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CONTROL TECHNOLOGY ASSESSMENT

FOR

COAL GASIFICATION AND LIQUEFACTION PROCESSES

BI-GAS Pilot Plant
Homer City, Pennsylvania

Report on Site Visit

of August 1979

Final

Contract No. 210-78-0010

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Submittec to

National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
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Foreward

On August 16 and 17, 1979, representatives from Enviro Control, Inc., and the National Institute for Occupational Safety and Health visited the BI-GAS Pilot Plant in Homer City, Pennsylvania. An introductory meeting was held to acquaint the BI-GAS personnel with the purpose of the site visit and of the control technology study. The following were present for this initial meeting:

BI-GAS Pilot Plant

- Donald E. Hull, Programs Manager (Phillips Petroleum Co.)
- Enoch M. Fox, Plant Manager (Stearns-Roger)
- James Howard, Operations Manager (Stearns-Roger)
- Jerry Wells, Maintenance Manager (Stearns-Roger)
- Jack C. Glenn, Process Engineer Supt. (Stearns-Roger)
- William R. Miller, Engineering Supt. (Stearns-Roger)
- Gene Klanica, Safety Supervisor (Stearns-Roger)
- Donald Frelin, Mechanical Engineer (Stearns-Roger)
- W. J. Brown, Industrial Hygienist (Phillips Petroleum Co.)

National Institute for Occupational Safety and Health

- John T. Talty, Branch Chief, CTRB
- Laurence D. Reed, Research Industrial Engineer, Project Officer

Enviro Control, Inc.

- James M. Evans, Project Manager
- Donato R. Telesca, Principal Investigator
- Russell K. Tanita, Senior Industrial Hygienist
- Jan S. Scopel, Chemical Engineer

I. SUMMARY

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 BI-GAS Pilot Plant in Homer City, Pennsylvania, during the site visit on August 16 - 17, 1979.

Because steady-state operating time at BI-GAS has been limited, the plant has never been operated as a whole. Major problem areas are the slag removal system and the coal/char gasifier feed system. Areas which have yet to be operated include shift conversion, acid gas removal, sulfur recovery, and methanation. Because these areas have not been operated they are not included in this report.

The plant was not in operation from February 1979 to September 1979. The plant underwent repairs to correct damage caused by a rupture in the char-burner line which resulted in an equipment damaging fire. Major efforts have been directed at both reducing the potential for worker exposure to such occurrences by providing fire baffles, alternate escape routes, and off-limit areas during gasifier operation; and eliminating the cause of the failure by redesigning the char burners, and using different materials of construction.

II. INTRODUCTION

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 potentially hazardous agents in coal conversion plants.

The BI-GAS Pilot Plant is being included in this study because the BI-GAS coal gasification process is recognized as an important emerging technological development in the gasification of coal to a high-Btu fuel. The process uses a relatively simple, scalable two-stage, entrained-flow gasifier design to convert virtually any type of coal (with no pretreatment) to a high yield of substitute natural gas.

A. History of the BI-GAS Pilot Plant Project

The BI-GAS Pilot Plant is part of the continuing Gas Generator Research and Development program to develop a method for producing high-Btu pipeline-quality gas (substitute natural gas) from caking and non-caking coals. Development of the BI-GAS coal gasification process was begun in December 1963 by Bituminous Coal Research, Inc. (BCR) with the support of the Energy Research and Development Agency (ERDA) and the American Gas Association (AGA). Bituminous Coal Research was directed to conduct laboratory-scale gasification experiments to verify the technical and economic feasibility of producing high-Btu gas using the BI-GAS process and to design, construct, and operate a research pilot plant.(1) Early experiments confirmed the basic assumption that a relatively high yield of methane could be obtained directly from coal by reaction with steam at elevated temperature and pressure.

Data from continuous-flow experiments were extrapolated to design a process equipment development unit (PEDU) to simulate the upper portion (Stage II) of the BI-GAS process. The PEDU was interanlly fired and could process 100 pounds of coal per hour.(1) Subsequent experiments were designed to determine the optimum residence time, coal rank (type), temperature, pressure, hydrogen partial pressure, etc., to produce the greatest yield of methane. Pennsylvanie high volatile A bituminous coal, Wyoming subbituminous C coal, and North Dakota lignite were used in these experiments.

