FINAL

# CONTROL TECHNOLOGY ASSESSMENT

# FOR

# COAL GASIFICATION AND LIQUEFACTION PROCESSES

Combustion Engineering Process Development Unit
Windsor, Connecticut

Report for the Site Visit of
January 1979

Contract No. 210-78-0084

March 1982

Submitted to:

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## FOREWORD

On January 18, 1979, Enviro Control, Inc. (ECI) visited the Combustion Engineering Process Development Unit (C-E PDU) in Windsor, Connecticut to conduct a study of the technology to control worker exposure to hazardous agents at the facility. An initial meeting, held to acquaint personnel with the objectives of the control technology assessment (CTA) study was attended by the following persons:

National Institute for Occupational Safety and Health

Barry Pallay, Project Officer, Industrial Hygiene Characterization

Combustion Engineering

Susan Walker, Industrial Hygienist
Cornelius R. Russell, Project Engineer, Coal Gasification
Robert C. Patterson, Product Development Manager, Coal Gasification

Enviro Control, Inc.

James M. Evans, Project Manager
Donato R. Telesca, Principal Investigator
Russell K. Tanita, Senior Industrial Hygienist
Reuben Sawdaye, Industrial Hygienist

Because a fire had occurred in the baghouse, the visit was not completed. On March 8, 1979, a second visit was made to the Combustion Engineering PDU. The following persons were present:

Combustion Engineering

Robert C. Patterson, Product Development Manager, Coal Gasification
Allan R. Griggs, Manager, Low-Btu Coal Gasification
Cornelius R. Russell, Project Engineer, Coal Gasification

Enviro Control, Inc.

James M. Evans, Project Manager
Donato R. Telesca, Principal Investigator
Russell K. Tanita, Senior Industrial Hygienist

A comprehensive industrial hygiene survey of the plant was conducted in April 1981 by ECI under NIOSH Contract No. 210-78-0040 during a period of maximum coal feed rate. Additional control information obtained during this visit was used to augment information obtained from the CTA visits.

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## A. Contract Background

The objective of the "Control Technology Assessment for Coal Gasification and Liquefaction Processes" program is to study the control technology that is available to prevent occupational exposure to hazardous agents in coal conversion plants. This report details the control technology and industrial hygiene information gathered at the Combustion Engineering Process Development Unit (C-E PDU) located at Windsor, Connecticut, during the site visit of January 18, 1979.

Combustion Engineering, Inc. is developing this low-Btu gasification method for electricity generation under the sponsorship of the Department of Energy and the Electric Power Research Institute. The overall objective of the program is to produce an economical low-Btu coal gas to generate electricity in an environmentally acceptable manner with a minimum of process development. The Combustion Engineering project is of particular interest to this control technology assessment study because there is maximum use of proven processes with the only unproven process being gasification.

## B. History of the Combustion Engineering Low-Btu Gasification Project

The objective of the Combustion Engineering, Inc. (C-E) program is to produce an economical low-Btu coal gas to generate electricity with a minimum of process development. Data from the design and operation of the PDU is expected to provide a viable basis for scale-up to large-size equipment. Under the sponsorship of the Department of Energy (DOE) and an industry team composed of C-E and the Electric Power Research Institute, C-E has conducted a three-phase program involving the design, construction, and operation of a coal gasification pilot plant.

The process chosen for development was air-blown entrained gasification of coal at atmospheric pressure. Design of the Combustion Engineering Process Development Unit began in 1974. The unit, located at Windsor, Connecticut, has a capacity of five tons of coal per hour. By the end of 1975, the design of many of the subsystems was completed and preparation of the construction site began. Construction was completed in the fall of 1977; and the plant was dedicated on October 18, 1977. The first attempt to fire coal in the gasifier's combustor was made December 4, 1977, but problems were encountered in the plant's pulverizing system during start-up. During the first quarter of 1978, 122 hours of coal firing were logged, although continuous firing was hampered by erratic coal feed. About 58 tons of coal were burned in the combustor at rates from 250 to 3000 lbs/hour for up to 11 hours continuously. After analysis of the operational problems encountered with the PDU, gas-making operations were initiated in the second quarter of 1978.

## C. Description of the Facilities

The Combustion Engineering gasification process development unit is housed in an open, multi-storied structure. The individual unit operations and associated equipment are identified within this structure by the numerical identification system given in Table 1. The plant layout, Figure 1, shows the relative location of the unit operations.

The ground level of the process structure is covered with gravel. Individual equipment located on this level is set on concrete blocks. The presence of a gravel ground floor may cause some problems for the facility housekeeping program by hampering the cleanup of spills. During the survey, wet and caked coal dust and debris were evident at the ground and upper levels. This debris was the residual from the baghouse fire on January 16, 1979, and maintenance activities on the feed chute to the pulverizer which occured prior to the survey.

A combination of 18-gauge aluminized steel-ribbed siding and ribbed translucent panels are installed on the PDU structural steel on portions of the north, east, and west faces. Siding is being installed to comply with the Uniform Building Code, nominal 25 psf geographic area. Roofing, where installed, will comply with snow loading of 40 psf. The installation of siding is designed to protect both equipment and operating personnel to a practical extent from adverse winter weather.

Table 1

NUMERICAL IDENTIFICATION SYSTEM FOR UNIT OPERATIONS
(Combustion Engineering, Windsor, Connecticut)

| Identification Number | Process Area |
|---|---|
| 100 | Coal unloading and storage |
| 200 | Coal preparation - includes pulverizer and bag filters |
| 300 | Gasifier - includes induced heat removal |
| 400 | Ash handling - includes dewatering bin |
| 500 | Gas cleanup - includes spray dryer, cyclone, scrubber, sludge thickener |
| 600 | Char recycle - includes char storage bin |
| 700 | Sulfur removal and disposal - includes Stretford units |
| 800 | Product gas incinerator |
| 900 | Plant utilities and general services |

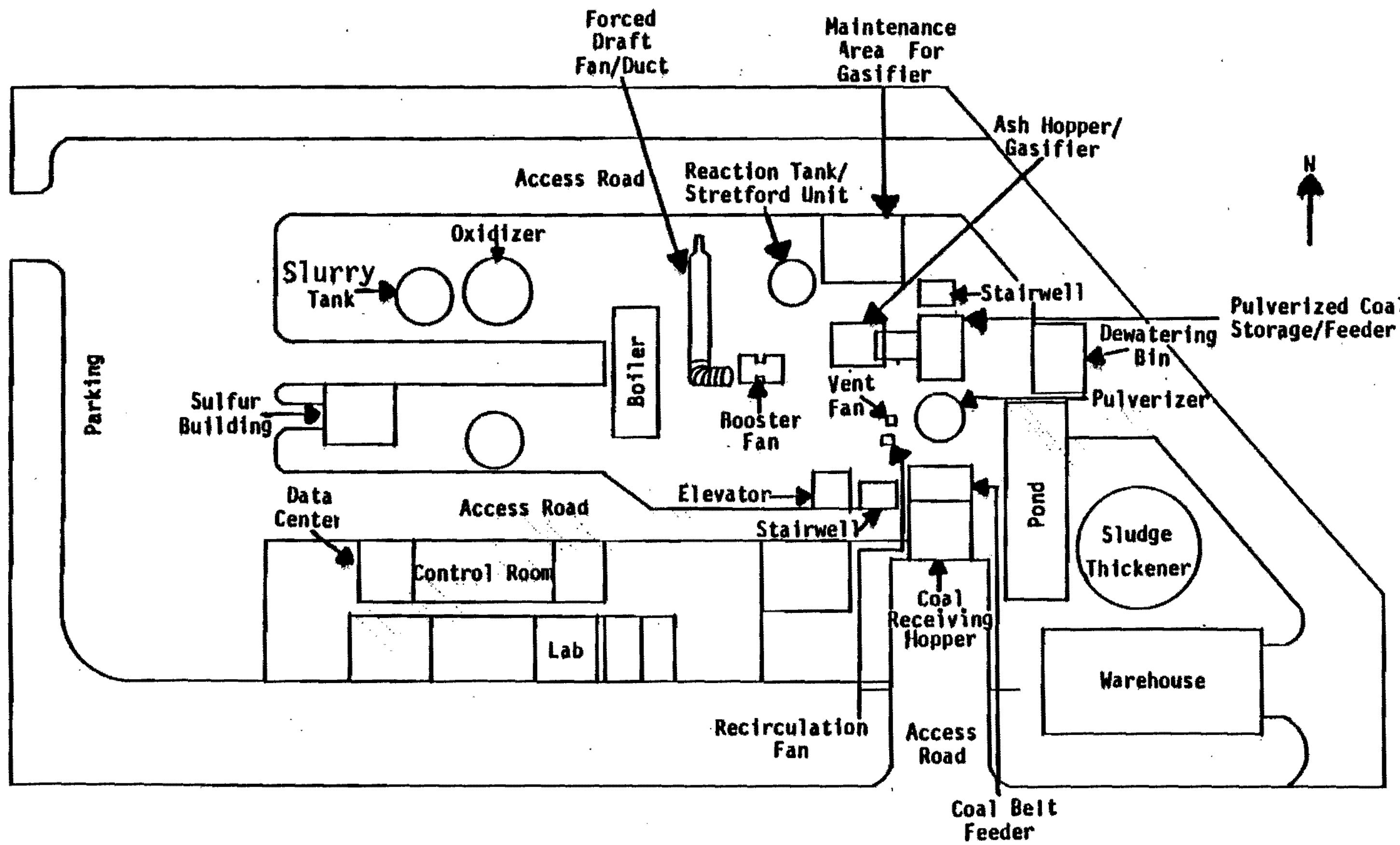


Figure 1. Layout of the Combustion Engineering Process Demonstration Unit

On each of the three faces, siding is installed only up to that elevation where rain and cold winds have inhibited work or presented problems with freezing. Above this level, isolated areas wherein freezing problems have occurred are being addressed individually. In most cases, siding does not begin at ground level but at the first elevation (approximately 12 feed above ground) to permit access by working personnel and equipment around the perimeter of the plant.

