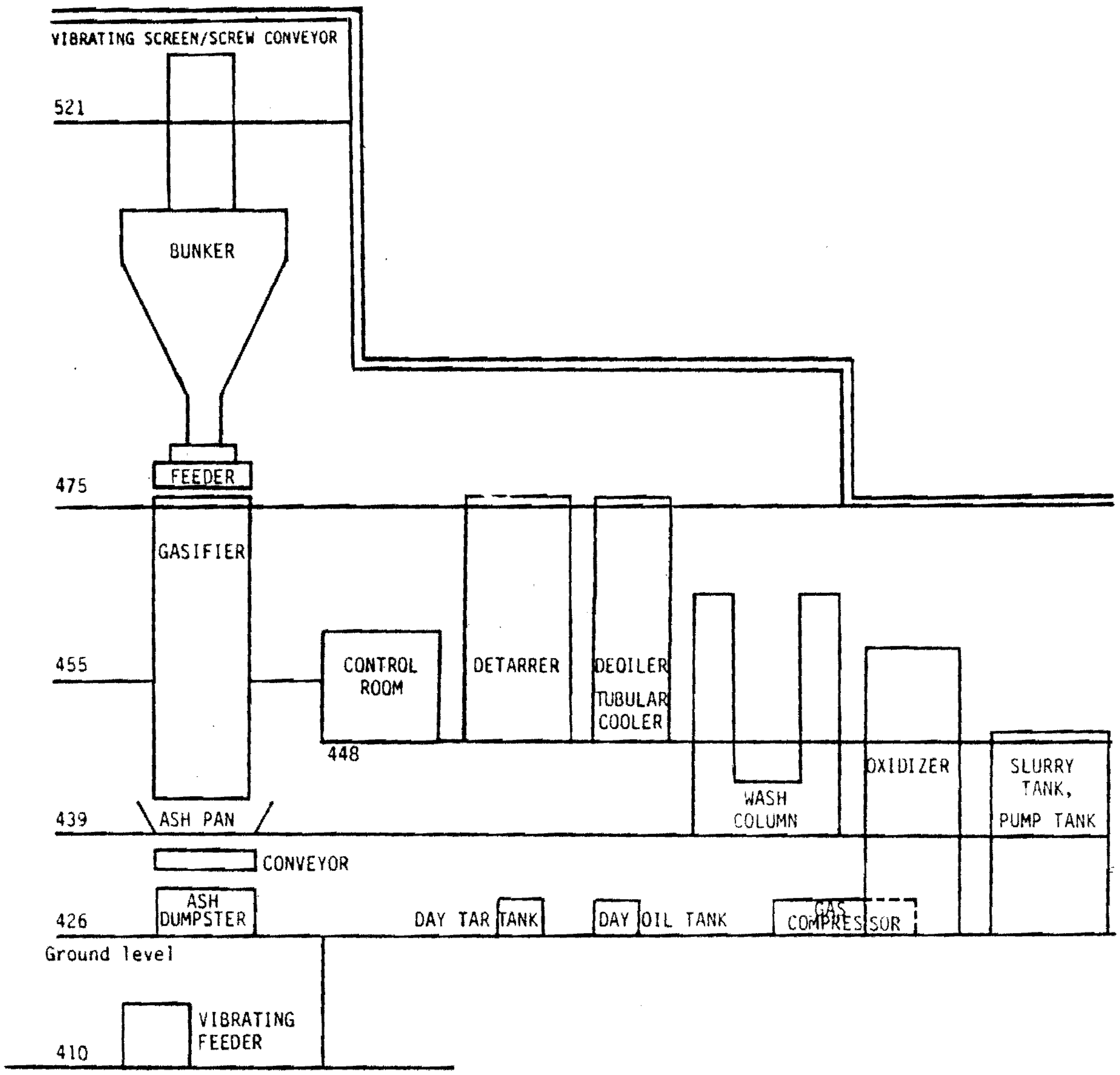

Figure 3. Schematic Elevation of Major Process Equipment

TABLE 1

Potential Hazards By Process Area
Gasification Facility, Pennsylvania
(Bituminous Coal)

Process Area	Potential Hazard
Coal Storage and Handling	Respirable Coal Dust Noise Fire Carbon Monoxide
Gasification	Carbon Monoxide Polynuclear Aromatics (tars/oils) Hydrogen Sulfide Flammable/Explosive Gases
Ash Removal System	None
Product Gas Cleaning/ By-Product Recovery	Carbon Monoxide Polynuclear Aromatics (tars/oils) Hydrogen Sulfide Flammable/Explosive Gases Phenols
Desulfurization	Carbon Monoxide Hydrogen Sulfide
Tar/Oil Storage	Polynuclear Aromatics (tars/oils)

D. Anthracite Coal

1. Process Description

During the August 1980 site survey one gasifier was operated using anthracite to permit NIOSH to conduct a sampling survey of an anthracite gasification operation. When using anthracite in the gasifiers the product gas cleaning, by-product recovery, and desulfurization units are bypassed. Instead, all of the gas is taken from the top gas exit, passed through a cyclone to remove dust (coal fines, carbon, and ash), and flared. The process operations required for anthracite gasification are coal storage and handling, gasification, ash removal, particulate removal, and flaring. The flow diagram for anthracite gasification is shown in Figure 4.

The process for anthracite is the same as for bituminous coal except for the last two operations. Particulates collected in the cyclone are disposed of with the tar, and the flared gas dissipates in the atmosphere as carbon dioxide and water.

2. Physical Description of Facility

The plant layout is the same as when bituminous coal is gasified with the exception that only the coal-handling, gasifying, and ash-handling equipment, shown in Figures 1 and 2, are used. The cyclone and flare, which are only used with anthracite coal, are not shown in Figures 1 and 2.

3. Potential Hazards

As with bituminous coal, there are potentially hazardous chemical and physical agents associated with anthracite gasification. However, due to the low volatile matter and sulfur content of anthracite, tars and oils (and thus PNAs), and sulfur compounds will essentially be absent. Table 2 lists, by process area, agents of concern.

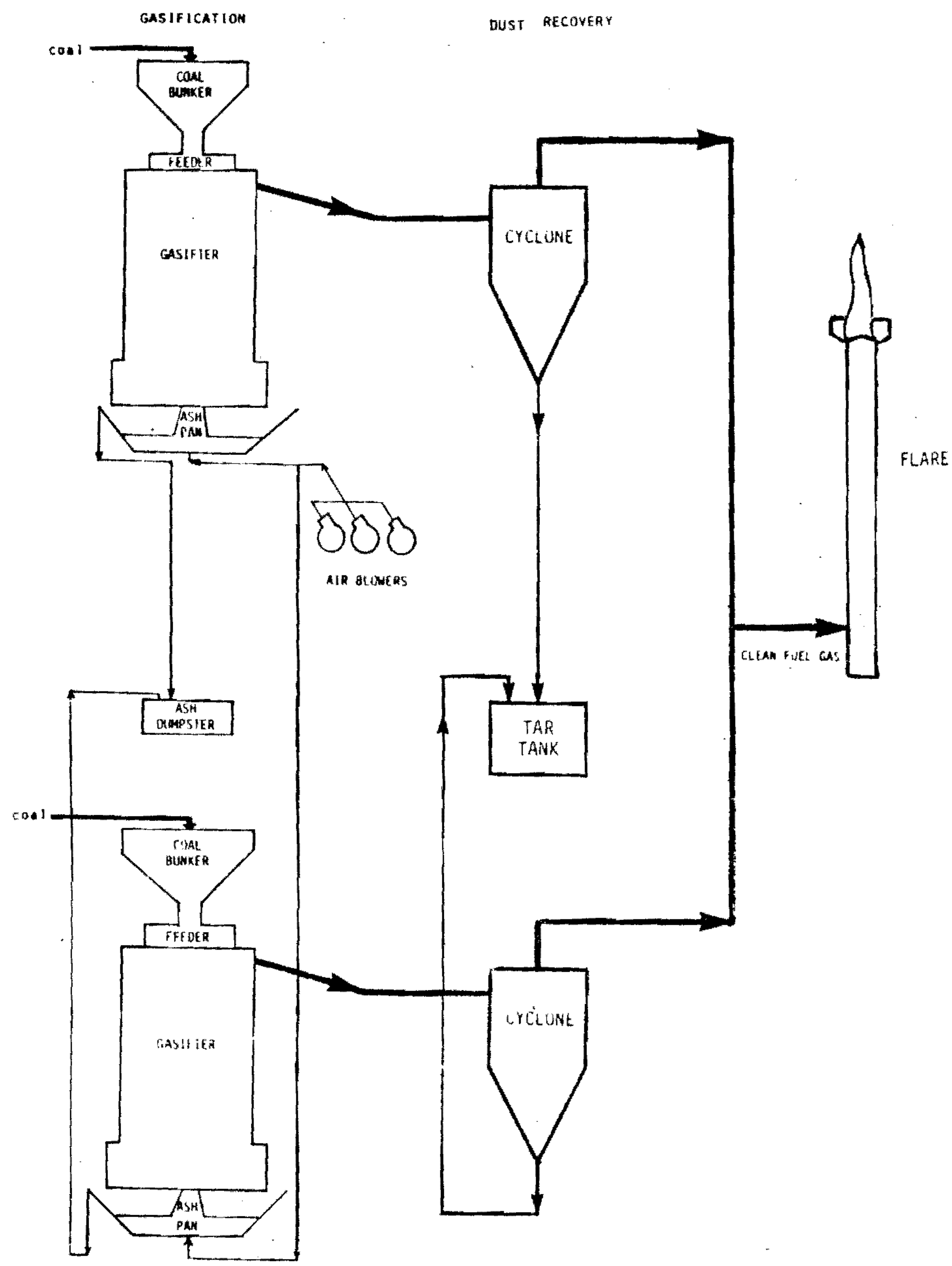

Figure 4. Simplified Process Flow Diagram
Anthracite Coal Gasification

TABLE 2

Potential Hazards By Process Area
Gasification Facility, Pennsylvania
(Anthracite Coal)

Process Area	Potential Hazard
Coal Storage and Handling	Respirable Coal Dust Noise Fire Carbon Monoxide
Gasification	Carbon Monoxide Flammable/Explosive Gases
Ash Removal System	None
Cyclone	Respirable Dust Carbon Monoxide Flammable/Explosive Gases
Flare	Carbon Monoxide Flammable/Explosive Gases

II. ENGINEERING CONTROL TECHNOLOGY

A. Introduction

A two part discussion of each process area of the gasification facility is presented. The first part is a process description. The second part is a discussion of potentially hazardous chemical and physical agents and associated engineering controls. The term "engineering controls" includes the use, modification and/or substitution of hardware, chemical feedstocks, operating conditions, process design, and instrumentation/process controls that result in reduction or elimination of occupational exposures to potentially hazardous agents.

The primary form of engineering control is a closed-system operation from the time coal enters the system through the outside grate, to the actual use of the clean low-Btu product gas. Only poking operations for fire-bed depth determinations and periodic maintenance require breaking into the system. Other engineering measures include dilution ventilation and explosion-proof electrical equipment throughout the gas plant.

The dilution ventilation system consists of ten exhaust fans and nine intake vents. The location of the exhaust fans is shown in Figure 5. The intake vents are located at various levels. The vents are equipped with heaters, but the system does not provide for cooling of makeup air. The control room is ventilated by a separate system which provides heating and air-conditioning. The rectifier and motor control rooms are under positive pressure from outside air. To prevent gas accumulation within the facility, the dilution ventilation system is designed to provide six air changes per hour within the structure with the doors and windows closed. However, during the summer months, doors at the ground level are kept open because of the absence of air-conditioning, and this results in an increase of air flow through the building.