A cold flow model of Stage I (lower portion of the BI-GAS process gasifier) and the bottom of Stage II were developed when it was found that the physical design of Stage II of the process equipment development unit (PEDU) influenced methane yield.[1] This enabled the investigation of methods for improving the flow patterns in Stage II and the establishment of design criteria for the slagging section of the gasifier.

On July 11, 1972, Stearns-Roger was awarded the contract for constructing a pilot plant facility capable of processing 120 tons of coal per day and producing 100,000 standard cubic feet per hour of clean, pipeline-quality gas. Bituminous Coal Research, Inc., developed the basic design criteria for the facility.

The management contract of the pilot plant was awarded to Phillips Petroleum Company in November 1974. Babcock and Wilcox, a Stearns-Roger subcontractor, designed the two-stage, high-pressure, entrained-flow gasification vessel in use at the BI-GAS pilot plant operation. Phillips Petroleum Company formally accepted the completed pilot plant from Stearns-Roger on September 15, 1976. The flash drying and gasifying system were successfully operated by the end of the year. In November 1977, a 24-hour, steady-state operating period was achieved. The longest run to-date (August 1979) has been sixty hours.

The pilot plant was not in operation from February 1979 to September 1979 due to a ruptured char-burner line to the gasifier. Current work is directed toward correcting this problem. Other operational problems have limited steady-state gasifier operation. As yet, the entire process has never been operated as a whole.

In November 1979, Phillips Petroleum Company formally withdrew from the program and Stearns-Roger became prime contractor to the Department of Energy replacing Bituminous Coal Research who elected to take a subordinate role as a subcontractor.

B. Process Description(2)

The purpose of the BI-GAS pilot plant is to demonstrate the technical and economic feasibility of the BI-GAS process (a two-stage, high-pressure, oxygen-blown entrained-bed coal gasification system) to produce high-Btu pipeline gas. A diagram of the BI-GAS process is provided in Figure 1. The principle unit process areas are coal receiving and storage, coal preparation, coal slurry pressurizing and drying, coal gasification, carbon monoxide shift, acid-gas removal, methanation, and sulfur production. The plant layout is shown in Figure 2.

Raw coal is conveyed to a storage vessel. The coal is ground to size and a coal-water slurry is prepared. The slurry is flash dried and pneumatically conveyed to the top of the gasifier structure. The coal is then introduced along with steam and oxygen into Stage II of the gasifier where under high pressure (1500 psi design pressure) and temperature (1700-2200 F (926-1200 C)) it is converted to a methane-rich synthesis gas and char.

The raw synthesis gas and char leaving the gasifier are quenched and separated. The char is sent back to the gasifier as feed to Stage I, while the raw gas is passed through a water scrubber to a carbon monoxide shift converter and then to the gas clean-up system. The resulting clean gas stream is passed through a fluidized-bed catalytic methanation system for upgrading to yield a high-Btu, pipeline-quality gas.