Plastic sheets were used as windbreakers on the upper levels of the structure to shield workers from the winds during the winter months. These sheets were located along the outside perimeter of the structure in high worker activity areas, such as the fifth level near the cyclone and scrubber.

## D. Process Description

The Combustion Engineering Low-Btu Coal Gasification Process Development Unit is illustrated schematically in Figure 2. Coal is stored off-site in a 10,000-ton contract storage facility and trucked as needed to the PDU. Process Unit 100 of the PDU accommodates unloading and storage of coal. It consists of an unloading hopper, transfer belt, bucket elevator, screw conveyor at the top of the bucket elevator, and a 400-ton coal storage silo. The coal storage silo is provided with a small baghouse filter to minimize fugitive dust emissions.

From the storage bin, coal is gravity-fed to the pulverizer where it is pulverized and dried. The pulverized coal is separated from the transport gas in a cyclone and gravity-fed into a storage bin. The cyclone exit gas is partitioned, with one part being recirculated to the pulverizer and the other part being vented through bag filters to the atmosphere.

The gasification process is based on an air-blown, atmospheric pressure, entrained-bed gasifier. In the process, a portion of the pulverized coal and recycled char are fed to the combustion section of the gasifier and burned to supply the heat necessary for the endothermic gasification reaction. In the combustion section, nearly all of the ash in the system

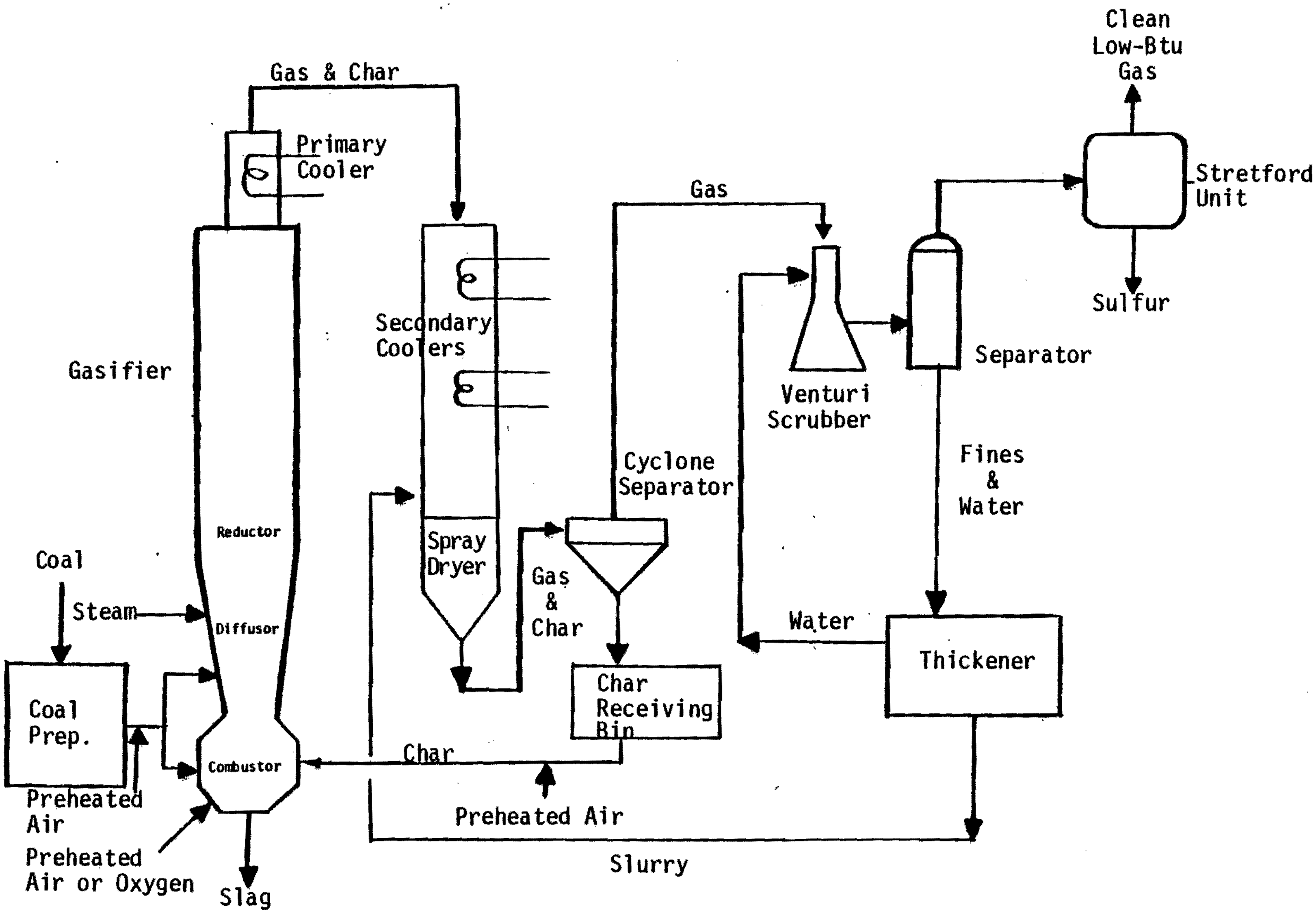


Figure 2. Schematic of the Combustion Engineering Low-Btu Coal Gasification Process

is converted to molten slag, which is then drawn off the bottom of the gasifier. The remainder of the pulverized coal is fed to the diffuser portion of the gasifier where it is mixed with hot gas entering the diffuser from the combustor. Gasification takes place in the reductor section of the gasifier where the coal is devolatilized and reacts with the hot gases to produce the desired product gas. This 1,700 F (925 C) product gas leaves the heat exchanger at 500 F. At this point, the gas contains solid particles and hydrogen sulfide that must be removed. Solids are removed and recycled by means of a spray dryer, cyclone separators, and venturi scrubbers. Hydrogen sulfide is removed and elemental sulfur is produced by the Stretford unit. The clean low-Btu gas (about 120 Btu per standard cubic foot) can then be delivered to the burners of boilers, gas turbines, or combinations of the two in a combined-cycle power generator.

## E. Potential Hazards

Table 2 lists the hazardous agents that may be present at each of the process areas or equipment cited. The potential for worker exposure to airborne dust would be the highest in the coal preparation area, in the vicinity of the coal and char feeders and droplegs to the feeders. As long as a less-than-atmospheric pressure is maintained, there should be no leakage of product gas into the surrounding work- place environment. Process upsets or positive pressure conditions may result in potential exposure to process constituents in the area of the gasifier, product gas ductwork, and induction fan. The Stretford Unit and the duct from the booster fan to the service boiler are operated at a pressure, slightly above atmospheric, and may lead to exposure from fugitive emissions. Qualitative area air sampling was performed at the PDU by an industrial hygiene survey team for the concurrent study "Walk-through Industrial Hygiene Characterization of Coal Gasification Plants" (NIOSH Contract Number 210-78-0040). Results of the survey are summarized in Appendix A.

Table 2

POTENTIAL HAZARDS BY PROCESS AREA/EQUIPMENT
Combustion Engineering, Windsor, Connecticut

| Process Area/Equipment | Potential Contaminants |
|---|---|
| Coal Preparation | Dust - primarily coal<br>Trace elements<br>Ionizing radiation<br>Noise |
| Gasifier | Polynuclear aromatics<br>Aromatic amines<br>Benzene, toluene, xylene<br>Hydrogen sulfide<br>Carbon monoxide<br>Sulfur dioxide<br>Nitrogen oxides<br>Noise |
| Ash Disposal | No exposure to personnel |
| Induced-Draft Fan | Polynuclear aromatics<br>Aromatic amines<br>Benzene, toluene, xylene<br>Hydrogen sulfide<br>Carbon monoxide<br>Sulfur dioxide<br>Nitrogen oxides<br>Noise |
| Stretford | Hydrogen sulfide<br>Carbon monoxide<br>Sulfur dioxide<br>Nitrogen oxides<br>Mercaptans<br>Ammonia |

II. CONTROL TECHNOLOGY

A. Engineering Controls

(1) Coal Receiving and Storage (Area 100)

(a) Process Description

Coal is stored off-site in the 10,000-ton contract storage facility. As needed, it is trucked to the plant and dumped into a ground-level receiving hopper. The coal is transferred by bucket elevator to a 400-ton coal storage bin. During the coal feeding cycle, displaced air from the storage bin is atmospherically vented through a filter assembly.

(b) Control Technology

To maintain low dust levels the coal can be wetted down by the use of water sprays before it is transported by bucket elevator to the storage silo. In addition, a small filter has been erected on top of the site to reduce dust levels.

The workers are not exposed to high noise levels at the PDU because the coal is received pre-sized and no further physical grinding of the coal is required.

The only special metallurgical requirements for the equipment in this area is the installation of stainless steel plates at the various transfer points to minimize the hangup which occurs as a result of moisture.