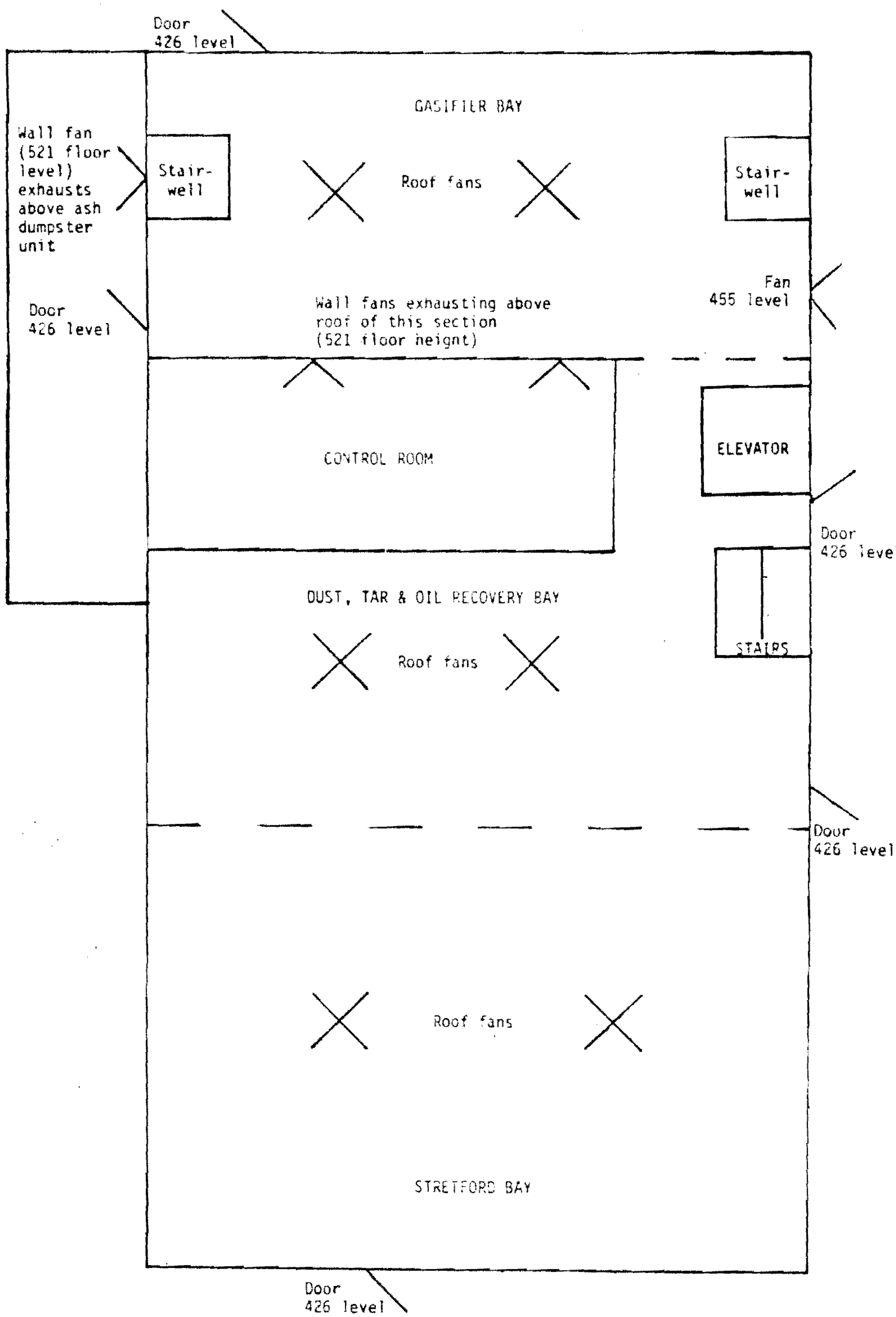

Figure 5.

Exhaust Fan and Door Locations
Coal Gasification Facility, Pennsylvania

B. Coal Storage and Handling

1. Process Description

Coal storage and handling includes all operations from coal receiving to coal bunker storage just prior to the gasifier feeding system. Coal is brought to the gasification facility storage yards by truck. A front-end loader moves the coal to coal storage piles where it is stacked eight to nine feet high.

When required, the loader dumps coal into a grate located outside of the gasifier building. The coal drops through the grate to an underground hopper that feeds a vibrating feeder. Coal from the feeder is conveyed to a bucket elevator. The bucket elevator carries the coal to the 521 level of the gas plant (see Figure 3). The coal is dropped onto a vibrating screen to remove coal which is less than 1/2 inch by 1/2 inch. This undersized coal drops through a downleg to a storage bin and is sent to the steam plant.

From the screen, the sized coal drops into an enclosed screw conveyor. Half-way along the conveyor, coal can be diverted to the coal bunker for the east gasifier (not in operation at the time of the visit). Coal carried to the end of the conveyor is dropped through a downleg to the west coal storage bunker. The downleg uses a "pants-leg" design to provide a more even distribution of coal in the bunker. A coal bunker dump downleg is provided on each bunker to evacuate the stored coal to the north side of the building in the event of an emergency such as a fire. A shuttle conveyor just under the coal bunker enables coal to be used from either bunker to feed both gasifiers.

2. Control Technology

Undersized coal and fines are removed using the vibrating screen located between the bucket elevator and the inclined screw conveyor. A separate storage yard is provided for this reject coal for use in the adjacent steam plant.

All coal handling equipment above the 410 elevation is now enclosed. All enclosed equipment is under negative pressure. This air is passed through a baghouse before being exhausted to the atmosphere. The enclosure also reduced the level of noise caused by coal dropping onto the vibrating screen on the 521 level.

Another problem in this process area is the accumulation of high concentrations of carbon monoxide in the coal pit located in the basement of the facility (410 level). Levels of carbon monoxide are usually less than 5 ppm but levels of 50 to 100 ppm have been reported. On occasion levels in the 500 to 1500 ppm range have been reported. Gases escape from the gasifier during the coal feeding operation. This gas, which is 26% carbon monoxide, enters the coal feed bunker. The gases that accumulate in the bunker are normally exhausted to the atmosphere through a baghouse; however, when the baghouse is plugged the gases are pulled from the coal bunker through the enclosed coal handling equipment and into the coal pit area (410 level) by the building ventilation system. This situation is made worse when all the outside doors of the building are closed. Cleaning and replacing the filter bags more often has only partially solved this problem.

C. Gasification

1. Process Description

Coal from the storage bunker above the gasifier drops into a rotating drum feeder and is held there until the gasifier is ready to accept another load of coal. The coal drops through a DeZurik knife valve into the top of the gasifier. The knife valve shuts and the feeder rotates to accept another load of coal from the coal storage bunker.

The gasifiers are two-stage, air-blown, fixed-bed, dry ash units. A simplified diagram of a two-stage gasifier is shown in Figure 6. Each gasifier is designed to consume 67.5 tons of coal per day, and produce 7 million cubic feet of low-Btu gas. The bed pressure of the gasifier is 20 inches of water. The bed temperature varies with the type of coal and location within

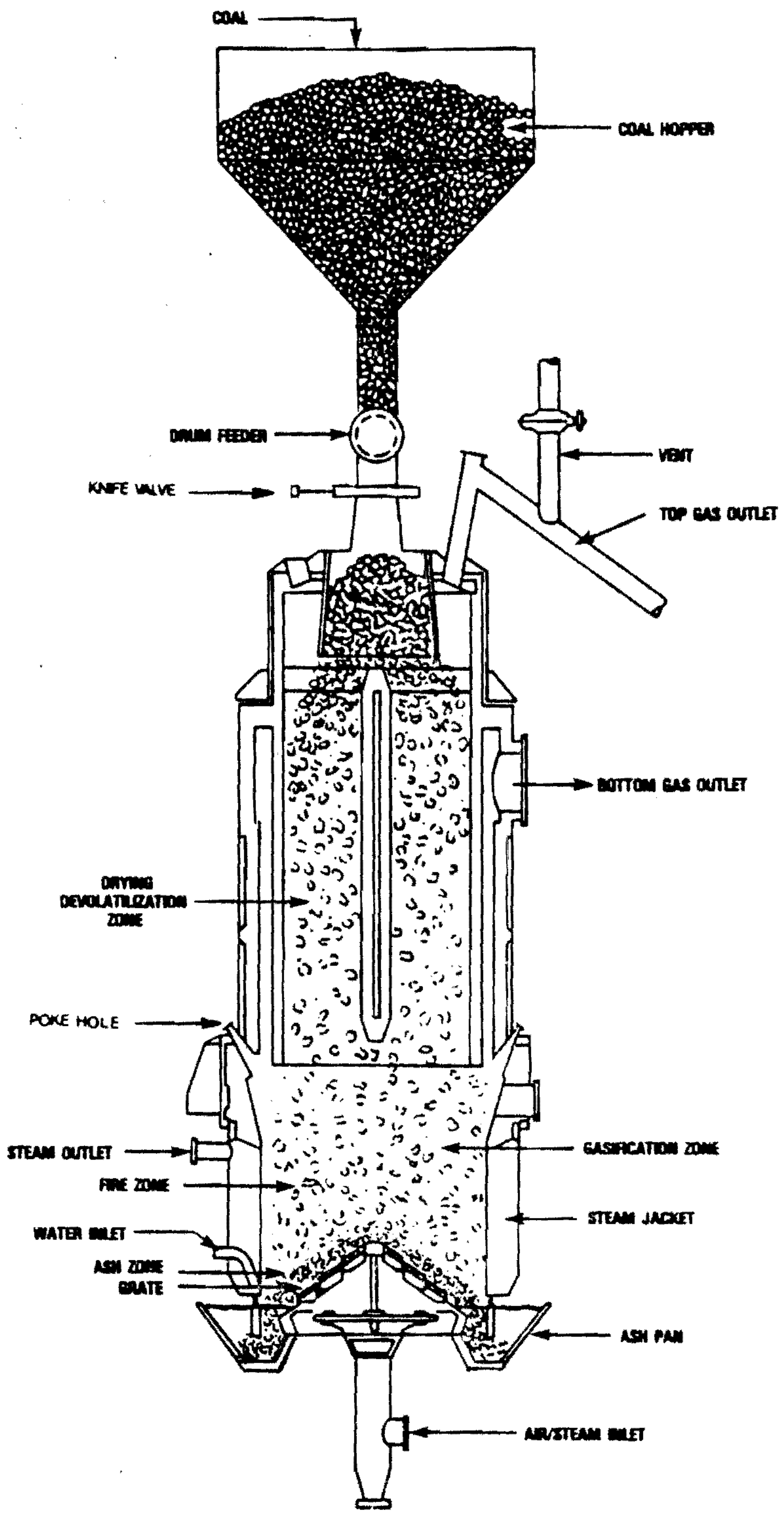

Figure 6. Schematic Diagram of a Two-Stage Gasifier

the gasifier. The highest allowable temperature is determined by the coal ash fusion temperature. A typical temperature range for the fire bed (combustion zone) is 1800 to 2100 F (982 to 1149 C). The top of the gasifier (devolatilization zone) operates at 200 to 300 F (93 to 149 C), while the temperature in the gasification zone is 800 to 1000 F (427 to 538 C). Ash withdrawn from the water quench is at ambient temperature. As ash is removed from the bottom of the gasifier, devolatilized coal moves downward into the gasification zone where an endothermic reaction takes place with steam rising from the bottom of the reactor. The gasification reaction produces a gas composed principally of carbon monoxide, hydrogen, and nitrogen. One portion of this gas is directed into the devolatilization zone to heat and devolatilize the entering coal. The gas leaving the devolatilization zone is composed primarily of CO, H_2, N_2 and vaporized tars and oils. This stream is called the top gas. The remaining portion is removed directly from the gasification zone as a product stream called the bottom gas, composed primarily of CO, H_2, and N_2.

The char remaining after gasification moves into the combustion zone where the remaining carbon is burned with air to produce heat for the gasification zone above. Ash is removed through the circumferential gap between the rotating grate and the gasifier wall to the water sealed ash pan. Temperature in the combustion zone is maintained below the ash fusion temperature by using a water jacketed gasifier wall and controlling the amount of steam introduced through the grate. Sixteen poke holes in the combustion zone are used to determine fire-bed depth and to break up any bridging or agglomeration just above the fire-bed. The fire-bed is checked twice each shift. During each check, two holes, 90 degrees apart, are poked. The rotational speed of the ash grate is adjusted to keep 18 to 24 inches of ash over the grate.