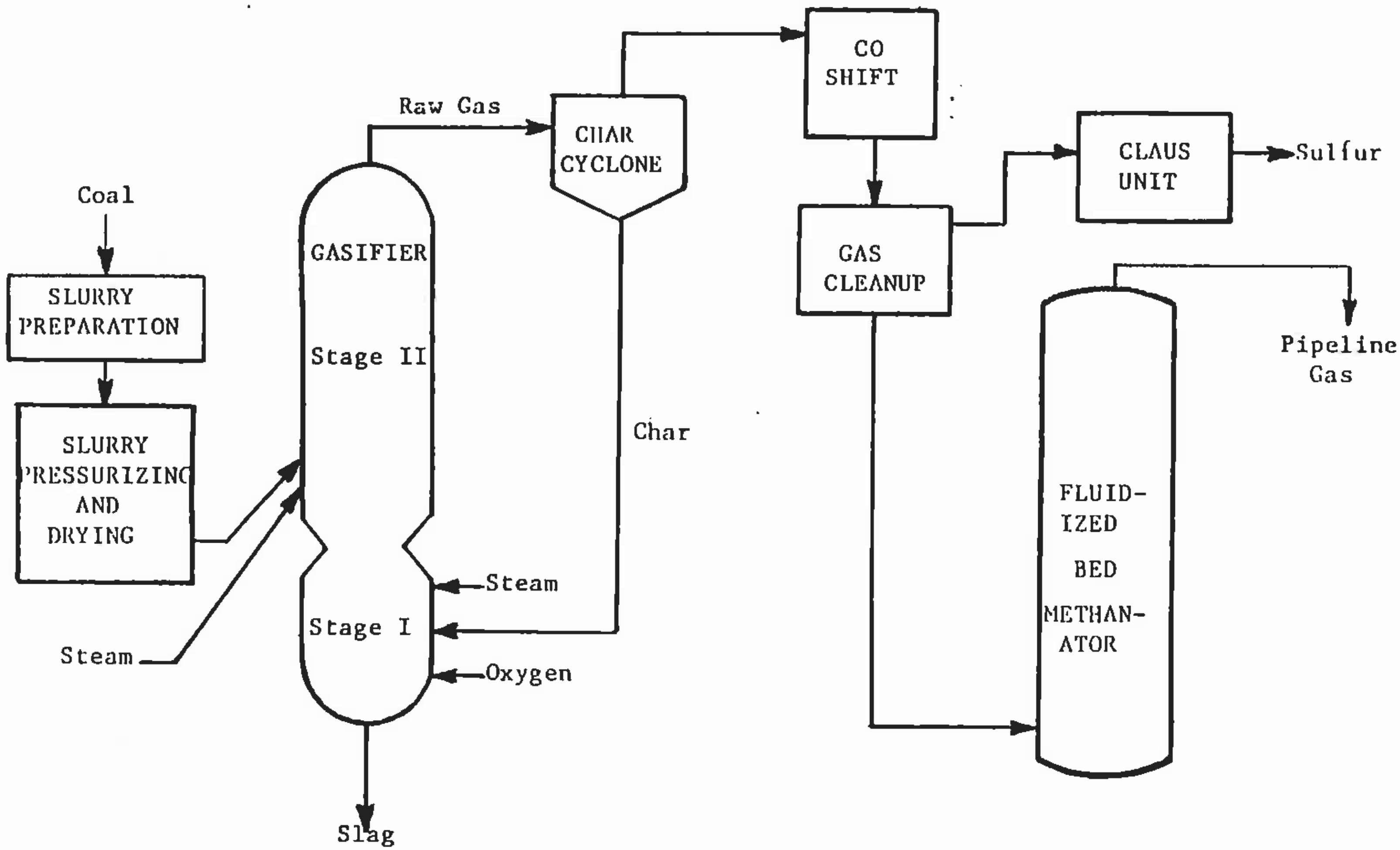

FIGURE 1. Schematic of the BI-GAS Coal Gasification Process

(adapted from Reference 1)

1 - Office Parking
2 - Plant Personnel & Office Parking
3 - Main Sub-Station
4 - Office & Laboratory
5 - Service Building
6 - VCC Building
7 - Control Building
8 - Compressor Building
9 - Shop & Warehouse
10 - Methanation Structure
11 - Gasifier Structure
12 - Spray Dryer
13 - Recycle Gas Heater
14 - CO Shift Feed Heater
15 - Methanator Feed Heater
16 - Cooling Tower
17 - Coal Conveyor (elevated)
18 - Coal Storage Piles
19 - Coal Dump Hopper
20 - Holding Pond
21 - Domestic Water Storage Tank
22 - Thickener Overflow Pump Box
23 - Centrifuge Feed Tank
24 - Auxiliary Building
25 - H_2O Storage
26 - Sulfur Removal
27 - Coal (flux) Handling Building
28 - Thickener
29 - Sewage Plant
30 - Thermal Oxidizer Area
31 - Fuel Oil Storage
32 - Oxygen & Nitrogen Storage