2. Coal Preparation (Area 200)

(a) Process Description

Process Unit 200 is the coal pulverizing, drying, and feeding process unit. From the storage bin, coal is gravity-fed to the pulverizer where it is pulverized and dryed. The pulverized coal is separated from the transport gas in a cyclone and gravity-fed into a storage bin. The cyclone exit gas is partitioned, with one part recirculated to the pulverizer and the other part vented through bag filters to the atmosphere via the vent fan. The pulverized coal feeders are auger-type gravimetric feeders.

To provide experimental flexibility, the PDU gasifier is not direct-fired by the pulverizer as a commercial-size gasifier would be. The PDU uses an indirectly fired or bin-supplied firing system. It consists of a small bowl mill under the coal storage silo; a 20-ton pulverized coal (p.c.) storage bin; a cyclone separator; recirculation and vent fans; a bag filter on the system vent; a hot flue gas supply duct from the plant boiler; interconnecting ductwork for the close-loop pulverizing system; four p.c. feeders; two primary air fans; two exhauster blowers; and the primary air and p.c. transport piping to the combustor windboxes and reductor fuel nozzles.

(b) Control Technology

Coal from the raw coal storage silo is fed through the volumetric feeder into a C-E type RB bowl mill capable of grinding 16,800 pounds per hour of coal.

Hot flue gas from the product gas incinerator enters the bottom of the mill, drys the coal being pulverized and transports it to a cyclone separator. The cyclone collects the pulverized coal and drops it into the storage bin. In an emergency, nitrogen can be supplied to the flue gas system to inert the atmosphere. A recirculation fan sends the flue gas back through the mill. To control temperatures in the loop, a vent fan draws expanded (cooled) gas from the loop discharging it to the atmosphere through the baghouse dust collector - while drawing in hot make-up flue gas from the product gas incinerator. The loop control temperature is 170 F at the pulverizer outlet. In the event of a mill puff the force is expelled through the baghouse which is equipped with rubber-type blow out panels. The baghouse is also equipped with an automatic shaking system so that the bags are shaken clean periodically thus maintaining their cleaning efficiency.

Utilizing the indirect firing system, pulverized coal from the storage bin is fed by gravimetric feeders to venturi pickups. Primary air from the gasifier force draft fan, heated through the tubular air heater, transports the coal from the venturi pick-ups to tangentially arranged fuel nozzles in the combustor and reductor sections of the gasifier. The coal feed and air control systems for the production scale gasifier will be similar to the commercial units used on utility boilers.

Control and measurement of coal pulverizing and firing is done remotely from the central control room. Equipment is insulated and/or electrically heat traced to prevent condensation. Receiving and storage bins are protected from spontaneous coal combustion by inert gas blanketing systems and gas monitors. In the area 200 there are special metallurgical requirements. Stainless steel plates, etc., to prevent hangup of coal caused by moisture are used where required. The entire system is under the Furnace Safeguard Supervisor System (FSSS[1,2,3]) design and the whole control process is an analog system, with digital interlocks for safety.

Combustion Engineering runs with two sampling trains because of the excess dust in samples, as high as 25 grains of dust per cubic foot makes oxygen measurement difficult. Because the analyzer requires an exceptionally high level of maintenance, and plant personnel expressed the need for an alternative system.

Combustion Engineering is directing its main effort toward the commercial utility practice. The same techniques are being used for the gasifier as for utility boilers; the primary difference is that in the utility boilers the mixture is air-rich while in the gasifier the mixture is fuel-rich.

3. Gasification (Area 300)

(a) Process Description

The PDU gasifier, process unit 300, is approximately 90 feet tall and 11 feet in internal diameter. Temperatures inside the gasifier are high, varying from a maximum of 3,200 F (1,760°C) in the combustion zone (combustor) to a minimum of 1,700 F (927°C) as the product gas exits the gasifier at the reductor outlet. Approximately one-third of the coal is fed to the gasifier combustor and the remaining two-thirds to the lower portion of the reductor called the diffuser. Construction of the gasifier walls is substantially the same as for commercial-size boiler designs, except that the inside of the gasifier is refractory-lined.

A gas-tight, fusion-welded wall of 1-1/2" thick steel, on the outside for thermal efficiency and personnel protection, comprises the main portion of the gasifier. The gasifier is air-blown and operates slightly below atmospheric pressure (-1/2" WG* at the reductor outlet).

(b) Control Technology

Pulverized coal is delivered to the gasification reaction chambers at the combustor and diffusor. Coal in the combustor is burned near stoichometric conditions. Reductor coal is fired with essentially no additional air.

The combustor has four coal injection nozzles and four char reinjection nozzles, all at the same elevation of tangential windboxes. There is one elevation of oil ignitors and warm up guns in four of the eight windboxes. Two elevations of reductor coal nozzles are located in the diffusor section.

The gasifier operates at slightly below atmospheric pressure. Seal welds have been utilized throughout the plant to avoid air leakage into the sys-

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*WG - water gauge is a meassure of pressure differential in terms of inches of water.

tem. Steam seals and mechanical packings are used on rotary and retractable sootblowers. When on line area oxygen analyzers are in service to give an indication of the amount of air leakage into the system. During an outage, the integrity of the system is checked by use of a smoke bomb test. Gasifier pressure parts are designed for 700 psi operating pressure at water temperatures up to 450 F. Heat picked up in the waterwalls is removed in a heat rejecting heat exchanger designed to provide measurement of heat absorbed in the combustor, diffusor, reductor and convection cooler sections of the gasifier.

Pressure transmitters for the high and low pressure water are used to protect the equipment in the event of the primary cooler system failure. Temperature, pressure, and flow rates can be seen on the control room board and are used to inform the operator of any upset conditions.

There are no special metallurgical requirements for the equipment in this area.

The Stretford unit was not removing hydrogen sulfide effectively. Equipment is being purchased to control and reduce the temperature at the Stretford to improve hydrogen sulfide removal efficiency. From an energy standpoint, the Stretford unit is the most economical for sulfur removal and its use is planned for the commercial unit.

4. Ash Removal System (Area 400)

(a) Process Description

The slagged ash handling system consists of conventional equipment of the same type supplied commercially to coal-fired utility power plants. The equipment consists of a refractory-lined slag tank located beneath the combustor taphole, a crusher, jet slurry pump, an ash dewatering bin, a cooling and low and high-pressure circulating water pump and necessary interconnecting piping. The slagged ash from the combustor collects in an ashhopper and is dumped when necessary into a dewatering bin. The dewatered slag is periodically disposed of by landfilling.

b) Control technology

Commercial equipment is used as much as possible in the PDU. The ash removal system, which is also a commercial system, was developed by the United Conveyor Corporation. A low pressure sluice and a two-stage high-pressure jet pump system are used for moving the ash. The ash system has a stand-alone protection quench system, which is commercially available. There are 20-32 reserve hours in the quench tank based on a twice-per-shift (every 4 hours) sluicing schedule.

Inhalation exposure is minimized by both the granular nature of the slag and the quenching operation.* The material dropping into the ashhopper is a glassy slag which fractures into smaller particles upon contact with the quench water. The material is sluiced out of the ashhopper every 4 hours to the dewatering bin. The water is sent to the cooling pond.

The ash system is on a recycle which allows the ash to be sluiced into a dewatering bin, and the water from the dewatering bin is fed back into the sluice system. The system is protected by water-level controllers and level alarm flow systems. Slag from the gasifier combustor goes through a "monkey hole" which is a hole in the center of the gasifier floor at the bottom of the combustor. The slag flows into the ashhopper where it is periodically removed by the sluicing pump. Oversized material is broken down in the ashhopper so that it passes freely into the dewatering bin.

No treatment or filtering is required before placing the material in the cooling pond. Periodically, the settled solids are removed from the cooling pond and disposed of by a commercial company. The ash has not been analyzed for trace elements, but because this is a closed loop, any trace metals present in coal will be found in the sludge. The slag, which is really a glass, contains less than one percent carbon. A test is underway to evaluate corrosion, but at the time of the visit, no corrosion or erosion had been found in the ash removal system.

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* See Appendix A

## 5. Particulate Removal System (Area 500)

### (a) Process Description

The product gas exiting the gasifier is cooled by a primary cooler to 825-850 F (450 C) and by secondary coolers to a temperature of 500 F (260 C) before entering the Process Unit 500 Particulate Removal System. This system separates and collects unburned carbon (char) and fly ash present in the product gas for refiring in the combustor. Major equipment in this area are a spray dryer, two cyclone collectors, a venturi scrubber and thickener, and necessary interconnecting piping and ductwork. Recycled liquid from the sludge thickener is used in the spray dryer to clean the raw product gas and in the wet venturi scrubber to remove entrained particulates. The particulates removed at the spray dryer consist of char and ash and are recycled to the combustor. The cleaned gas passes through a gas reheater in the top of the separator, then exits and passes through an induced draft fan which transfers the gas to the Stretford unit for sulfur removal. The gas is then burned in a boiler. The induced draft fan imparts a less than atmospheric pressure to the system from the top of the gasifier (-1/2" WG) to the induced-draft fan (-35" WG).

### (b) Control technology

Thickened slurry pumped up to the spray dryer has a solids concentration of approximately 20% solids during normal operation. It is atomized and dried to form particulate heavy enough for separation in the cyclone. Venturi scrubber solids concentration is maintained below 1 %.

A manual analysis of the thickened slurry is taken regularly to monitor solids collection rates. Monitoring and control of the char removal unit is accomplished form the central control room. In area 500, it has been necessary to use stainless steel, fiberglass piping and epoxy coatings because of the potential for corrosion. The gas scrubbing system has a ph of approximately 6. Makeup water for this sytem is approximately 2 to 4 gallons per minute.