2. Control Technology

The major potential hazards associated with the operation of the two-stage gasifier include exposure to carbon monoxide and polynuclear aromatics (PNAs). Carbon monoxide is a product of the gasification reaction, while

PNAs are present in the tars and oils produced in the devolatilization section of gasifier. Other potential hazards are hydrogen sulfide, noise, heat, and fire. General engineering controls include dilution ventilation and explosion-proof electrical equipment.

Primary control of exposure to many of the hazards mentioned is achieved by maintaining the integrity of the closed system. Operations which require opening the system include coal feeding, and fire-bed depth checking. The following engineering controls minimize the emissions of gasifier products into the workplace during the coal feeding operations.

- The DeZurick knife gate valve is open only while coal is being fed. This minimizes the emission of product gas, and tar and oil vapors from the gasifier into the coal feeding equipment where condensing tars and oils can clog the equipment. Cleaning the equipment would expose maintenance workers to PNA and other hydrocarbons.

- Just prior to coal feeding, the knife gate valve is opened. As the feed drum is rotated, coal is dropped through the open valve and into the top of the gasifier. Since the knife gate does not come into contact with the coal, wear on the gate and seals is minimized. This helps prevent leakage of product gases when the valve is closed and also reduces valve maintenance, resulting in less exposure of the maintenance workers.

- A vent line to the roof is used to draw off gases that escape from the gasifier when the DeZurik knife gate is withdrawn. This minimizes equipment plugging and exposure problems that would occur if the gases and vapors entered the coal feeding equipment.

- Any gases not vented to the roof that enter the coal bunker are exhausted through a baghouse to the atmosphere. This prevents the accumulation of toxic and explosive gases in the bunker and around the coal feeding equipment.

- A muffler was installed on the DeZurik knife valve exhaust port to reduce noise during the venting of gases from the gasifier.

- The rotary drum feeder originally rotated in one direction only. This caused coal to be loaded into one side of the gasifier, resulting in unsteady gasifier operations. Unsteady gasifier operation can cause increased exposure because of increased poking requirements, or gasifier shutdown for maintenance and repair caused by uneven heating. The drum was modified to rotate in alternate clockwise and counterclockwise direction thus providing a symmetrical feed to the gasifier.

The following engineering controls are used to minimize the emission of gasifier products into the workplace during poking operations.

- Both upper and lower gasifier poke holes have been fitted with venturi steam injectors. Steam pressure and flow must be reliably maintained so that there is no loss of injector operation while poking is conducted. The venturi injectors are designed so that the steam enters the gasifier tangentially. When adjusted properly, the swirling steam forms a vortex which pulls outside air into the gasifier. The injectors do not operate continuously. Before the gasifier is poked, the steam valve to the poke hole is opened. After approximately 2 minutes, the poke hole cover is removed and a steel poke rod is inserted. The 2-minute warm-up period is necessary to achieve proper steam flow to the poke hole. This procedure is repeated at a second poke hole which is 90 degrees from the first hole. Two additional holes are poked later in the shift.

- The poke holes are equipped with special foot-operated dogs* and covers which enable the operator to manipulate the cover without having to place his face close to the poke hole.

- Poke hole leakage is minimized by proper gasketing with synthetic gasket, maintaining the gasket, and properly seating the cover after poking. Individual poke holes are periodically checked with a portable CO monitor. If a hole is leaking, it is reseated and checked again. If the leaking continues, the hole number is reported for regasketing.

- Upper pokeholes are provided to check for bridging since the two-stage gasifier is not equipped with a stirrer. The frequency of poking depends on the type of coal. A highly caking coal is checked more frequently.

- During the start-up mode, non-caking anthracite coal is fed to the gasifier. This prevents bridging problems which require excessive poking and result in potential exposure to gases as well as providing tar and sulfur free gas which can be flared without cleanup.

D. Ash Removal

1. Process Description

A wet granular ash is produced by the two-stage gasifier. Because of the high carbon conversion rate associated with this fixed-bed gasifier (approximately 1% unconverted carbon), the ash is suitable for landfill, for the manufacture of cinderblock, or for road cover.

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*A dog is any of various simple mechanical devices for holding or fastening.

Ash is removed from the gasifier by a rotating unit consisting of a conical, screw-shaped grate, a lobed ash grate holder, and a water-filled ash pan. This mechanism rotates beneath the suspended gasifier.

The function of the grate is to continuously remove dry ash from the combustion zone to allow for the downward movement of coal from the top of the gasifier. The screw-shaped design of the grate forces the ash downward and radially outward. The ash drops past a lobed grate holder, which breaks clinkers, to the water-filled ash pan. The ash pan is attached to and rotates with the grate via the grate holder. A plow on each side of the gasifier accumulates and directs the quenched ash to an overflow catch and drop chute. The wet ash drops onto a belt conveyor located on the 426 level. The conveyor passes through the west wall of the gas plant and drops the ash into a dumpster.

2. Control Technology

The wet ash removal system is an effective method of controlling exposure to ash dust, a potential hazard associated with gasifiers using dry-ash removal systems. Enclosed conveyors for ash removal are not necessary for dust suppression.

The depth of the water forms a seal that prevents combustion zone gases from entering the workplace through the ash removal system.

E. Product Gas Cleaning/By-Product Recovery

1. Process Description

Top gas exits the gasifier at a temperature of approximately 250 F (121 C) and flows to an electrostatic precipitator (detarrer) for tar removal. Approximately 1000 gallons of tar are produced from 70 tons of Ohio bituminous coal. The operating temperature of the detarrer is approximately 200 to 300 F (93 to 149 C). Proper tar flow has been maintained by heat tracing and insulating the lines.

The tar flows by gravity to a "day tank" located on the 426 level. The tar, which at this point is about 200 F (93 C), is pumped to an outside 16,000 gallon storage tank. This tank is insulated and steam traced to maintain the tar at 200 F (93 C).

The bottom product gas stream exits the gasifier at approximately 1000 F (538 C) and enters a U-shaped water wash column. The gas enters the top of one end of the wash column, contacts water in the column, and exits the column at the top of the other end. This operation removes particulate matter entrained in the gas and cools the gas before it is mixed with the detarred top gas at the outlet of the tubular cooler. The wash water is sent to a wash settling tank located outside along the east side of the gasifier facility. The wash water cools while in the settler. In order to control the buildup of solids in the settler, the sludge is blown down once a day to the common wastewater treatment plant serving the manufacturing plant.

Detarred top gas enters a tubular cooler where it is mixed with bottom product gas from the water wash column. Cooling water in the tubular cooler flows inside vertical tubes while the mixed product gas passes over the outside of the tubes. The temperature of the exit stream is sufficiently low so that any remaining condensibles are droplets when they reach the deoiler.

The deoiler is an electrostatic precipitator which removes the condensibles present in the entering stream. No additional heat tracing or insulation is required for proper oil flow. The resulting low-Btu gas, which is now 80 to 100 F (27 to 38 C) and free of particulate matter and condensible hydrocarbons, is compressed and sent to the Stretford unit for hydrogen sulfide (H_2S) removal.

Recovery of by-product oil from the deoiler requires the separation of oil from phenolic liquor. This is accomplished in a series of holding vessels. The oil and phenolic wastewater from the deoiler flows to an oil/liquor separator tank. The phenolic liquor forms a bottom layer which flows to a phenolic liquor storage tank. Liquor from this tank is pumped to a storage tank located outside the structure and from there to a producer gas fired thermal oxidizer.

Oil, which forms a top layer in the separator tank, flows by gravity to a "day tank" located on the 426 level of the gasifier facility. Oil from this tank is pumped to an outside 6500 gallon storage tank.

2. Control Technology

The major potential hazards associated with the Product Gas cleaning and By-Product Recovery process area are exposure to polynuclear aromatic hydrocarbons, carbon monoxide, fire, and explosions. Other potential hazards are hydrogen sulfide, and phenols.

The general engineering controls throughout this process area include explosion proof electrical equipment and general dilution ventilation. These controls minimize the risk of fire, explosion, and exposures to process constituents once they enter the workplace. The primary methods of reducing emissions of process constituents into the workplace are maintenance of a closed system.

Examples of this control strategy are listed below.

- Metal tops on the seal pots were inadequate because the metal to metal seal and the vapor vent allowed vapor emissions into the workplace. The vapor vent was sealed and rubber gaskets were installed eliminating the source of emissions.

- The tar and oil day tanks and pumps located on the 426 level leak hydrocarbons. This skid-mounted equipment is the source of an odor problem and a potential source of PNA exposure. This equipment is to be moved outside and enclosed in a separate room.

- The oil, which is suitable for use as a substitute for No. 2 boiler fuel, can be pumped directly to the steam plant, minimizing the handling of this material and consequently reducing the potential for exposure of the plant operators.

- With the exception of the detarrer electrostatic precipitator, the entire tar collection system is steam traced and insulated to provide proper tar flow. Proper tar flow is important in reducing maintenance of the collection system and minimizing exposure to the PNA-containing tar.

- Phenolic liquor is separated, collected in the phenolic liquor storage tank, and then sent to a thermal oxidizer for destruction rather than being processed for phenol recovery.

- The detarrer and deoiler electrostatic precipitators have operated very reliably. The one notable exception was plugging of the detarrer during a start-up on anthracite coal. Anthracite coal gasification produces very little tar and oil; however, the top gas exiting the gasifier contained a sufficient amount of dust to plug the detarrer. All gas produced during start-up is now passed through a cyclone/condenser and vented to a flare on the roof.

- The vent valves (for N_2 purge) on the detarrers and deoilers were previously vented to the workplace. To reduce workplace contamination, all vents are now located outside the building above the roof level.

- The wash water settling tank and phenolic liquor storage tank are located outside of the gasification building. The wash settling tank, which was previously open, is now covered to reduce evaporation.

F. Desulfurization

1. Process Description

Low-Btu gas from the deoiler is compressed and sent to the Stretford unit for H_2S removal. The gas first enters the venturi scrubber where the gas is intimately mixed with Stretford solution. The gas then passes to the Stretford plate tower where the gas is contacted countercurrently with additional Stretford solution.

The Stretford solution consists of an aqueous solution of the following chemicals: anthraquinone-disulfonic acid (ADA); sodium metavanadate ($NaVO_3$); citric acid; and sodium carbonate (Na_2CO_3). Hydrogen sulfide is oxidized in this solution to elemental sulfur. During this reaction the vanadium is reduced from the pentavalent state to its quadrivalent state. The reduced vanadium is subsequently oxidized by a redox reaction with ADA. Since the quadrivalent vanadium could precipitate out in the alkaline solution, citric acid is used as a complexing agent to keep the vanadium dissolved.

The H_2S free gas exits the top of the plate tower. The Stretford solution goes to two oxidizer tanks where air is blown through the liquor to reoxidize the ADA and separate the elemental sulfur by froth flotation. The sulfur froth flows to the sulfur slurry tank, and the regenerated Stretford solution goes to the pump tank. From the pump tank, the solution is cooled and recirculated to the absorber.

Sulfur from the slurry tank is pumped to a rotary vacuum filter. Filter cake is discharged to the sulfur dumpster, and filtrate is returned to the pump tank.

2. Control Technology

The potential hazards associated with the desulfurization process area include inhalation of carbon monoxide (CO) and hydrogen sulfide (H_2S), fires, and explosions. As a commercially proven process for the removal of H_2S, the Stretford process operates reliably.

The oxidizer and slurry pump tanks for the Stretford unit are located inside the gasifier building. The walk-through survey team took CO meter readings near the slurry tank before and after covers were fitted. Degassing of process constituents from this open-topped tank resulted in excessive emissions into the workplace. CO concentration readings near this vessel were consistently above 300 ppm. After the cover was placed on the tank, CO readings ranged from background levels to 10 ppm.