6. Char Recycle (Area 600)

(a) Process Description

The char storage and feeding systems consist of a 20-ton storage bin, two auger-type gravimetric feeders, a char primary air fan, and the primary air and char transport piping to the combustor windboxes. The normal mode of operation is to recycle continuously to the gasifier all char collected.

(b) Control Technology

Char collected from the are 500 cyclone separator and multiclone and stored in the char storage bin is fed into the gasifier the same as the pulverized coal. Gravemetric feeders feed char though venturi pickups. Primary air, maintained at 350 F transports the char from the venturi pickups to tangentially arranged fuel nozzles in the combustor section of the gasifier.

Control and measurement of char firing is done remotely from the central control room. Equipment is insulated and/or electrically heat traced to prevent moisture condensation. The char storage hoppper is blanketed with nitrogen for safety.

With the exception of the feeders, which are stainless steel, there are no special matallurgical requirements in the area. All other equipment is carbon steel.

7. Sulfur Removal System (Area 700)

(a) Process Description

Included in the sulfur removal and disposal portion of the PDU is a combination hydrogen sulfide absorber/reaction tank through which product gas flows countercurrent to the Stretford scrubbing solution, an oxidizer tank in which reacted Stretford solution is sparged with air to regenerate the Stretford solution and float elemental sulfur floc, a slurry tank, a rotary vacuum filter to wash and dewater the sulfur, and a sulfur storage hopper. Only the Stretford absorber vessel is part of the product gas ductwork system, since other equipment is "stand-alone closed loop".

(b) Control Technology

Since a basic objective of this program is the development of an environmentally acceptable system to facilitate increased use of coal for production of electric power, it follows that control of particulate matter and sulfur compound concentrations to acceptable levels in the stack gas effluents of the plants that use this gasification system automatically becomes a requirement of the program. The Stretford $H_2S$ absorption process was selected for inclusion in this system because of its demonstrated ability to reduce $H_sS$ concentrations in various commercial process gas streams to very low levels. The PDU sulfur removal system has had no specific problems associated with leakage of sulfur or sulfur dioxide around the Stretford units. Because of the difficulty of maintaining solution operating temperature, elemental sulfur had been difficult to recover. Since the installation of two new coolers, one for cooling and product gas, and one for cooling the solution, the Stretford system has operated successfully: however, some of the fine particles have carried over from the char recovery system into the Stretford Unit, thereby contributing to the increase in solution solids concentrations.

There has been no odor of hydrogen sulfide ($H_2S$) or sulfur dioxide (SO ) in the area of the Stretford unit. Air samples have not been taken to determine the concentration of the hydrogen sulfide around the work areas in the 700 area.

Two exhaust fans have been installed in the roof and wall of the sulfur room, an enclosed structure on the fifth floor of the plant. The fans exhaust air directly to the outside environment with make up air entering from the open doorway. Fan efficiency was not checked because the sulfur recovery process was not operating during the survey.

Recovered sulfur from the PDU has been used by the Connecticut Department of Transportation in sulfur extended asphalt tests. Results will soon be available. There are special metallurgical requirements for this area. Because of the alkaline nature of the stretford solution, including the suspended solids in the solution gas, the pumps and control valves have been changed to stainless steel. The $H_2S$ absorber and the Stretford reaction tanks are coated with a coal tar epoxy lining to prevent corrosion.

## B. Monitoring

Continuous monitoring is directed towards the evaluation of key components in the process stream (hydrogen sulfide, nitrogen). Monitoring for health purposes is directed towards the hazards of carbon monoxide. There are eight monitoring stations in the process area using the CO ecolyzer system which is set to sound an alarm when carbon monoxide levels reach 50 ppm, the current federal standard. None of the alarms have been activated by process emission of carbon monoxide. However, there have been incidents when extraneous sources of carbon monoxide such as diesel engine exhaust have set off the alarms.

## C. Work Practices

### 1. Operating and Housekeeping Procedures

The gasifier is operated on a balanced draft mode. Welded construction of piping, ductwork, etc., is used whenever possible to prevent or reduce leaks for each process. Throughout the plant the unit has been designed for higher negative pressures to prevent damage form excursions during upset conditions. As part of the preventative maintenance program, an ultrasonic testing device is used during outages to determine possible weakening of walls in vessesl and/or piping. Smoke test, hydrocarbon atomizer tests, etc., are also used to pinpoint other possible leaks. Problems are recorded in a daily log book and reports are sent to the engineering group so that these problems can be investigated and necessary design changes instituted.

To protect the workers and the equipment, standard operating procedures have been established. These procedures are continually updated. Safety procedures have also been instituted with a process development unit manual, which describes the process and includes safety requirements for the particular area in which personnel work.

Most control valves are operated from a central control room. In addition, there are two stand-alone stations--one in the 100 area, which is the coal receiving and storage area, and in the 400 area, which is the ash removal system. Aside from these, there are no special equipment requirements in the plant.

Because the Combustion Engineering PDU operates under vacuum, with the exception of the coal preparation area, there have been few problems with valves or flanges. A valve (similar to a Keystone) with a resilient seat is recommended by Combustion Engineering.

The emissions from the plant are vented to the atmosphere from the stack in the 800 area, but to date, there are no plans to analyze these gases until the plant is operated at full load. Stack opacity is measured. Exiting gases have not entered the plant area to date.

## 2. Administrative Controls

### (a) Workforce Organization

The Combustion Engineering Pilot Plant workforce is composed of 20 shift workers and 16 nonshift workers. A breakdown of these employees by job title and positions in the plant organization is shown in Figure 3.

The plant operates with three 8-hour shifts, 24 hours per day, 7 days per week using five rotating shift crews. Each crew consists of one shift supervisor, one control room operator, and two plant equipment operators. One shift crew is off during the weekdays and two are off on weekends. On 4 weekdays, the day shift is manned by two crews; other shifts have one crew.

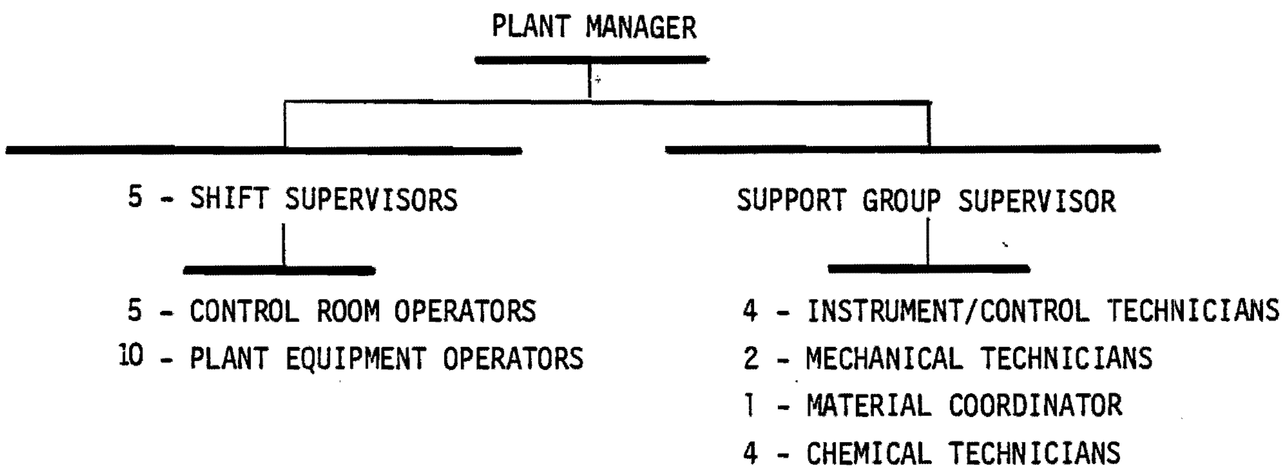


Figure 3. Combustion Engineering Organization

The nonshift personnel work the day shift, Monday through Friday, and consist of a support group supervisor, 4 instrument/control technicians, 2 mechanical technicians, 1 material coordinator, and 4 chemical technicians. One supervisor and two engineers also work at the PDU to maintain the computer system located adjacent to the control room and they seldom enter the process areas. These engineers are not part of the PDU staff but are members of the Combustion Engineering field testing department.

The support group staff handles general repair work and equipment maintenance activities. Plant renovations, repair, and maintenance activities considered to be a major effort are performed by an outside contractor. The contractor maintains a staff of about seven workers, primarily welders, to handle all welding activities and to complete major work activities. They work days only, Monday through Friday, and most of their activities are conducted in the process area.

(b) Job Description and Scheduling

All workers described below are potentially exposed, although to varying degrees, to hazardous agents emitted by the process. The equipment operators and maintenance staff are a particular health concern because their duties require that they be in the process area a majority of the time.

Shift Supervisor. The shift supervisor inspects the plant on a periodic basic to ensure that all process areas are operational and equipment is functioning normally. His duties require him to be in the field 60 to 70 percent of the time.

Control Room Operator. The control room operator operates the critical PDU equipment through the use of the analog and digital control systems. He coordinates the activities of the plant equipment operators when the plant is operating. When the plant is down, he performs routine maintenance activities. Time spent in the process area by the control room operator is 5 percent during plant operations and variable when the plant is down.

Plant Equipment Operator. The plant equipment operator is in the process area 60 to 70 percent of the time when the plant is in operation. At least hourly, he monitors and operates PDU equipment such as fans, pumps, conveyors, and stand-alone systems from local control stations located outside the central control room. During these rounds, he records operation and performance data such as pressure, temperature, and flow. In the event the control room workload becomes excessive, he functions as an assistant control room operator. When the plant is down, the plant equipment operator performs maintenance duties; his time in the field is variable during this period.

Support Group Supervisor. Responsibilities of the support group supervisor are primarily administrative and include scheduling of maintenance activities. Because his time in the process area is essentially zero, exposure is minimal.

Instrument/Control Technician. The instrument/control technician spends 25 percent of his time in the process area calibrating, repairing, and maintaining instrumentation and control equipment. Included in these duties are necessary modifications to commercially available analyzers and instrumentation for use in the PDU process and reprogramming the computer control system to meet changes in operating parameters. He also performs additional site maintenance functions when the plant is down.

Mechanical Technician. Equipment lubrication and other general and minor equipment maintenance activities are the responsibility of the Mechanical technician. Additional duties are performed as needed are are highly variable. He averages about 30 percent of his time in the process area.

Material Coordinator. The material coordinator has responsibility for receiving, storing, and shipping all materials, new equipment, and spare parts entering or leaving the plant site. He is in charge of spare parts accounting and has limited responsibility for ordering new material. As such, the coordinator spends more than 80 percent of his time in the warehouse. However, he is available to perform maintenance duties as required.

Chemical Technician. Approximately 15 percent of the technician's time is spent in the field collecting and analyzing samples, adding chemicals to treatment tanks including the Stretford unit. Process samples collected and analyzed include coal, char, ash cooling water, and the Stretford sulfur removal system solution. His field duties also include monitoring boiler water quality and maintaining the boiler water treatment system. In addition to the analysis of samples, his laboratory duties include the inventory and maintenance of laboratory equipment and chemicals. The technician also performs maintenance duties as needed.

3. Health and Safety Programs

There is no health and safety program specific to the Combustion Engineering Pilot Plant. Instead, health and safety is regulated by a division program under the Power Systems Group. The medical aspects of the program consist of a preemployment and annual examination; no special medical tests or monitoring activities are included. Examinations are standard as applied to all Combustion Engineering employees.

The preemployment physical examination includes chest x-rays and electrocardiograms. Electrocardiograms, chest x-rays, and pulmonary function tests are provided every third year as a part of the annual examination.

The Power Systems Group health and safety program has one industrial hygienist with responsibility for the C-E gasification pilot plant and 24 other plants. A sampling program to evaluate the pilot plant work environment is being implemented and consists of personal monitoring and area sampling. These results are supplemented by grab samples using direct-reading detector tubes for compounds such as hydrogen sulfide, carbon monoxide, and mercaptans.

Two industrial hygiene monitoring surveys have been conducted at this facility under Contract No. 210-78-0040. A summary of the results of these surveys is presented in Appendices A and B. Findings show low worker exposure to aromatic compounds at concentrations in the parts-per-billion range (microgram-per-cubic-meter).

As a part of this program, personal monitoring of equipment operations for arsenic exposure was undertaken in response to a request by the Department of Energy. This survey was expanded to include beryllium, cadmium, lead, and nickel. NIOSH-recommended procedures were used, and levels were reported to be below current federal limits.

Showers are not mandatory except in special cases. For example, if an operator is contaminated with process materials, the supervisor can direct him to shower and change clothes. A washer and dryer is located on the premises, and all clothing is washed.

## D. Personal Protective Equipment

Protective clothing and respirators are used to supplement engineering controls in controlling worker exposure to process constituents. Safety shoes, safety glasses, and hard hats are required in the process areas. Other protective clothing such as neoprene gloves and protective overalls are available; their use is mandated in operations where contaminated equipment may be handled or where splashes or spills may occur.

Respirators (half-mask Wilson repsirator with organic vapor cartridges) are required in activities where high vapor exposure may occur such as entering tanks or vessels. Employees engaged in these activities participate in the Power Systems Group respiratory program. This program consists of a physical examination which emphasizes the cardiorespiratory system, the maintenance and care of respirators, and respirator fitting.

## III. CONCLUSIONS AND RECOMMENDATIONS

The potential for worker exposure to coal dust is greatest in the coal preparation area, in the vicinity of the coal and char feeders and drop-legs to the feeders. However, this problem will be minimized in a commercial size gasifier. On a commercial-scale, the gasifier will be directly-fired from the pulverizer rather than indirectly fired through the reductor and combustor coal feeders as in the case in the PDU gasifier.

The slightly negative pressure operation of the Combustion Engineering gasifier provides an effective method to control exposure to process stream constituents. Leaks which may occur in seals and flanges and through erosion and/or corrosion of piping, vessels, and ductwork result in the workplace air being drawn into the gasifier.

The Combustion Engineering Process Development Unit is located in a multi-storied open structure. The open structure provides an effective method to control exposure to process constituents by natural dilution ventilation. Although the structure has been modified by enclosing the north and west sides, the remaining open sides allow sufficient ventilation while providing workers and equipment a degree of protection from severe winter weather.

The Combustion Engineering Furnace Safeguard Supervisor System (FSSS™) was developed as a safety system for utility boilers. This fuel firing protective technology is applicable to the entrained-bed gasification process, because the operation is similar to the C-E utility coal burner. It has the potential to ensure safe operation by continuously monitoring the firing parameters and providing automatic corrective action.

The current plant health and safety program provides some degree of protection against inhalation and skin contact with process constituents, especially the PNAs, in high-exposure activities. For example, workers potentially exposed to process constituents include the equipment operators and maintenance workers whose job responsibilities require them to enter and work in the process area. Equipment operators would most likely be exposed to process constituents during stream sampling. Maintenance exposures occur while working on on-line process equipment and when duties require vessel entry.

Greater emphasis should be placed on personal hygiene, a major tool in controlling prolonged skin contact with process constituents, especially the PNAs. Workers should be provided with sufficient change of clothing to insure a clean uniform for each work period. In addition, a clean area/dirty area system should be used in the locker rooms to segregate contaminated clothing from street clothing. Showers should also be mandatory.

The proposed industrial hygiene monitoring program should be implemented as soon as possible to characterize the exposure of the workers to workplace contaminants. This data would be useful evaluating the potential health risk of these workers with regard to their potential long-term exposures.

Results from the industrial hygiene walk-through sampling survey indicate that the concentrations of PNAs and simple aromatics such as benzene and toluene, are in the parts-per-billion/microgram-per-cubic-meter range. Compounds noticeably absent from the environment included aliphatics, aromatic amines, and phenols.

The respirator protection program can be improved by providing a greater selection of respirator types for different hazardous conditions that may occur. Escape-type respirators should be located throughout the facility for easy worker access during emergencies. Self-contained breathing apparatus should be readily available for rescue or emergency entry situations. Supplied-air respirators should be used in place of air-purifying respirators for vessel entry.

## REFERENCES

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3. Schuss, J.A., V. Pileika. "FSSS for Steam Gnerator Conversion to Alternate Fuel Firing," presented at Instruemtn Society of America, Power Symposium, Boston, Massachusetts, May 20-22, 1974, Combustion Engineering, Inc.

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# APPENDIX A

## Industrial Hygiene Characterization Walk-Through Survey Summary of Results

Samples taken by Enviro Control, Inc. included direct-reading detector tubes, a carbon monoxide analyzer, and 8-hour area samples (Table A-1). NIOSH-approved detector tubes were used, where available, to test for selected toxic gases. The area samples were used for the identification of organics, trace elements, and particulates.

Area samples for organic analyses were collected on charcoal tubes (600-mg size), silica gel tubes (875-mg size), and silver membrane filter/ Chromosorb 102 sample cassettes (Figure A-1). Charcoal and silica gel tube samples were collected at a flow rate of 100 ml/min. The cassette samples were collected at a flow rate of 9.2 lpm.

Charcoal and silica gel samples were analyzed for the contaminants listed in Tables A-2 and A-3 by gas chromatograph using the NIOSH analytical methods. The contaminants selected represented the simple aromatics, phenolics, and the aromatic amines; chemical classes which in Enviro's opinion may be found in the process. Aliquots of these samples were also qualitatively screened by gas chromatograph/mass spectrograph (GC/MS) and a compter spectral library of more than 25,000 entries for the presence of other organic compounds or compound classes.

The sample cassettes were analyzed for 30 polynuclear aromatics listed in Table A-4 for which analytical standards are available. The PNAs were selected for analyses because Enviro suspects their presence in the C-E process environment. Analyses were by GS/ MS and high-pressure liquid chromatography.

The trace elements and total particulate samples were collected on cellulose acetate and PVC filters, respectively, at a flow rate of 1 liter/min. Respirable dust samples were collected on PVC filters at 1.7 liter/min using 10-mm nylon cyclones. Particulate and respirable dust samples were analyzed gravimetrically and trace elements by atomic absorption.