III. WORK PRACTICES

A. Introduction

Plant management considers hydrogen sulfide, carbon monoxide, and the polynuclear aromatics contained in the tar to be the major health hazards; hydrogen sulfide and carbon monoxide because of their acute toxicity and high concentrations in the product gas, and polynuclear aromatics because they are potential carcinogens. Plant management also considers the flammable and explosive nature of the product gas to constitute a major hazard. Regulations to protect workers against the flammable and toxic nature of the product gas include protocols for entry into confined spaces and for breaking into process lines. There is also an established training program covering the selection, use, and maintenance of respirators. These regulations and programs have been designed either in accordance with current OSHA requirements or were based on recommendations found in NIOSH documents on Entry Into Confined Spaces, Coal Tar Pitch Volatiles, Coal Gasification Plants, and Coal Liquefaction Plants.

The safety program for the gasifier facility is described in the plant Operations Manual and other plant communications which modify or expand elements within the manual. The manual and all safety communications are available to the workers. The safety procedures described below are taken from these sources. These procedures are designed to protect visitors and personnel working in the gasification facility from inhalation exposure and skin contact with toxic substances. Most of these measures are for specific activities where exposure to these substances is most likely to occur.

B. Administrative Controls

The gasifier facility has been designated as a limited access area and entry into this facility is carefully regulated and monitored. The facility and associated equipment are fenced in or enclosed, and all gates and doors are locked to facilitate monitoring of personnel entry. Doors designated as emergency exits are equipped with panic-bar hardware and an alarm system to alert the control room in the event these doors are opened. The main entrance to the facility is equipped with an electric lock operated from the control room. Cameras are located at the main entrance and other sections of the facility for remote monitoring of entry/exit points and process equipment by the control room operator.

All visitors are required to use the page phone located next to the main entrance to contact the control room and identify themselves. The control room operator activates the electric lock giving the party 20 seconds to enter the facility. Upon entering the facility, all visitors must report directly to the control room located on the third level to check in with the control room operator and sign in on the personnel log. If the visitor's business requires entering the process area he is accompanied by a plant escort with a portable carbon monoxide monitor equipped with an audible alarm set to be activated if CO levels exceed 50 ppm. Upon completing their business, visitors are required to report to the control room and sign out. When leaving the facility, they must use the page phone to inform the control room that they have left the premises. A ratio of at least one trained person to two untrained visitors is required.

The plant recognizes three categories of visitors: outside maintenance contractor, company employee, and visitor. Visitors follow the basic procedure outlined above with one portable CO monitor per group. Each group of visitors must be accompanied by plant personnel trained in the safty procedures for the gasifier unit. Plant personnel carry the CO monitor.

Contract employees also follow the entry and exit basic procedures. However, they do not have to sign out when they leave the facility if they plan to return that same day. Instead they must report to the control room their intent to temporarily leave the facility, turn in the CO monitor, and inform the control room by the page phone that they have left the facility. Returning to the facility, they follow the basic procedure for entry but are not required to sign in again. One portable CO monitor is provided per group. They must sign out when they leave for the day.

Company employees must also adhere to the entry/exit procedures; however, they are allowed to leave the facility without signing out if they will be out only briefly. Upon re-entering they have to follow the entry procedures except they do not have to sign in again.

Any employee seeking entry into the gasification facility must also have participated in a training program given by the Safety Office and Security within the past year. Most maintenance of the gasification facility is performed by manufacturing plant employees. Company maintenance workers must have completed training within the past 6 months. Training records and dates for each company employee are kept in the control room. The control room operator refers to this list to determine if the worker seeking entry meets the training requirement. If not, the worker is refused entry.

The training program is designed to inform the employee of the health hazards present, the symptoms of overexposure, and the types of protective clothing and equipment required. Employees are also told when respirators should be used, how to put them on, and what additional safety equipment is available for optional use.

Special precautions are required for anyone entering the coal pit located in the basement of the facility. These precautions are taken because of excess levels of CO in the coal pit. Whenever anyone enters the coal pit the following precautions must be taken:

1. Take a CO reading at the top step (elev. 426) before proceeding down the stairs.

   a. If the reading is above 50 ppm, a second man is required. Both men will have CO monitors and check for CO as they go down into the pit; highest reading will be logged. (Notify the Coal Gas foreman.)

   b. If below 50 ppm, descend into the pit -- leave CO display on and read all the way into the pit ... see #2.

2. If the level exceeds 50 ppm, a second man is required in descending the stairs and entering the pit; log the highest reading. (Notify the Coal Gas foreman.)

3. In any case, if the CO level exceeds 50 ppm and the exposure period is 5 minutes or more, breathing apparatus must be used (notify the Coal Gas foreman); i.e., to investigate the cause of the high CO. If the exposure period is 8 hours, do not exceed 50 ppm for that time period.

C. Housekeeping and Personal Hygiene

Operators on the three shifts are responsible for keeping the facility clean. A daily cleaning schedule which includes floors and vessels distributes the work among the shifts. Soap and water or steam cleaning is used for general clean-up and spills, with waste water being sent to the waste treatment plant. All concrete floors are protected with epoxy-base paint to minimize absorption of tars and oils.

Although not mandatory, thorough washing with soap and water is encouraged whenever contact with tars or oils occurs. Shower facilities are provided for use at the end of a shift and for immediate use in cases of skin contact involving large areas of the body. Shower and locker facilities are located on the same level as the control room. Each worker permanently assigned to the gasifier is provided with separate lockers to keep street clothing and work coveralls separated.

D. Job Descriptions

The project manager, shift supervisor, and shift operators are permanently assigned to the gasification facility. The operators are stationed in the control room on the third level (455 level) and the supervisor in an office outside the facility. The maintenance workers and laboratory technicians enter the gasification facility as needed to complete their assignments.

The project manager has the overall responsibility for meeting the objectives of the gasification project while the shift supervisor has the responsibility for the day-to-day operation of the facility. Their exposure to process contaminants occurs during inspections of the facility. Maximum exposure will occur during the initial phases of start-up and during process upsets which place an additional demand on their time. During normal operations they spend up to 40 percent of their time in the facility, increasing to 80 percent during start-up and process upsets.

Nonrotating shifts are used at the gasification facility which is operated on a 24 hour per day, 7 day per week schedule. The use of nonrotating shifts is not expected to produce differences in exposure levels among the three daily shifts because duties and responsibilities, for each job type are the same in all three shifts and because the enclosed gasification facility should reduce the effects of daily variations in weather conditions on worker exposure.

Maintenance workers and laboratory technicians are not assigned to the gasification facility on a full-time basis. These workers enter the facility as needed to complete their work. Laboratory technicians enter the area once per week to obtain a Stretford gas sample. There are no formal regulations to ensure that the same workers are sent to this facility to perform maintenance and sampling; however, three maintenance workers are given a majority of the assignments because of their experience and familiarity with the gasification system. Workers who are familiar with the hazards in the facility will perform their jobs more safely.

There are two classes of operators in the workforce assigned to the gasification unit. These include the control room operator and the remote operator (roamer). Duties of the two types of operators are handled differently on the three shifts. On two of the three shifts the control room operators exchange duties with the remote operators daily. Therefore, personal sampling on these shifts can differentiate between the exposure level of the two operator job types. On the remaining shift, the operators share the duties of the two jobs thereby masking exposure differences that may exist between the two jobs.

One control room operator is assigned to each shift. He spends nearly 100 percent of his time in the control room. The control room has a separate ventilation system with makeup air from outside the facility; nevertheless personal and area sampling indicates that there is no significant difference between the exposures of the control room operator and the remote operator. The reasons for this are discussed later in the report.

One remote operator is assigned to each shift. On one day per week there are two remote operators.

The remote operator regulates valves and makes adjustments to the system as required. These tasks are performed during his inspection of the process area, which takes place every 2 hours. The first tour of inspection takes 30 minutes with subsequent trips lasting 20 minutes. Other duties performed by the remote operator include:

- Determine the depth of the fire-bed once per shift. This activity takes 15 minutes.
- Obtain a wash settling tank sample once per week.
- Take a sample of the boiler water condensate once per shift.
- Collect a sample of the cooling water once per week.
- Add chemicals to the cooling water once per week as directed.
- Mix and add Stretford solution to Stretford unit. Frequency varies from 10 times in a 3-week period during the initial phases of startup to once every 3 weeks while the plant is running. The chemicals added include ADA, sodium vanadate, sodium carbonate, and citric acid.
- Conduct minor maintenance.
- Assist maintenance mechanics in major repair activities.

The remote operator spends on the average 40 percent of his time in the process area completing these activities.

Fire-bed depth determination presents the potential for acute exposures to high levels of toxic gases such as carbon monoxide and hydrogen sulfide. Pokeholes are located around the circumference of the gasifier at the 455 level. In determining the fire-bed depth one pokehole is selected and a steam valve is opened. After 2 minutes the cover is removed and a rod is inserted into the opening along the side of the gasifier until it reaches the bottom of the gasifier. This procedure is repeated at a second pokehole which is 90 degrees from the first opening; however, in the second pokehole the rod is inserted towards the bottom center of the gasifier. After 3 minutes the two rods are removed, the covers are closed, and steam valves turned off. The cherry-red section of the rods is measured and this represents the depth of the fire-bed. The section below the cherry-red portion represents the depth of the ash bed.

In this procedure the steam creates a negative pressure in the pokehole preventing process gases from leaking into the working environment. An exposure problem can occur if the steam system does not operate properly. A failure of the steam control mechanism was observed during the survey of this plant, but was immediately corrected by adjusting the steam valve.

For the remote operators, contact with tars, oils, and phenolics can be health hazards. Tars and oils are encountered primarily while cleaning the detarrer and deoiler and while assisting pipefitters in replacement or cleaning of process lines.

Two utility helpers are assigned to each shift. The helper has job responsibilities at the gasification unit and at the heating plant, another facility. Because of his duties at these facilities, the utility helper is in the field at least 7 hours per shift.

The duties of the utility helper and the hazardous agents he is exposed to are discussed below. The helper monitors the ash bins and moves them with a 966 front end loader. When full, a contract hauler removes the bins. An ash sample is taken once per week. Since the ash is wet as it enters the bin, ash dust exposure is not a problem.

The coal feed system, consisting of two vibrating screens, a vibrating feeder, a bucket elevator, a screw conveyor, and a belt conveyor, to size and transport coal to the coal bunker located on the 521 level, is monitored and regulated by the helper according to instructions from the control room operator. Other duties in this area include taking a coal sample once per week and cleaning the vibrating screens and feeder. The helper time in this area depends on the amount of coal required.

The belt conveyor and vibrating feeder are located in the gasification unit basement, the 410 level. The bucket elevator conveys coal to the vibrating screen at elevation 521 which feeds the screw conveyor. All equipment above level 410 is enclosed during operation to keep the generation of coal dust under control minimizing worker exposure. It is reported that dust does not pose a problem under these conditions. However, at the time of the first survey, the screen was not enclosed during operation because frequent monitoring by the helper was required to keep the screen from clogging. Operation of the screen without the cover produced a dust problem and worker protection was a half-mask particulate respirator. There were no complaints by the helpers with regard to the use of the respirator.

The primary problem with the coal feed system is noise produced by the vibrating feeder. The helper time in this area varies depending on the amount of coal needed. With reported noise levels in excess of 90 dBas, overexposure can occur if the helper is in the area for the entire shift. For these circumstances ear muffs are provided.

Seven maintenance crafts are used in the gasification unit. These crafts and their respective duties are given below.

Millwright	- installation, servicing, and repair of mechanical equipment - assist other crafts
Sheet Metal Workers	- fabricate, install, and repair sheet metal items of equipment - assist other crafts
Pipefitters	- install, service, and repair piping and plumbing system - assist other crafts

Electrician	- builds, installs, and repairs electrical and electronic circuits used on machine tools and plant equipment - tests faulty equipment to diagnose malfunctions - aligns, balances, and calibrates equipment
Maintenance Laborer	- performs tasks such as concrete breaking and pouring; sewer, pit, machine, and conveyor cleaning; floating and leveling; excavation
Welder	- gas and arc welding - brazing and soldering - assist other crafts
Machine Repairman	- repairs, adjusts, overhauls, and rebuilds machine tools and allied equipment.

None of these crafts are assigned full-time to the gasification unit. Instead, crafts serve the unit on an on-call basis, entering the facility only when needed to perform maintenance. Exposure is expected to be intermittent and variable depending on the job, and chronic exposure to low concentrations of toxicants is not expected to be a problem. The major hazard is believed to be acute exposure to high levels of toxic gases such as carbon monoxide while entering vessels, or breaking into process lines to make repairs. Standard protective equipment for these activities are full-body suits with supplied-air respirators and rubber boots.

The greatest potential long-term hazard is skin contact with tar-contaminated equipment. Wipe tests (Table 3) suggest that these deposits are likely to contain high molecular weight PNAs which have been associated with skin cancer. Protection is provided by rubber gloves. Face shields and coveralls are also worn if face or body contact is possible.

Gas samples are taken three times per day at the laboratory sample line. This line runs from the gas distribution system to the laboratory, directly to the gas chromatograph. Once per week laboratory personnel obtain a sample of the Stretford unit solution. This sample is analyzed under a laboratory hood.

TABLE 3

PNA Analytical Results for Wipe Samples and Bulk Samples: Coal Gasification Facility, Pennsylvania)

Compound	Wipe Samples																		Bulk Samples	
	Equipment					Tools			Clothing						Control Room					
Sample Site:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Sample Number:	2-036	2-019	2-018	2-017	046	1-017	1-018	1-073	040	041	042	043	1-027	1-028	1-075	1-019	045	044	1-071	1-072
Date Collected:	4/29*	4/28*	4/28*	4/28*	8/20†	4/28*	4/28*	5/1*	8/20†	8/20†	8/20†	8/20†	4/29*	4/29*	5/1*	4/28*	8/20†	8/20†	5/1*	5/1*
Naphthalene	●	●	●	●	-	●	●	●	-	-	-	-	●	●	●	●	-	-	●	●
1-Methylnaphthalene	-	●	●	-	-	●	-	●	-	-	-	-	●	-	-	●	-	-	●	●
2-Methylnaphthalene	-	●	●	-	-	●	-	●	-	-	-	-	●	-	-	●	-	-	●	●
Quinoline	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-
Acenaphthalene	-	-	-	-	-	●	-	-	-	-	-	-	●	-	-	-	-	-	●	●
Acenaphthene	-	-	●	-	-	●	●	●	-	-	-	-	●	●	-	-	-	-	●	●
Fluorene	-	●	-	-	-	●	-	-	-	-	-	-	●	●	-	●	-	-	●	●
Phenanthrene/Anthracene	●	●	●	●	●	●	●	●	●	●	-	-	●	●	●	●	●	-	●	●
Acridine	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●	●
Carbazole	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●	●
Fluoranthene	●	●	●	●	-	●	●	●	●	-	-	-	●	●	●	●	-	-	●	●
Pyrene	●	●	●	●	-	●	●	●	●	●	-	-	●	●	●	●	-	-	●	●
Benzo(a)fluorene/ Benzo(b)fluorene	-	●	-	-	-	●	-	●	-	-	-	-	●	●	-	-	-	-	●	●
Benz(a)anthracene/ Chrysene/Triphenylene	●	●	●	●	-	●	●	●	●	-	-	-	●	●	●	●	-	-	●	●
Benzo(j)fluoranthene/ Benzo(b)fluoranthene/ Benzo(k)fluoranthene	-	-	-	-	¤	●	-	-	¤	¤	¤	¤	●	-	-	-	¤	¤	●	●
Benzo(e)pyrene/ Benzo(a)pyrene	-	-	-	-	-	●	-	-	-	-	-	-	●	●	-	-	-	-	●	●
Perylene	-	-	-	-	-	●	-	-	-	-	-	-	●	-	-	-	-	-	-	-
Dibenz(a,j)acridine	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	●	●
Dibenz(a,i)carbazole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	-	-	-	-	-	●	-	-	-	-	-	-	●	-	-	-	-	-	●	●
Dibenz(a,h)anthracene	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	●
Benzo(g,h,i)perylene	-	-	-	-	-	●	-	●	-	-	-	-	●	●	-	-	-	-	●	●
Coronene	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●	-
Dibenz(a,i)pyrene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-
Dimethylbenz(a)anthracene	-	-	-	-	¤	-	-	-	¤	¤	¤	¤	-	-	-	-	¤	¤	●	-
3-Methylcholanthrene	-	-	-	-	¤	-	-	-	¤	¤	¤	¤	-	-	-	-	¤	¤	●	-
6,13-Dimethyldibenz(a,j)-anthracene	-	-	-	-	¤	-	-	-	¤	¤	¤	¤	-	-	-	-	¤	¤	●	-

Key: *1981. †1980. ● = compound detected. - = compound not detected. ¤ = samples not analyzed for these compounds.

Equipment

A = oil/liquor separator, weir handle
B = handrail above compressor
C = handrail below Stretford unit
D = handrail on top of gasifier
E = side of gasifier

Tools

F = used on tar pump
G = stored in control room
H = used on gas compressor

Clothing

I = rubber glove, outside surface
J = rubber glove, outside surface
K = rubber glove, inside surface
L = rubber glove, inside surface
M = gloves of millwright at tar pump
N = trousers (under coveralls) of tar pump worker

Control Room

O = bathroom handles
P = desk top
Q = desk top
R = stair rail

Bulk Samples

S = tar from d[illegible] tar tank
T = oil from d[illegible] oil tank

IV. PROTECTIVE CLOTHING AND EQUIPMENT

The plant safety program requires the use of safety glasses in any plant facility and prohibits wearing rings within the plant. In the gasification facility, the safety program recommends the use of additional protective clothing and equipment.

Protective clothing that is available to the workers includes:

- Cotton or polyester coveralls mandatory for operators/helpers
- Disposable paper coveralls with vinyl coating
- Gloves
  - polyvinyl chloride (PVC)
  - neoprene
  - leather/heat-treated cotton
- Neoprene full-body suits
- Neoprene boots
- Hardhats
- Safety goggles

The plant Safety Office reported good worker acceptance of the program. Cotton coveralls are issued to workers permanently assigned to the facility to provide protection against contact with coal tars. Coveralls are to be worn whenever the worker is within the facility. Seven coveralls are issued to provide each worker with spares and a set for cleaning.

Disposable coveralls are available at the plant Safety Office supply room and are to be used by maintenance personnel when performing activities with a potential for contact with coal tars. Workers permanently assigned to the unit are also encouraged to use these disposable coveralls in place of cotton coveralls in completing duties where there is a possibility of contamination. The contaminated disposable coveralls should be removed upon completion of the job and disposed of with the ash. Contaminated suits should not be taken out of the facility.

Rubber or PVC gloves are used while handling tars, oils, and phenolic liquor. Leather gloves inserted in the cotton gloves are used by the operators to grasp the rods during poking operations. Slip-on boots are provided to prevent contamination of the worker's shoes while in an area contaminated with oils or tars. Boots should be removed when leaving the contaminated area.

A full-body suit is used in any activity requiring entry into a vessel contaminated with tars, oil, or phenolics. This includes the detarrer, deoiler, and cooler. The suit is steam cleaned after each use. However, because steam cleaning is not completely effective in removing tars and oils these suits are discarded when judged to be too contaminated by the supervisor.

Available safety equipment includes ear muffs and respirators. Ear muffs are recommended for workers entering the coal pit (410 level) when the vibrating feeder is in operation. The five types of respirators available include:

- 5-minute escape pack
- 30-minute, pressure-demand, self-contained breathing apparatus (SCBA)
- Pressure demand supplied-air respirator
- Disposable dust respirators
- Comfo II full-mask with acid gas/organic vapor cartridges.

All respirators are made by the Mine Safety Appliances Company.

The 5-minute pack is intended to provide the worker with sufficient time to evacuate an area under emergency conditions. Emergency situations include fire, explosion, and high CO levels greater than 1500 ppm. Two air packs are located in each of three locations to provide ready accessibility in an emergency. These areas are the rectifier room (475 level), control room (448 level) and the coal bunker (521 level). Plant policy requires that these packs be serviced by the Safety Office after each use.

The SCBAs are intended for use during emergencies to enter or evacuate the area. Entry is limited to periods of less than 30 minutes, and all SCBAs are equipped with an audible low air supply warning device. The SCBAs are located in the elevator, control room, coal bunker area (521 level), and coal pit (410 level). The SCBAs are maintained and serviced by Security personnel.

The other respirators are kept in the control room. The supplied-air respirators are not used when repacking poke holes, disassembling gas lines, cleaning spills, or for repair work where there is a potential for release of toxic material. These respirators are not used in IDLH (immediately dangerous to life and heatlh) areas. The Comfo II respirator is used while mixing soda ash. Disposable dust masks are intended for use in areas such as the coal pit (410 level) where there is coal dust.

All workers entering the facility must participate in a training program that includes the proper use of respirators. Training is required semi-annually for maintenance workers and yearly for other workers. Each employee is responsible for the proper function of his assigned respirator. Used and malfunctioning respirators are given to the Safety Office for cleaning and repair.

All respirators except SCBAs are inspected every two weeks by the Safety Office. SCBAs are inspected every two weeks by Security. In addition, the second shift security supervisor, who is certified, inspects all respirators in the control room on a periodic basis.

V. MONITORING

A. Continuous CO Monitoring

Carbon monoxide is a major constituent of the product gas (26%) and has therefore been selected as an indicator gas for detecting leaks in the system or identifying areas with high levels of process constituents. Continuous CO monitors are located throughout the facility and are designed to trigger an alarm in the control room when CO levels exceed 50 ppm, and an audible/visual alarm outside the control room when levels exceed 200 ppm. The visual alarm, a flashing red light, is situated outside the control room to notify anyone entering the facility that a condition of high CO level exists within the facility. Only properly trained personnel are admitted to the facility under these conditions. The only persons admitted are those who are properly equipped to assist with the emergency.

There are 12 CO sensor probes, located in the gasifier bay; in the dust, tar, and oil recovery bay; at the 426 level; and in the 521 level (vibrating screen area). The system is equipped with an audible alarm with the trigger point set at 50 ppm and an audible/visual alarm set at 200 ppm. The audible and visual alarms are located outside the control room (448 level) and at the control panel. Hand-held CO monitors are also provided. Provisions for their use as well as guidelines for responding to the audible and visual alarms were presented previously.

The audible alarm is used to alert workers already in the facility of the problem. Because the audible alarm for high CO levels is the same as that signifying process upsets, the control room operator will use the page phone to inform all workers of the reason for the alarm. This message is repeated twice. If any worker cannot decipher the message because of noise he is required to pick up the nearest page phone and request that the message be repeated.

B. Industrial Hygiene Monitoring

Guidelines and regulations to protect workers from the flammable and toxic nature of the product gas constituents are supplemented by monitoring activities. Plant management considers hydrogen sulfide, carbon monoxide, and the polynuclear aromatics in the tars and oils to be the major health concerns.

VI. NIOSH SAMPLING PROGRAM

Although the gasifier operates on bituminous coal, startup and shutdown are performed with anthracite. The NIOSH sampling program included two sets of samples, one taken when operating on each coal type.

A. Bituminous Coal Gasification

1. Walk-Through Survey August 18-20, 1980

Area and grab samples were collected at this facility under NIOSH Contract 210-78-0040 (Industrial Hygiene Characterization of Coal Gasification Plants) to identify emissions during bituminous coal gasification. Sampling and analytical procedures used in this survey were the same as those used in performing the anthracite gasification survey (Section VI-B and Appendix A).