Table A-1

EIGHT-HOUR AREA SAMPLING MATRIX FOR INDUSTRIAL HYGIENE WALK-THROUGH SURVEY:COMBUSTION-ENGINEERING COAL GASIFICATION PROCESS DEVELOPMENT UNIT

| Process Area | Sample Type: Charcoal Tube | Silica Gel | PNA | Trace Metals | Total Particulates | Ionizing Radiation | Respirable Dust |
|---|---|---|---|---|---|---|---|
| Coal Storage (100) | | | | | | | |
| Pulverizer (200) | | | | 1 | 2 | 1 | 2 |
| Gasifier (300) | 2 | 4 | 2 | 2 | | | |
| Ash (400) | | | | | | | 1 |
| Scrubber (500) | 1 | | 1 | | | | |
| Char (600) | 1 | 2 | 1 | 2 | | | |
| Environment (800) | 1 | | | | | | |
| Total | 5 | 6 | 4 | 5 | 2 | 1 | 3 |

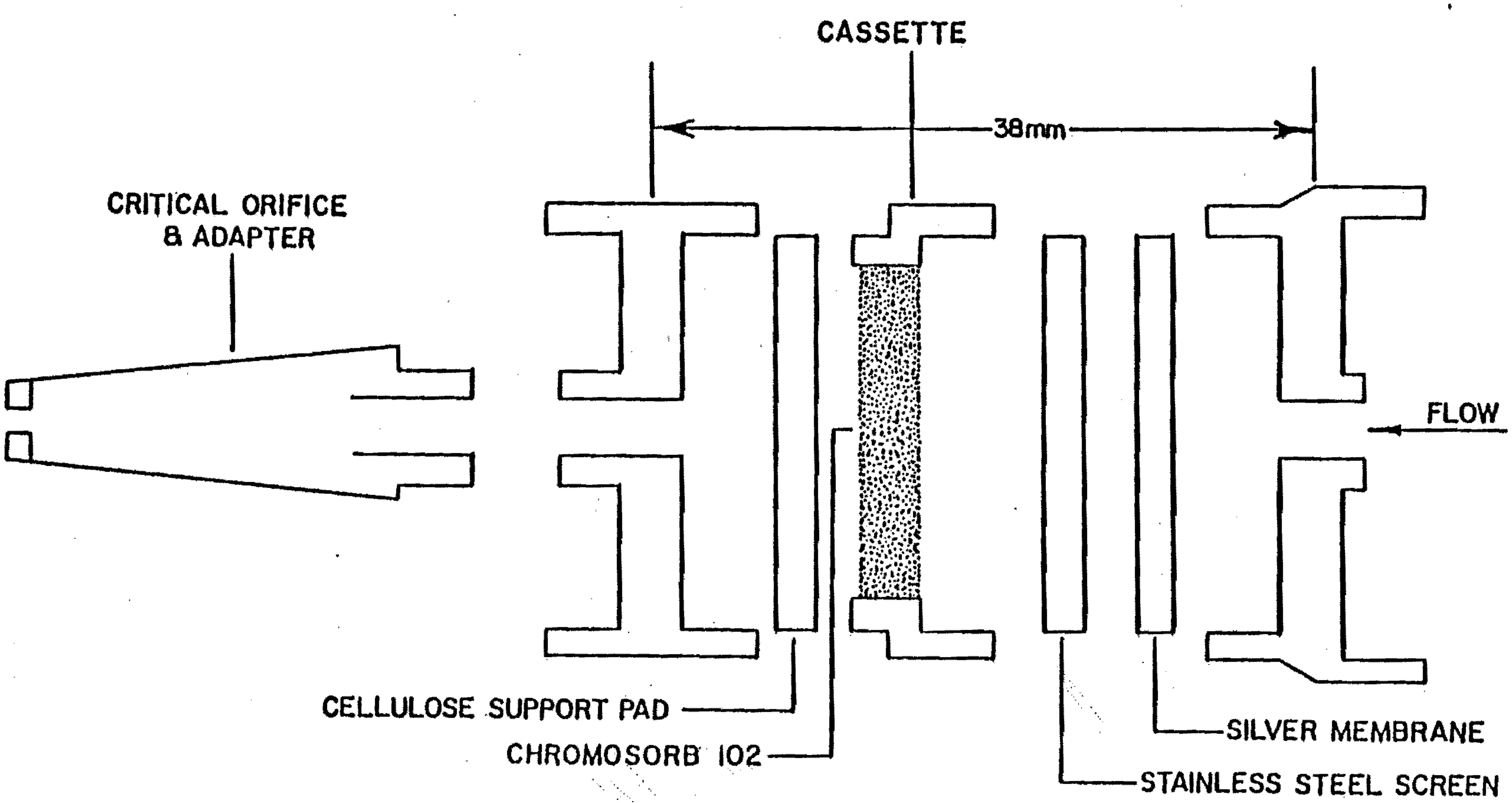



Figure A-1. HIGH-VOLUME SAMPLING DEVICE FOR PNA

## Table A-2

### ANALYTICAL RESULTS IN PPM FOR SILICA GEL AREA SAMPLES
### COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
### JANUARY 26 - 28, 1979

C-2A

| Sample Site | Cyclone/Scrubber System | Gasifier | Inductor Fan | Blanks | |
|---|---|---|---|---|---|
| Sample Number | 003 | 006 | 033 | 041 | 043 |
| Sample Volume (L) | 47 | 49 | 52 | | |
| Sample Time | 1239-2030 | 1231-2037 | 1032-1908 | | |
| Compound | | | | | |
| Aniline (0.13)[a] | ND[b] | ND | ND | ND | ND |
| N,N-Dimethylaniline (0.05) | ND | ND | ND | ND | ND |
| o-Anisidine (0.05) | ND | ND | ND | ND | ND |
| p-Anisidine (0.05) | ND | ND | ND | ND | ND |

a = detection limit in ppm.
b = not detected.

C-2B

| Sample Site | Gasifier (Bottom) | Char Receiving Bin | Blanks | |
|---|---|---|---|---|
| Sample Number | 007 | 010 | 017 | 040 |
| Sample Volume (L) | 48 | 48 | | |
| Sample Time | 1230-2034 | 1243-2040 | | |
| Compound | | | | |
| Phenol (0.1)[a] | ND[b] | ND | ND | ND |
| Cresol (0.1) | ND | ND | ND | ND |

a = detection limit in ppm.
b = not detected.

Table A-3

ANALYTICAL RESULTS IN PPM FOR CHARCOAL TUBE AREA SAMPLES
COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
JANUARY 26 - 28, 1979

| Sample Site | Cyclone/ Scrubber | Gasifier | Inductor Fan | Sludge Thickener | Blanks | |
|---|---|---|---|---|---|---|
| Sample Number | 002 | 008 | 028 | 031 | 018 | 039 |
| Sample Volume(L) | 47 | 49 | 52 | 48 | | |
| Sample Time | 1235-2027 | 1232-2039 | 1021-1903 | 1036-1856 | | |
| Compound | | | | | | |
| Benzene (0.1)[a] | 0.02 | 0.02 | 0.02 | 0.02 | ND | ND |
| Toluene (1.0) | <0.01 | <0.01 | <0.01 | <0.01 | ND | ND |
| Xylene (1.0) | ND | ND | ND | ND | ND | ND |

a = detection limit in ppm.

ND = not detected.

< = present but below level of quantification.

## Table A-4
## PNA ANALYTICAL RESULTS IN $\mu g/m^3$ FOR AREA SAMPLES [a]
## COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
## JANUARY 26 - 28, 1979

| Sample Site | Cyclone/ Scrubber | Thickener | Gasifier | Inductor Fan | Blank[b] | |
|---|---|---|---|---|---|---|
| Sample Number | 001 | 015 | 026 | 027 | 016 | 036 |
| Sample Volume(L) | 3450 | 3538 | 4508 | 4462 | | |
| Sample Time | 1330-1945 | 1321-1945 | 0941-1841[c] | 0945-2050[c] | | |
| **Compound** | | | | | | |
| Indene (1)[d] | | | | | | |
| 1,2,3,4-Tetrahydronaphthalene (1) | | | | | | |
| Naphthalene (1) | 0.02 | <0.01 | | 0.03 | 13 | 33 |
| 2-Methylnaphthalene (1) | 0.05 | <0.01 | <0.01 | 0.04 | 11 | 18 |
| 1-Methylnaphthalene (1) | | | | | | |
| Quinoline (1) | | | | | | |
| 1,1'-oxybisbenzene (1) | | | | | | |
| Acenaphthalene (1) | | | | | | |
| Fluorene (1) | 0.1 | | | | 22 | 27 |
| Phenanthrene/Anthracene (1) | 0.08 | <0.01 | <0.02 | <0.01 | 19 | |
| Acridine (2) | | | | | | |
| Carbazole (2) | | | | | | |
| Fluoranthene (1) | | | | | | |
| Pyrene (1) | <0.02 | | <0.01 | <0.02 | 22 | 15 |
| Benzo(a)fluorene (4) | | | | | | |
| Benzo(b)fluorene (4) | | | | | | |
| Benz(a)anthracene (2) | | | | | | |
| Triphenylene (2) | | | | | | |
| Chrysene (2) | | | | | | |
| Naphthacene (9) | | | | | | |
| Benzo(e)pyrene (5) | | | | | | |
| Benzo(a)pyrene (6) | | | | | | |
| Perylene (4) | | | | | | |
| Dibenzanthracene (14) | | | | | | |
| Indeno(1,2,3-cd)pyrene (17) | | | | | | |
| Benzo(g,h,i)perylene (2) | | | | | | |
| Anthanthrene (44) | | | | | | |
| Dibenzpyrene (15) | | | | | | |
| Dibenz(a,j)acridine (14) | | | | | | |
| Dibenz(a,i)carbazole (14) | | | | | | |

[a] Blank spaces indicate compound not detected.

[b] In nanograms/sample.

[c] Compressed air pumps turned off for 50 minutes for sample 026 and 3 hours for sample 027 because of drop in air pressure.

[d] Detection limits in nanograms per sample.