Low-sulfur anthracite coal is used to start-up the gasifier because the gas produced is clean. After the gasifier has achieved steady-state operation on anthracite, the operators begin feeding bituminous coal to the gasifier. The anthracite gasification cyclone/condenser and flare stack are not used during bituminous coal gasification. Instead, product gas from the gasifier is passed through a clean-up system consisting of a detarrer, washer, cooler, deoiler, and Stretford unit. The only equipment used during both anthracite and bituminous coal gasification is the coal feed system, the gasifier, and the ash systems. The results of this sampling show the following:

- Benzene, toulene, and xylene were not detected.
- Airborne and aromatic amines were not detected.
- Analysis for ionizing radiation showed background levels or less.
- PNA's were detected at or below ug/m^3 levels as shown in Table 4.
- Total particulates detected were 0.1 mg/m^3 or less as shown in Table 5.

TABLE 4

PNA Analytical Results in ug/m^3 for Bituminous Coal Gasification
Gasification Facility, Pennsylvania
August 18-20, 1980

Sample Site		Top of Gasifier	Poke Hole	Day Tar Tank	Between Cooler and Deoiler	Between Washer and Detarrer	Blank[a]	
Sample Number		005	009	017	020	021	026	033
Sample Volume(L)		4416	4480	4618	4020	4020		
Sample Time		2205-0605	2203-0610	2208-0630	2118-0435	2118-0435		
Compound	Detection Limits ($\mu g/m^3$)							
Naphthalene	0.01	12.4	3.2	5.4	4.2	5.1	0.2	-
Quinoline	0.01	-	-	-	-	-	-	-
2-Methylnaphthalene	0.01	4.1	1.4	3.1	2.7	2.5	0.09	-
1-Methylnaphthalene	0.01	3.2	0.6	1.7	1.1	1.06	0.05	-
Acenaphthalene	0.01	-	0.03	0.3	-	-	-	-
Acenaphthene	0.01	0.1	0.06	0.2	0.07	0.05	0.03	-
Fluorene	0.01	0.1	0.07	0.6	0.08	0.04	-	0.1
Phenanthrene Anthracene	0.01	0.1	0.09	0.6	0.2	0.1	0.09	0.2
Acridine	0.01	-	-	0.01	-	-	-	0.2
Carbazole	0.01	-	-	-	-	-		-
Fluoranthene	0.01	0.01	0.01	0.02	0.02	0.01	-	0.08
Pyrene	0.01	-	0.01	0.02	0.01	0.01	-	0.07
Benzofluorene	0.01	-	-	-	-	-	-	0.08
Benz(a)anthracene Chrysene Triphenylene	0.01	-	-	-	-	-	-	0.03
Benzo(e)pyrene Benzo(a)pyrene	0.01	-	-	-	-	-	-	-
Perylene	0.01	-	-	-	-	-	-	-
Dibenz(a,j)acridine	0.01	-	-	-	-	-	-	-
Dibenz(a,i)carbazole	0.01	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	0.01	-	-	-	-	-	-	-
Dibenzanthracene	0.01	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	0.01	-	-	-	-	-	-	-
Coronene	0.2	-	-	-	-	-	-	-
Dibenzpyrene	0.2	-	-	-	-	-	-	-
PNA TOTAL		20.02	5.5	12.0	8.4	8.9		
Benzene Soluble[b] Fraction	Filter	10	-	-	-	-	-	

[a] nanograms per sample

[b] detection limit 10$\mu g/m^3$

- dash denotes not detected

TABLE 5

Total Particulate Analytical Results for Bituminous Coal Gasification
Gasification Facility, Pennsylvania
August 18-20, 1980

Sample				Concentration (mg/m^3)
Number	Volume(L)	Time	Location	
-002	918	2150-0553	Vibrating screen (521 level)	0.03
013	974	2213-0620	Ash pan (439 level)	0.03
019	966	2130-0533	Middle of conveyor belt to coal bunker (521 level)	0.1
026	960	2122-0522	Between deoiler and detarrer	0.08
027	912	2123-0523	Washer (448 level)	0.1
029	1056	2132-0532	Ash Pan (439 level)	0.1
028			Blank	-
035			Blank	-

- denotes not detected

- Analyses of airborne samples for trace metals showed that these were below the detection limit although they are present in both the coal and ash as shown in Table 6.
- Direct reading measurements for CO, hydrocarbons, SO_2, H_2S, NH_3, NO_x, CS_2, HCN, AsH_3, O_3, and mercaptans gave negative results at all levels except as shown in Table 7.
- Qualitative screening of silica gel airborne samples indicated the presence of those compounds shown in Table 8.

Wipe samples were taken during bituminous coal gasification of work surfaces in the gasifier area and in the control room and from rubber gloves used by the operators in handling contaminated equipment. Results show the presence of PNAs containing three or more aromatic rings. Whether the source of these PNAs was anthracite or bituminous coal cannot be determined because the contaminated surfaces were exposed during both anthracite and bituminous coal gasification. However, these results confirm that heavier PNAs can be deposited on work surfaces within the facility. Since these heavier PNAs include known skin carcinogens such as benzo(a)pyrene, skin contact can be an important mode of PNA exposures if the protective clothing provided is not worn.

2. Comprehensive Survey, May 1981

A comprehensive survey of the gasification facility was conducted during the week of April 27 to May 1, 1981, while the facility was gasifying bituminous coal. In this survey 24 personal and 40 area samples were collected to evaluate worker exposure to benzene, toluene, and xylene (BTX), and to PNAs. Workers selected included the remote operators, utility helpers, and maintenance people having assigned duties in the gasification facility. Details of the comprehensive survey are presented in Final Report, Comprehensive Industrial Hygiene Survey, Coal Gasification Plant, Enviro Control Division, March 1982, Contract No. 210-78-0040, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

BTX was not detected in 11 personal and 17 area samples indicating concentrations of less than 0.01 ppm, the detection limit of the analytical method. With potential exposure of less than 0.01 ppm, worker exposure is insignificant.

TABLE 6

Trace Metal Analytical Results for Bituminous Coal Gasification, Bulk Coal and Ash Samples, ppm by Weight, Gasification Facility, Pennsylvania

August 18-20, 1980

		Coal	Ash
Compound	Detection Limits (ppm)		
Beryllium	0.001	1.0	< 0.001
Cadmium	0.001	0.6	4.4
Tellurium	0.001	< 0.001	0.7
Copper	0.14	14.4	23.7
Manganese	0.14	7.5	4.4
Nickel	0.14	15.0	32.1
Arsenic	0.07	8.0	9.9
Strontium	0.14	26.2	124.3
Magnesium	0.14	422.5	374.2
Mercury	0.03	0.8	0.4

TABLE 7

Direct-Reading Measurements in ppm Bituminous Coal Gasification Gasification Facility, Pennsylvania

August 18-20, 1980

Location	CO	Hydrocarbons	Comments
Top of Gasifier 475 Level	ND-8	ND	Not Detected: SO_2, H_2S, NH_3, NO_x, CS_2, HCN, AsH_3, O_3, Mercaptans
Poke Hole 455 Level	ND-5	ND	
Coal Conveyer to Coal Bunker 521 Level	5-21	ND	No other compounds testes for
Top of Deoiler, Washer, Cooler 475 Level	5-60	ND-1	
Top of Detarrer	ND-55	ND-1	
Extra 448 Level	ND-5	ND-1	
Ash Pan 439 Level	ND-5	ND	
Ground Level (426)	ND-5	ND	

Compound

		SO_2	H_2S	NH_3	NO_x	HCN	Mercaptans
Stretford Unit	a	ND	ND	0.5	ND	ND	NT
448 Level	b	ND	ND	0.8	NT	2	NT
Wash Settling Tank (Outdoors)		NT	2	NT	NT	NT	16

a-Stretford Slurry Tank
b-Stretford oxidizer

ND-Not detected
NT-Not tested

Note: Values are concentration above background outside facility (5 ppm)

TABLE 8

Qualitative Silica Gel Sampling Results for Bituminous Coal Gasification, Gasification Facility, Pennsylvania

August 18-20, 1980

Sample Location Sample Volume(L) Sample Time	Top of Gasifier 96 2157-0558	Poke Hole 97 2207-0614	Blank 1	 2
Qualitative Screening Results (Screened by GC/MS using aliquot of extract from sample)	Naphthalene 1-Methylnaphthalene 2-Methylnaphthalene Trialkyl-substituted Benzene Dihydro-Dimethyl substituted Indene	Naphthalene 1-Methylnaphthalene 2-Methylnaphthalene Hexahydro-Dimethyl-Propyl-Naphthalene Methyl-Dimethylethyl Phenol	None detected	None detected

PNAs were detected both in the plant and the control room. Levels in the plant ranged from 13 to 76 ug/m^3. The OSHA PEL for naphthalene is 50 mg/m^3, thus the gasification process emits low ariborne levels of two and three ring aromatic hydrocarbons. Control room levels ranged from 13 to 31 ug/m^3, although the control room is ventilated with outside air. A portion of the PNAs found in the control room is due to the presence of tobacco smoke in the room while the samples were being taken.

The remote operators were monitored for their exposure to PNAs. Exposures averaged 20.5 ug/m^3 (10.4 ug/m^3 - 26.2 ug/m^3) while performing their routine monitoring assignments. The operators sampled averaged about 70% of their time in the control room. The presence of tobacco smoke in the control room and the fact that the operators spent most of their time there makes the source of their PNA exposure indeterminate.

The utility helpers time is divided between coal handling activities outside of the structure, activities inside the structure such as poking activities, and time spent in the control room. The two workers sampled had measured PNA levels of 14.8 ug/m^3 and 15.4 ug/m^3 for an average of 15.1 ug/m^3. These levels indicate that the utility helpers exposure to PNAs is not significantly different from that of the operators, and as in the previous paragraph may be due in part to tobacco smoke.

The maintenance workers had an average PNA exposure level of 124.3 ug/m^3 (30.5 ug/m^3 - 389.4 ug/m^3). These exposure levels were associated with the performance of repair activities. Workers repairing tar and oil removal system equipment had the highest exposure levels. It should be noted that measured exposure levels of the maintenance workers to airborne PNAs are not necessarily actual exposure levels since when working inside process equipment NIOSH certified respirators are used. Thus in such situtations the measured level will represent ambient air concentrations, not the air the worker is breathing, and will be higher than the actual worker exposure.

The area and personal samples contained two and three ring PNAs such as naphthalene and its derivatives, phenanthrene, anthracine, and fluorene.

Wipe samples of equipment in the process area also showed the presence of four-ring species such as pyrene, benz(a)anthracine, chrysene, and triphenylene. Operators working on or around this process equipment can be exposed to these higher molecular weight compounds through skin contact, if they do not use the protective equipment provided them.

Qualitative analysis of wipe samples from maintenance tools and the outside of clothing showed the presence of PNAs containing from two to seven rings. Wipe samples taken from inside gloves showed no contamination. This indicates that maintenance workers may be exposed to PNA compounds of higher molecular weight than other facility workers, particularly if they do not use protective equipment and observe good work practices.

B. Anthracite Coal Gasification, August 9, 1980

A total of seventeen (17) 8-hour area samples and 19 detector tube measurements were taken during the gasification of anthracite coal to identify the types of contaminants present in the workplace. Appendix A provides the sampling and analytical procedures used in this survey. Area sample site selections were based on available process information and on an initial tour of the facility. These sites were selected because they represented:

- equipment known or suspected of leakage or other mechanical problems, and
- areas where an accumulation of process constituents can occur.

These area samples were analyzed to identify the types of organics, toxic gases, trace elements, and ionizing radiation present in the gasification facility and the dust levels in selected areas. The selected areas were:

- the vibrating screen at level 521,
- the cyclone/condensor system at level 521,
- the top of the gasifier at level 475,
- the pokeholes at level 455, and
- the ash pan quench at level 439.