All analyses were performed at the University Hygienic Laboratory, University of Iowa, except for the optical sizing of particulate samples which was performed at Environmental Analysis Laboratories, LFE Corporation.

Results for the analysis of area samples are given in Table A-2 to A-5. Of the 30 PNAs or aza-PNAs considered, only five were detected in the four area samples taken (Table A-4). These include naphthalene, 2-methylnaphthalene, fluorene, the phenathrene/anthracene pair, and pyrene in the nanogram range. A check of the soluble-fraction results for the same five samples indicated levels in the microgramper-cubic-meter range (Table A-5).

The four aromatic amines and two phenolic compounds selected for study were not detected in the five samples taken (Table A-2). For the sampled aromatics, benzene, toluene, and xylene, only the presence of benzene and toluene was detected in the four charcoal tube samples (Table A-3). Findings suggest levels in the parts-per-billion range.

In a GC/MS scan of the charcoal and silica gel tube extracts, the presence of organics, such as the aliphatics and alicyclics, was not detected in any of the samples taken. Of the 28 detector tube readings taken (Table A-1), none of the toxic gases being studied were detected in the areas in which their presence was suspected. Carbon monoxide levels, as measured with a direct-reading instrument, showed a maximum level of 1 ppm above background (4 ppm).

At the pulverizer and ash disposal areas where dust exposure may be a problem, area sampling showed low particulate levels. For the total particulate samples, levels were in the microgram-per-cubic-meter range at the pulverizer while respirable dust fraction was not detectable in the microgram-per-cubic-meter range. Respirable dust levels at the ash disposal area were in the microgram-per-cubic-meter range. Optical sizing results for a particulate sample taken at the pulverizer are shown graphically in Figures A-2 and A-3. From these figures, it can be seen that respirable particulates at the pulverizer consist mainly of particles in the size range of 1.5 to 4.1 ppm.

Table A-5

SOLUBLE FRACTION RESULTS IN $mg/m^3$
COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
JANUARY 26 - 28, 1979

| Sample Site | Sample Number | Sample Volume(L) | Sampling Time | Silver Membrane Filter [a] | Chromosorb 102 [b] |
|---|---|---|---|---|---|
| Cyclone/ Scrubber | 001 | 3450 | 1330-1945 | 0.04 | 0.04 |
| Thickener | 015 | 3533 | 1321-1945 | <0.01 | <0.01 |
| Gasifier | 026 | 4508 | 0941-1841[c] | <0.01 | |
| Inductor Fan | 027 | 4462 | 0945-2050[d] | 0.01 | 0.02 |
| Blank[e] | 016 | | | 0.01 | 0.3 |
| Blank | 086 | | | 0.008[e] | 1.4[f] |

a = cyclohexane soluble fraction

b = methanol/methylene chloride soluble fraction

c = compressed air driven pumps turned off by plant operators for 50 minutes because of drop in air pressure

d = compressed air driven pumps turned off by plant operators for 3 hours because of drop in air pressure

e = mg/sample

f = contaminated and not used in correcting values

Figure A-2

PARTICLE SIZE DISTRIBUTION OF PARTICULATES AT PULVERIZER
COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
JANUARY 26 - 28, 1979

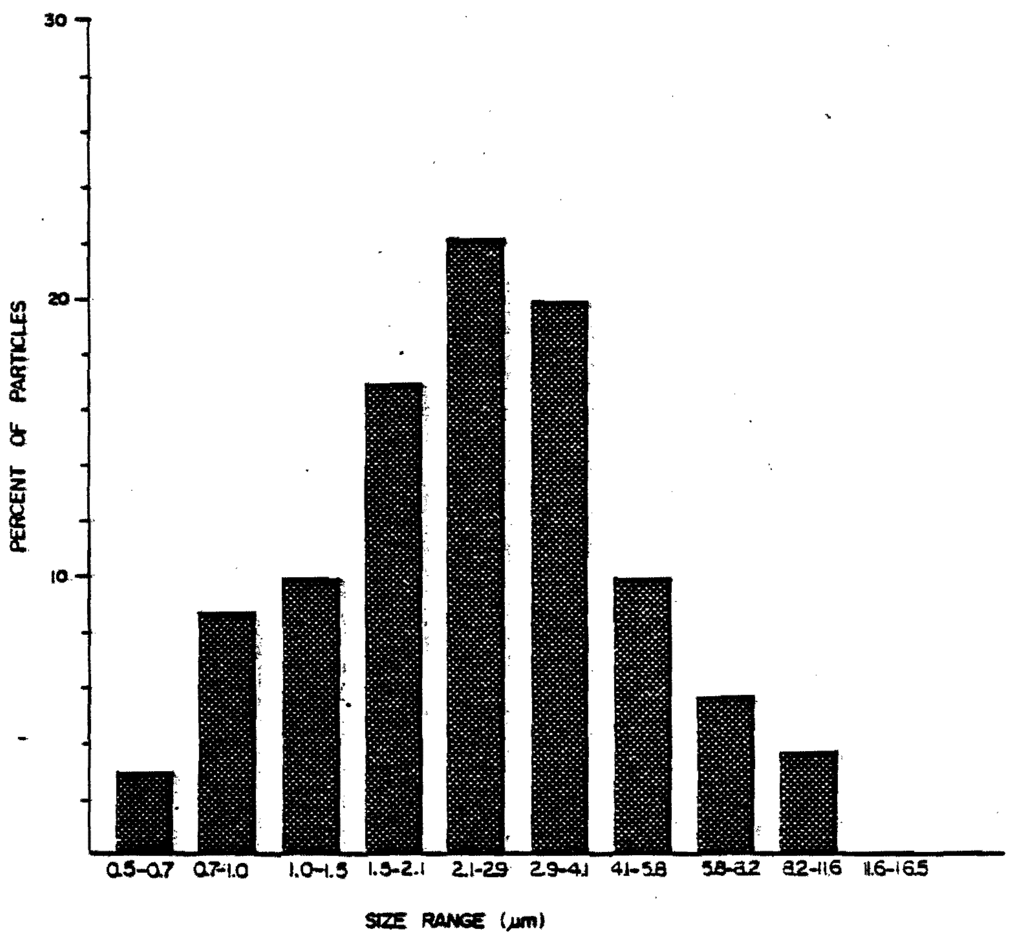
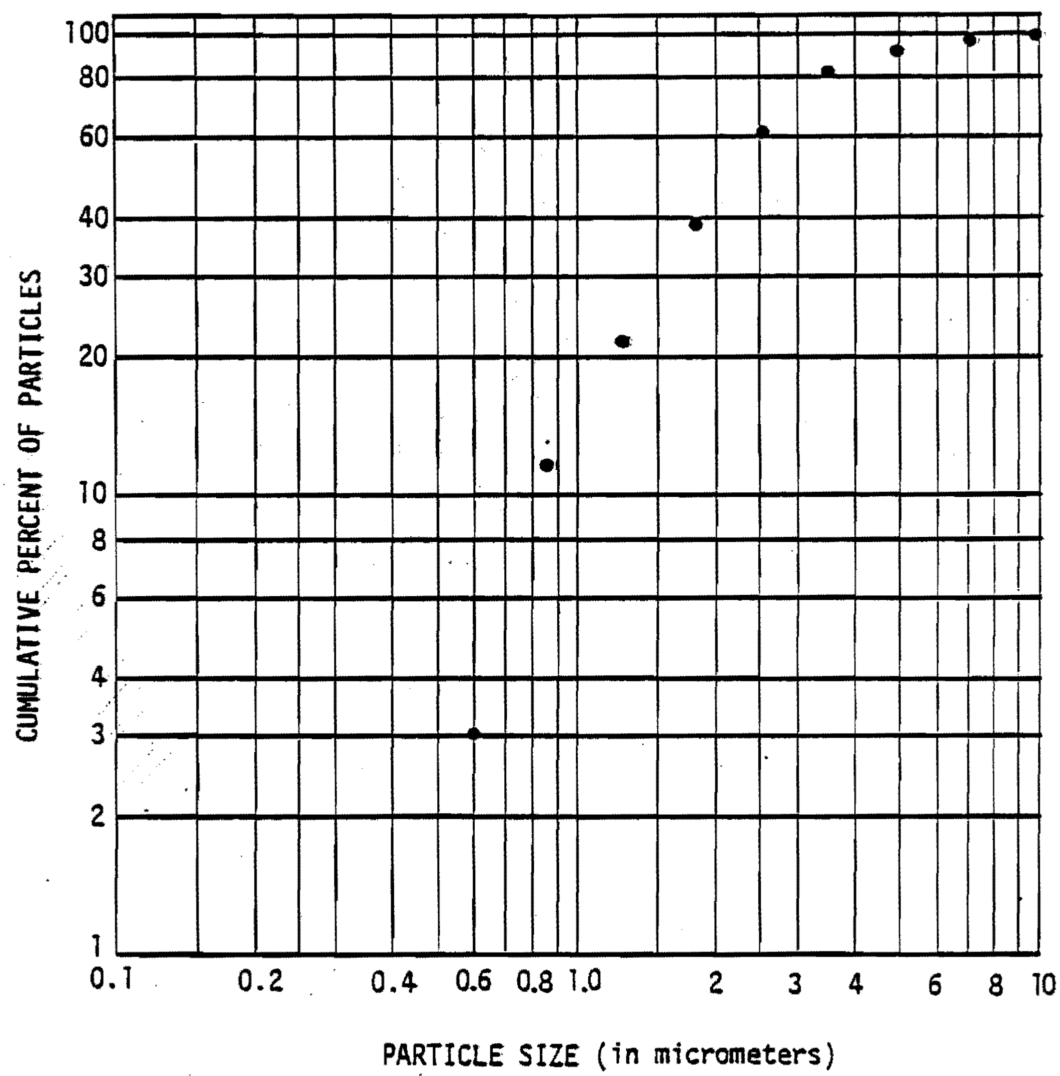


Figure A-3

CUMULATIVE PERCENT DISTRIBUTION OF PARTICULATES AT PULVERIZER
COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
JANUARY 26 - 28, 1979



Particulate samples collected on cellulose acetate filters at the C-E facility were analyzed for the trace elements arsenic, eryllium, cadmium, copper, mercury, magnesium, manganese, nickel, strontium, and tellurium (Table A-6). None of these 10 trace elements were detected in any of the samples taken at the gasifier, pulverizer, induced draft fan, and cyclone/scrubber. In the car receiving bin sample, manganese was identified at a concentration of 0.001 $\mu g/m^3$. The detection limits for these 10 trace elements ranged from 0.13 $\mu g/m^3$ for arsenic and cadmium, to 2.6 $\mu g/m^3$ for copper, magnesium, nickel, and strontium. The remaining elements had a detection limit of 0.26 $\mu g/m^3$.