Detector tubes were used to detect the presence of toxic gases. The toxic gases sampled for included hydrogen sulfide, sulfur dioxide, ammonia, nitrogen dioxide, ozone, arsine, carbon disulfide, and mercaptans. All detector tubes used were NIOSH approved except those used to detect arsine, carbon disulfide, and mercaptans. Detector tube measurements were made within a foot of the gasifier at levels 475 and 455 and the cyclone/condenser system at level 521. Measurements were taken while the gasifier was on-stream. Carbon monoxide measurements were made throughout the process area using a portable continuous reading instrument, the MSA CO Analyzer. The results of this sampling show the following:

- Benzene, toulene, and xylene were not detected.
- Analysis for ionizing radiation showed background levels or less.
- PNA's were detected at levels less than 1 ug/m^3 as shown in Table 9.
- Total particulates detected were 0.10 mg/m^3 or less as shown in Table 10.
- Airborne trace metals were not detected although they are present in both the coal and ash as shown in Table 11.
- Direct reading measurements for gases gave negative results at all levels except as shown in Table 12.
- Qualitative screening of silica gel and charcoal tube airborne samples indicated the presence of those compounds shown in Table 13.
- The presence of chlorinated hydrocarbons in the charcoal tube samples probably indicates contamination of the sample since one of the blanks contained tetrachloroethane.

Analysis of the six charcoal and three silica gel samples indicate the presence of aliphatics containing up to 8 carbon atoms. The simple aromatics including benzene, toluene, xylene, the aromatic amines, and phenolics were not identified in these samples. PNAs were detected in three silver membrane/Chromosorb 102 samples and included the lighter molecular weight compounds of two and three rings such as naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, acenaphthalene, fluorene, phenanthrene, anthracene, acridine, carbazole, fluoranthene, pyrene, and benzofluorene.

TABLE 9

PNA Contaminants in ug/m^3 for Anthracite Coal Gasification Gasification Facility, Pennsylvania August 9, 1980

Sample Location		Top of Gasifier (475 level)	Poke Hole (455 level)	Top of Gasifier (475 level)	Blanks[a]	
Sample Number		005	023	025	026	033
Sample Volume (2)		4416	4388	4434		
Sample Time		1658-0118	1810-0207	1730-0132		
Compound	**Detection Limits**					
Naphthalene	0.01	-	0.2	0.1	0.2	-
Quinoline	0.01	-	-	-	-	-
2-Methylnaphthalene	0.01	-	0.2	0.1	0.09	-
1-Methylnaphthalene	0.01	-	0.1	0.07	0.05	-
Acenaphthalene	0.01	-	0.03	0.02	-	-
Acenaphthene	0.01	-	0.03	0.02	0.03	-
Fluorene	0.01	0.04	0.1	0.09	-	0.1
Phenanthrene Anthracene	0.01	0.2	0.2	0.2	0.09	0.2
Acridine	0.01	-	-	-	-	0.2
Carbazole	0.01	0.02	0.01	-	-	-
Fluoranthene	0.01	0.04	0.03	0.03	-	0.08
Pyrene	0.01	0.05	0.03	0.02	-	0.07
Benzofluorene	0.01	-	-	-	-	0.03
Benz(a)anthracene Chrysene Triphenylene	0.01	-	-	-	-	0.03
Benzo(a)pyrene Benzo(e)pyrene	0.01	-	-	-	-	-
Perylene	0.01	-	-	-	-	-
Dibenz(a,j)acridine Dibenz(a,i)carbazole	0.01	-	-	-	-	-
Idene(1,2,3-cd)pyrene	0.01	-	-	-	-	-
Dibenzanthracene	0.01	-	-	-	-	-
Benzo(g,h,i)perylene	0.01	-	-	-	-	-
Coronene	0.2	-	-	-	-	-
Dibenzpyrene	0.2	-	-	-	-	-
TOTAL		0.4	0.9	0.6		
Benzene Solubles[b] Filter		-	-	-	-	-

[a] micrograms per sample

[b] mg/m^3

- dash indicates not detected

TABLE 10

Total Particulate Analytical Results for Anthracite Coal Gasification Gasification Facility, Pennsylvania

August 9, 1980

Number	Sample Volume(L)	Sample Time	Sample Location	Concentration (mg/m^3)
007	1000	1710-0130	vibrating screen (521 level)	0.06
008	992	1714-0130	coal conveyor (521 level)	0.08
017	966	1757-0200	ash pan (439 level)	0.08
018	966	1757-0200	ash pan (439 level)	0.1
028			blank	ND
035			blank	ND

ND - Not detected.

TABLE 11

Trace Metal Analytical Results for Anthracite Coal Gasification, Bulk Coal and Ash Samples, ppm by Weight, Gasification Facility, Pennsylvania

August 9, 1980

Compound	Detection Limits ppm	Coal	Ash
Beryllium	0.001	1.0	<0.8
Cadmium	0.001	<0.001	1.2
Tellurium	0.001	<0.001	<0.001
Copper	0.14	12.5	31.2
Manganese	0.14	2.5	10.6
Nickel	0.14	23.7	34.4
Arsenic	0.07	1.8	10.2
Strontium	0.14	30.6	22.5
Magnesium	0.14	328.7	479.3
Mercury	0.03	0.5	1.0

TABLE 12

Direct-Reading Measurements in ppm for Anthracite Coal Gasification
Gasification Facility, Pennsylvania

August 9, 1980

Location	CO	Hydrocarbons	Comments
Coal Conveyor 521 Level	ND-2	ND	No other compounds tested for.
Condenser-Cyclone 521 Level	20	ND	Not Deteced: NH_3, H_2S, SO_2, NO_x, AsH_3. No other compounds tested for.
Top of Gasifier 475 Level	ND-110	ND	Not Detected: H_2S, SO_2, NO_x, O_3 AsH_3, CS_2, Mercaptans. No other compounds tested for.
Gasifier Pokehole 455 Level	ND-20	ND	Not Detected: H_2S, SO_2, NO_x, O_3 AsH_3, CS_2, Mercaptans. No other compounds tested for.
Ash Pan 439 Level	ND-5	ND-1	No other compounds tested for

ND - Not Detected

TABLE 13

Charcoal Tube and Silica Gel Sampling Results for Anthracite Coal Gasification Facility, Pennsylvania

August 9, 1980

Charcoal Tube Samples				Silica Gel Samples		
Location	Volume (L)	Time	Qualitative Screening Results	Sample Volume(L)	Sample Time	Qualitative Sampling Results
Top of gasifier (475 Level)	492	1625-0037	Trichloroethane Tetrachloroetnane C_6 alkyl hydrocarbons C_8 alkyl hydrocarbons	97	1626-0033	Hexahydro-dimethyl-propyl-naphthalenone
Top of gasifer (475 Level)	97	1627-0034	Tetrachloroethane			NT
Condenser-cyclone	486	1726-0132	Tetrachloroethane C_6 alkyl hydrocarbons C_8 alkyl hydrocarbons	97	1726-0132	Hexahydro-dimethyl-propyl-naphthalenone
Condenser-cyclone	97	1726-0132	Tetrachloroethane			NT
Poke Hole	495	1810-0215	Trichloroethane Tetrachloroethane			NT
Poke Hole	97	1810-0215	Tetrachloroethane C_6 alkyl hydrocarbons C_8 alkyl hydrocarbons	97	1810-0215	ND
Blank 1			ND			ND
Blank 2			ND			ND
Blank 3			Tetrachloroethane			NT

ND: Not Detected
NT: Not Tested

A wide range of carbon monoxide levels were observed at the facility. The highest CO concentrations were recorded around the top of the gasifier (475 level) and the top gas outlet piping. Measurements taken within 6 inches of the piping indicated levels ranging from 75 to 110 ppm. A rapid drop-off was noted with increasing distance from the gasifier. At 1 foot, recorded levels ranged from 50 to 100 ppm and at 3 feet, 30 to 50 ppm. At distances greater than 3 feet, CO concentrations were less than 20 ppm, levels comparable to other floors. This rapid change in concentration is attributed to the dilution ventilation system.

The poking activity was of special interest because it involves opening ports in the gasifier while the facility is operating. The steam injection system for each poke hole was being adjusted while the CO levels were being recorded. CO levels obtained, therefore, are not representative of the system under normal operation but provide an indication of the CO levels that can occur when this control system is malfunctioning. With the poke hole open, CO concentrations climbed above 500 ppm, the maximum readout on the CO analyzer. Elevated levels continued as long as the poke hole remained open and dropped to 50 ppm within 45 minutes of closing the poke hole. At the 475 elevation, CO concentrations ranged from 200 to 450 ppm during the poking activity.

The results for CO monitoring suggest that a failure of the steam injection controls could lead to an acute overexposure to CO for operators and other workers on adjacent levels. The audible CO alarm/page system described earlier and the use of portable CO monitors provide a workable system to keep people in the facility aware of any potential problems arising from high CO levels. Other toxic gases were not detected.

The coal feed system including vibrating screens, vibrating feeder, and conveyor is operated on an as-needed basis. The vibrating screen at the 521 level would be considered by plant personnel to be the major dust generator if the dust cover were removed. Although the coal feed system was not used during the sampling period, the vibrating screen at level 521 and the ash pan at level 439 were still sampled for total particulates. Results are given in Table 10 while Table 14 provides sizing data.

TABLE 14

Particle Size Distribution - Anthracite Coal Gasification
Gasification Facility, Pennsylvania
August 9, 1980

Size Range (μm)	Number of Particles		Numerical Percent		Cumulative Numerical Percent		Volume Percent		Cumulative Volume Percent	
	Coal	Ash	Coal	Ash	Coal	Ash	Coal	Ash	Coal	Ash
0.4-0.7	10	96	3.2	30.8	3.2	30.8	0.0003	0.068	0.0	0.068
0.7-1.0	16	65	5.1	20.8	8.3	51.6	0.002	0.161	0.002	0.228
1.0-1.5	20	32	6.4	10.3	14.7	61.8	0.005	0.224	0.007	0.453
1.5-2.1	22	24	7.0	7.7	21.7	69.5	0.017	0.476	0.024	0.929
2.1-2.9	35	22	11.2	7.0	32.9	76.6	0.075	1.234	0.099	2.163
2.9-4.2	41	22	13.1	7.0	46.0	83.6	0.250	3.491	0.349	5.654
4.2-5.9	48	28	15.3	9.0	61.3	92.6	0.827	12.566	1.176	18.220
5.9-8.3	48	14	15.3	4.5	76.7	97.1	2.340	17.771	3.516	35.991
8.3-11.8	34	7	10.9	2.2	87.5	99.4	4.687	25.182	8.203	61.123
11.8-16.6	14	1	4.5	0.3	92.0	99.7	5.459	10.155	13.662	71.277
16.6-23.5	10	1	3.2	0.3	95.2	100.0	11.029	28.722	24.691	100.0
23.5-33.3	10	ND	3.2	-	98.4	-	31.194	-	55.885	-
33.3-47.1	5	ND	1.6	-	100.0	-	44.115	-	100.0	-

- Denotes none detected

Four air samples collected at the coal conveyor (521 level) and ash pan (439 level) were analyzed for the following trace elements: beryllium, cadmium, tellurium, copper, manganese, nickel, arsenic, strontium, magnesium, and mercury. None of these elements were detected in these four air samples. Bulk samples of anthracite and ash were then analyzed to determine the corresponding concentrations of these elements. Results of the bulk analyses are shown in Table 12.

Gross alpha, beta, and gamma radiation analyses were performed on two air samples and bulk samples of anthracite and ash. Results indicated background levels (5 to 10 counts/100 minutes) for alpha radiation. Beta and gamma radiation were not detected in either the air samples or bulk samples for particulates collected in these areas. Optical sizing showed that particles less than 10 um accounted for 87% of the coal dust at the 521 level and 99% of the ash dust at the 439 level, Table 14.

A floor-by-floor survey of noise levels was conducted on August 9, 1980. Results are shown in Table 15 and represent on-stream conditions. The observed noise levels do not suggest a potential problem in these areas. However, higher levels (85-95 dBA) were noted when the gasifier poke holes were opened and steam valves adjusted. Exposures at these higher levels for the short time period of 15 to 20 minutes required to complete these tasks is not expected to pose a problem.