Measurements were taken at this survey for noise and ionizing radiation. Heat stress was not studied at this time because seasonal weather conditions precluded any heat stress problems. Discussions with plant workers also indicated that weather conditions at other times of the year eliminated the heat stress problem. All equipment operating at elevated temperatures is adequately shielded.

Tests for ionizing radiation were conducted on a sample of coal dust taken at the site of the pulverizer. Ash samples were not analyzed for ionizing radiation because of the absence of worker exposure. This was evident from the results of total particulate samples taken in the ash disposal area. Gross alpha, beta, and gamma readings were made using a proportional counter and a NaI scintillation counter. None of these three types of radiation were detected in the coal dust sample at a detection limit of 0.4 pCi/filter for alpha radiation and 0.6 pCi/filter for beta and gamma radiation.

A preliminary noise survey was performed using a sound level meter to determine the range of noise levels observed and to associate these levels with specific sources. Readings obtained in this survey ranged from 69 dBA to 94 dBA, as shown in Table A-7. From these results, it is apparent that high noise levels above the current Federal standard of 90 dBA were observed on the third level by the air fans and Stretford unit, on the second level between the gasifier and circulating pumps, and on the ground level by the induced draft fan and forced draft fan. Worker

Table A-6

TRACE ELEMENT ANALYTICAL RESULTS IN $mg/m^3$
COMBUSTION ENGINEERING, WINDSOR, CONNECTICUT
JANUARY 26 - 28, 1979

| Sample Site | Cyclone/ Scrubber | Gasifier | Char Receiving Bin | Pulverizer | Inductor Fan | Blanks | |
|---|---|---|---|---|---|---|---|
| Sample Number | 004 | 005 | 009 | 011 | 032 | 019 | 037 |
| Sample Volume (L) | 946 | 972 | 956 | 1,014 | 1,040 | | |
| Sample Time | 1237-2030 | 1232-2038 | 1243-2041 | 1226-2053 | 1027-1907 | | |
| **Compound** | | | | | | | |
| Arsenic (0.13)[a] | ND | ND | ND | ND | ND | ND | ND |
| Beryllium (0.26) | ND | ND | ND | ND | ND | ND | ND |
| Cadmium (0.13) | ND | ND | ND | ND | ND | ND | ND |
| Copper (2.6) | ND | ND | ND | ND | ND | ND | ND |
| Mercury (0.26) | ND | ND | ND | ND | ND | ND | ND |
| Magnesium (2.6) | ND | ND | ND | ND | ND | ND | ND |
| Manganese (0.26) | ND | ND | 0.001 | ND | ND | ND | ND |
| Nickel (2.6) | ND | ND | ND | ND | ND | ND | ND |
| Strontium (2.6) | ND | ND | ND | ND | ND | ND | ND |
| Tellurium (0.26) | ND | ND | ND | ND | ND | ND | ND |

ND = not detected

a = detection limit in $\mu g/m^3$

Table A-7

NOISE SURVEY RESULTS
Combustion Engineering, Windsor, Connecticut
January 27, 1979

| Level | Area | Reading (dBA) | |
|---|---|---|---|
| | | Low | High |
| Ground level | | 84 | 91 |
| Ash hopper | 400 | 84 | 89 |
| Forced draft fan | 300 | 90 | 91 |
| Induced draft fan | 300 | | 89 |
| Pulverizer | 200 | 80 | 89 |
| First level | | 83 | 89 |
| Second level | | 82 | 94 |
| Gasifier | 300 | 82 | 93 |
| Circulating pump | 300 | | 94 |
| Third level | | 83 | 93 |
| Scanner air fan (GB306) | 200 | | 93 |
| Igniter air fan (GB307) | 300 | | 94 |
| Gasifier | 300 | 83 | 87 |
| Stretford unit | 700 | 89 | 94 |
| Scrubber system | 500 | 90 | 91 |
| Fourth level | | 82 | 85 |
| Fifth level | | 81 | 82 |
| Sludge thickener | 500 | 69 | 79 |

exposure to noise in the upper levels is expected to be minimal because time spent in these high-noise areas is not expected to be more than 2 hours per shift. The major contributor to a worker's exposure would be noise sources at the ground level where worker traffic is heaviest. Noise dosimeter readings ranged from 2 to 25 percent of the allowable exposure level for plant employees indicating that noise is not a problem. However, selected maintenance activities such as grinding of metal plates and hammering have been found to increase exposures to within 95 percent of the allowable limit.

Sampling results indicate that airborne contaminants within the C-E facility are probably present in the low parts-per-billion or microgram per-cubic-meter range. These compounds represent the PNAs which include naphthalene, 2-methylnaphthalene, fluorene, phenanthrene/anthracene and pyrene.

Employees most likely to be exposed to these PNAs include the two plant equipment operators in each shift, the two mechanical technicians, and the four instrument/control technicians. The equipment operators monitor and operate the equipment in the field while the technicians are maintenance workers with responsibility for equipment and instruments in the process area.

The major activities that contribute to the plant equipment operator's exposure is process stream sampling, which is conducted on a periodic basis. Other contributory activities are maintenancerelated and are performed during plant downtime. These activities are irregularly scheduled, so exposure from these sources will vary. For the maintenance technician, the major activities would involve the disassembly of process equipment and entry into tanks or vessels.

The contaminants selected represented the simple aromatics, phenolics, and the aromatic amines; chemical classes which in Enviro's opinion may be found in the process Aliquots of these samples were also qualitatively screened by gas chromatograph/mass spectrograph and a computer spectral library of more than 25,000 entries for the presence of other organic compounds or compound classes.

The sample cassettes were analyzed for 30 polynuclear aromatics listed in Table A-4 for which analytical standards are available. The PNAs were selected for analyses because Enviro suspects their presence in the C-E process environment. Analyses were by GC/ MS and high-pressure liquid chromatography.

The trace elements and total particulate samples were collected on cellulose acetate and PVC filters, respectively, at a flow rate of 1 liter/min. Respirable dust samples were collected on PVC filters at 1.7 liter/min using 10-mm nylon cyclones. Particulate and respirable dust samples were analyzed gravimetrically and trace elements by atomic absorption.

All analyses were performed at the University Hygienic Laboratory, University of Iowa, except for the optical sizing of particulate samples which was performed at Environmental Analysis Laboratories, LFE Corporation.

## APPENDIX B

### Combustion Engineering Comprehensive Industrial Hygiene Survey Results Summary

A comprehensive survey was conducted at the Combustion Engineering facility with a total of 45 personal and 36 area samples being collected. These samples were analyzed for either benzene, toluene, and xylene or PNAs. Because of operational difficulties, the plant was not on-stream for the entire survey. However, data collected did indicate the presence of benzene, toluene, and PNAs within the PDU environment. Xylene was not detected in any of the samples indicating a level of less than 0.02 ppm, the detection limit of the analytical method.

The concentration of benzene, toluene, and PNAs in both area and personal samples was low with maximum measured values of 0.2 ppm for benzene, 0.08 ppm for toluene, and 24.6 $\mu g/m^3$ for PNAs. The absence of these compounds in upwind samples indicates that these compounds are being formed within the gasification process. The low levels can be attributed to the use of oil during startups, the high operating temperature, 1800°F (980°C), and the use of a negative pressure system. The use of oil to heat the gasifier to operating temperatures before adding coal ensures that coal is not subjected to the lower temperatures which result in PNA formation. The high operating temperature provides the necessary energy to crack the aromatic structure leading to negligible aromatic compound formation. The negative pressure system ensures that any aromatic formed is contained within the system.

The presence of low levels of aromatics within the ambient environment indicates minimal worker exposure during normal plant operation. This is indicated by personal samples taken while the PDU was on coal. These samples showed benzene and toluene concentrations of less than 0.01 ppm, and a PNA level of 1.4 $\mu g/m^3$. However, workers engaged in repair and maintenance activities were found to be exposed to benzene and toluene in the range of 0.01 ppm to 0.2 ppm and had relatively higher levels of PNAs ranging from 3.0 $\mu g/m^3$ to 24.6 $\mu g/m^3$.

These activities mainly involved work with on-line process equipment where workers are exposed to coal, char, and product gas. Since the maintenance personnel and equipment operators share these duties, it is expected that they would be the group having the greatest chance of being exposed to these aromatic contaminants.