TABLE 15

Noise Levels By Floor-Anthracite Coal Gasification
Gasification Facility, Pennsylvania
August 9, 1980

Floor	Noise Level (dBA)		Source
	Minimum	Maximum	
475 level	70	80	Gasifier
455 level	80	90	Gasifier
439 level	80	87	Gasifier
521 level	70	79	Gasifier

Exposure to noise levels above 90 dBA occurs at the 410 level during the operation of the vibrating feeder. This could not be verified because this system was not operating during the survey. Personnel enter this area only to adjust the gate; normally no one is in the area during operation of the vibrating feeder. If entry during operation is necessary, ear muffs or plugs are used.

VII. MEDICAL PROGRAM

A medical program was initiated in September 1979 with the completion of the gasification facility. Workers assigned to the facility at that time consisted mostly of transfers from other facilities within the plant. These workers and new hires were given a pre-employment physical to establish a baseline for each worker with regard to their physical condition.

The pre-employment physical consists of a detailed medical history and a complete physical examination which includes:

- chest X-ray
- pulmonary function tests:
  - total forced expiratory volume
  - forced expiratory volume/one second
  - comparison graph
- SM 12 blood analyses
- urine tests including:
  - microscopic
  - pH
  - albumin
  - glucose
  - specific gravity
- skin examination
- ear, nose, and throat examination for respirator usage

The skin examination is given not only to workers assigned permanently to the gasification facility, but also to workers who may be assigned duties on an as needed basis within the facility, e.g., the maintenance workers.

Examinations will be repeated on an annual basis for the first 5 years and semi-annually thereafter for all employees permanently assigned to the unit, and for workers who may be assigned specific duties within the gasification facility.

The type of medical tests given and the frequency of the examinations were based on guidelines in NIOSH publication No. 78-120, Recommended Health and Safety Guidelines for Coal Gasification Pilot Plants.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Industrial hygiene surveys conducted at this gasification facility support plant management's assessment that the most hazardous activities are poking, cleaning and inspection of process equipment, and equipment maintenance. These activities are performed by the remote operators and maintenance staff; consequently, these workers have the greatest potential for exposure to hazardous agents.

Presented below are recommendations for improving the effectiveness of the current personal hygiene and respirator programs at the coal gasification facility.

- Shower and locker facilities are located next to the control room on level 455. Separate lockers for contaminated and uncontaminated clothing should be considered. The change area for street clothes should be located in a clean area.
- Currently the control room is used as the eating facility. The presence of workers with contaminated coveralls and the use of the control room as a depository for miscellaneous tools and equipment reduces the effectiveness of requiring workers to wash to control tar ingestion before eating. A separate lunch room should be considered in which coveralls and tools are prohibited.
- Two 5-minute escape packs are located in each of three locations: the rectifier room (475 level), the control room (448 level), and the coal bunker (521 level). SCBAs are located in the elevator, control room, and coal bunker. Other respirators, supplied air, disposable dust, and Comfo II full mask with acid gas/organic vapor cartridges, are located in the control room.
- Supplied-air respirators are not used under conditions immediately dangerous to life and health. SCBA's are necessary under such conditions.

Engineering controls that have been effective in reducing process emissions into the workplace at the gasification facility are discussed below. Also presented below are recommendations for improvements in the engineering controls to further reduce the potential for worker exposure to hazardous agents.

- All coal handling equipment above level 410 is enclosed and vented through a baghouse to the outside. This control has reduced coal dust emmissions.

- The gasifier pokeholes have been fitted with venturi steam injectors. These injectors draw air into the gasifier through the pokeholes, preventing the escape of toxic and flammable gases during the poking operation. In addition, pokehole covers that can be closed and latched by foot allow the operator to close the cover immediately after withdrawing the poke rod. It also allows the operator to close the cover without having to put his face close to the pokehole opening, where the concentration of any gases that have escaped will be greatest. Gaskets are installed on the pokehole covers to prevent leaks. Periodic checking of the cover gaskets for leaks with a portable CO monitor has added to the effectiveness of this control.

- The removal and handling of coal ash while it is wet effectively controls the emission of ash dust.

- The tar collection system is heat traced and insulated to ensure tar flow. Solidification of the tar will plug the tar handling equipment and transfer lines, necessitating maintenance and increasing exposure to PNA-containing material.

- CO monitors are connected to an audible and visual alarm outside the control room to warn workers of high concentrations of toxic gases. Currently the high CO alarm is identical to the alarm for a process upset, and workers must rely on hearing an announcement over the page system to know the reason for the alarm. Distinct audible and visual CO alarms should be considered to eliminate the possibility of confusing other conditions with CO emissions.

- The building ventilation system is an effective means of preventing the accumulation of potentially toxic or explosive gases.

- Disposal of the off gas from the feeding system should be addressed in the design stage, either to eliminate this or to handle it by incineration.

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APPENDIX A

Sampling and Analytical Protocol

Sampling devices used by the Enviro CTA survey team included charcoal tubes (600 mg size), silica gel tubes (875 mg size), and silver membrane filter/ Chromosorb 102 sample cassettes (Figure A-1) for organic analyses; cellulose acetate filters for trace elements and optical sizing of particulates; and PVC filters for total particulates and ionizing radiation. Charcoal and silica gel samples were collected at a flow rate of 100 ml/min. The silver membrane/Chromosorb cassette samples were taken at a flow rate of 9.2 liters per minute, and the filter samples (acetate and PVC) used a flow rate of 2 liters per minute. The filter cassettes were wrapped in aluminum foil to protect the collected sample against photodegradation. All samples were stored and shipped to the analytical laboratory in dry ice.

Charcoal and silica gel samples were analyzed for the contaminants listed in Table A-1, by gas chromatograph using NIOSH analytical methods. The selected contaminants (simple aromatics, phenolics, and aromatic amines) were chemical classes which Enviro suspected to be present in the process. Aliquots of these samples were also qualitatively screened by gas chromatograph/mass spectrograph (GC/MS) using a computer spectral library of more than 25,000 entries for other organic compounds.

The silver membrane/Chromosorb cassettes were analyzed for the 30 PNAs listed in Table A-1 for which analytical standards are available. These 30 PNAs were selected because Enviro suspects that compounds in this class are formed in the gasifier. Analyses were by GC/MS and capillary column chromatography.

Trace element samples were analyzed by atomic absorption for arsenic, beryllium, cadmium, copper, magnesium, manganese, mercury, nickel, strontium, and tellurium. PVC filters used for total particulates were preweighed at the analytical laboratory, and collected samples were analyzed gravimetrically.

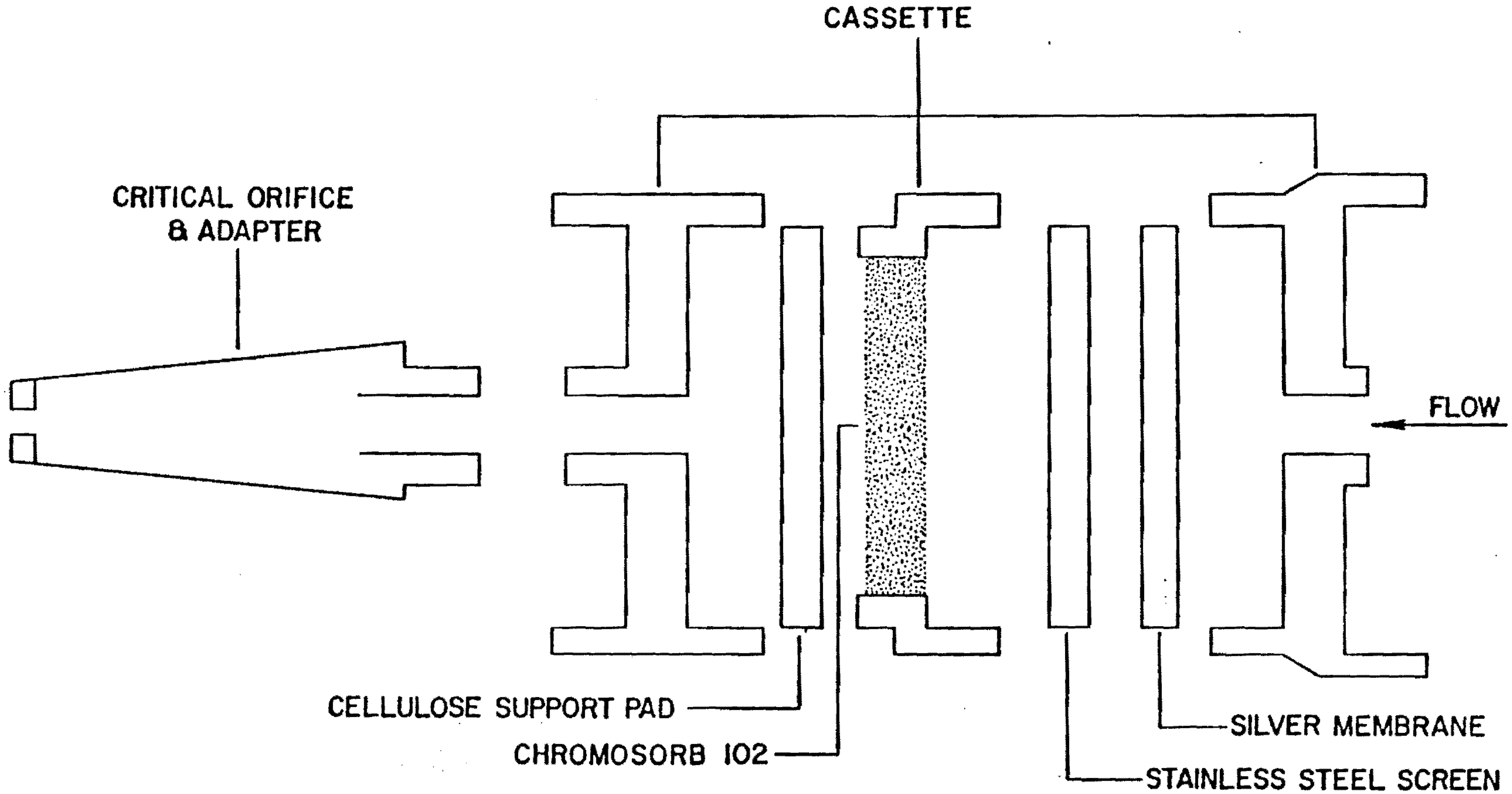

Figure A-1: HIGH-VOLUME SAMPLING DEVICE FOR PNA

TABLE A-1

List of Compounds for Which Quantitative Analyses Were Performed

Charcoal Tube	Silica Gel Tube	Filter/Chromosorb
Benzene	Aniline	Naphthalene
Toluene	N,N-Dimethylaniline	Quinoline
Xylene	2,4-Dimethylaniline	2-Methylnaphthalene
	p-Nitroaniline	1-Methylnaphthalene
	o-Toluidine	Acenaphthalene
	o-Anisidine	Acenaphthene
	p-Anisidine	Fluorene
	Alpha-naphthylamine	Phenanthrene
	Beta-naphthylamine	Anthracene
		Airidine
		Carbazole
		Fluoranthene
		Pyrene
		Benzo(a)fluorene
		Benzo(b)fluorene
		Benzo(a)anthracene
		Chrysene
		Triphenylene
		Dimethylbenz(a)anthracene
		Benzo(e)pyrene
		Benzo(a)pyrene
		Perglene
		Dibenz(a,j)acridine
		Dibenz(a,i)carbazole
		Indeno(1,2,3-cd)pyrene
		Dibenzanthracene
		Benzo(g,h,i)perylene
		Anthanthrene
		Coronene
		Dibenzpyrene

Ionizing radiation PVC filter samples were analyzed for gross alpha, beta, and gamma radiation using a proportional counter and NaI scintillation counter.

Analyses including preweighing of filters were performed at the University Hygienic Laboratory, University of Iowa, except for the optical sizing samples. These samples, collected on cellulose acetate filters, were analyzed at the Environmental Analysis Laboratory, LFE Corporation.

Bulk samples were taken of the coal and ash. These were analyzed using the methods noted above for trace elements and ionizing radiation.