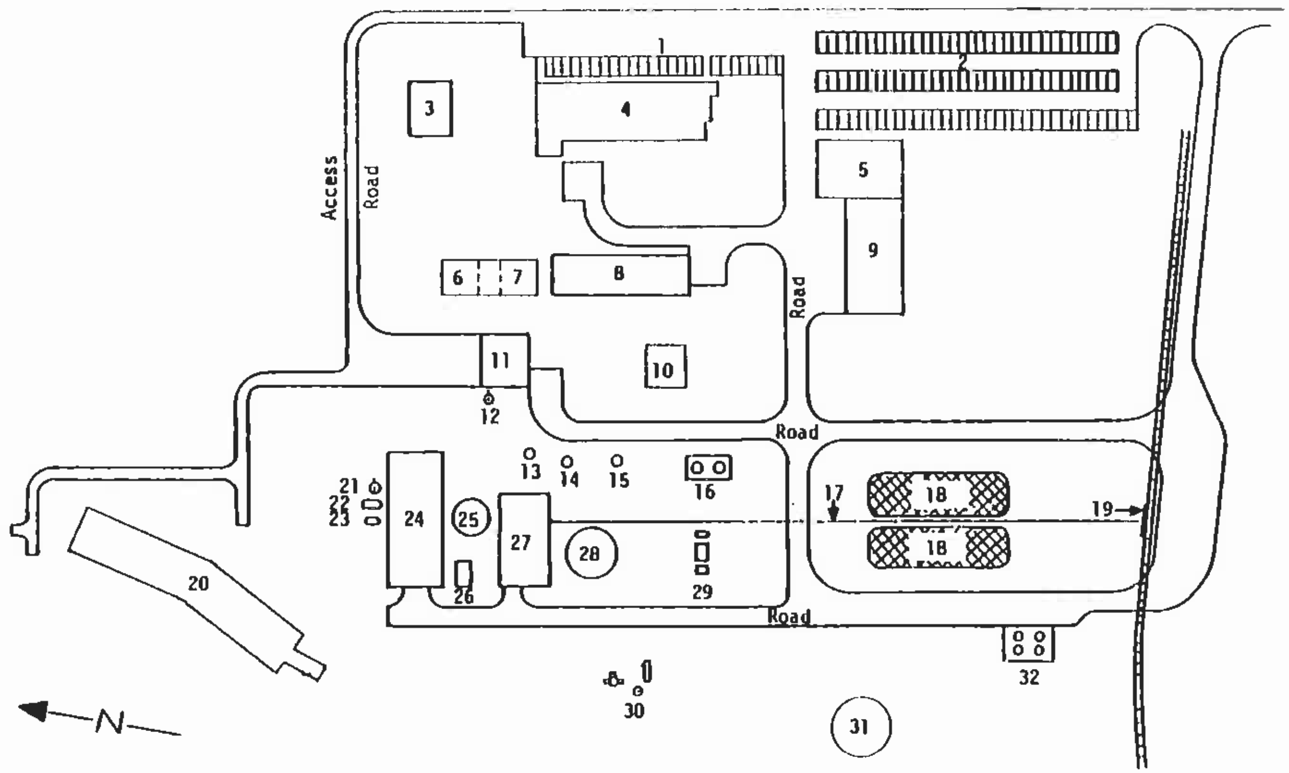

FIGURE 2. Layout of the BI-GAS Pilot Plant Facility

(adapted from: Coal Gasification Pilot Plant, Homer City, Pennsylvania, Final Construction Report; Stearns-Roger, Inc. Report No. 50. 1976. FE-1207-2)

The sulfur compounds and carbon dioxide are removed from the synthesis gas in a Selexol unit. The carbon dioxide is discharged, and the sulfur bearing gas is sent to a Claus unit to be converted to elemental sulfur.

III. CONTROL TECHNOLOGY ASSESSMENT

The BI-GAS Pilot Plant was not in operation from February 1979 to September 1979. The plant underwent repairs to correct damage caused by a rupture in the char burner feed line which resulted in a gasifier depressurization and fire. Previous to that, additional operational problems, some of which are discussed below, have prevented the process facility from operating as a whole. The following information is based on personal communication with plant personnel, a tour of the pilot plant when it was not in operation, and additional process information supplied by management personnel.

A. Potential Process Emission Sources

The potential hazards of each BI-GAS process area are given in Table 1. The major potential emission sources of hazardous agents as discussed with plant personnel include:

- Blowdown from Gas Washer (contains small amounts of naphthalene);
- Leakage through valves, flanges, seals, and pumps; and
- Char burner feed line rupture.

B. Coal Storage and Feed Preparation

(1) Process Description[3]

Coal is brought to the BI-GAS Pilot Plant by rail or truck and dropped into an underground bin. A conveyor moves the coal to

TABLE 1

POTENTIAL HAZARDS OF BI-GAS PROCESS AREAS

Process Area	Potential Hazard
COAL STORAGE AND PREPARATION	
Raw Coal Handling and Storage	• Noise • Fire in coal storage piles, bins • Coal dust
Spray Dryer	• High temperatures - 450 F (232 C) • High pressures - 750 psig • Asphyxiation - inert recycle gases (CO_2)
GASIFICATION	
Gasification	• High temperatures - 2200 F (1204 C) • High pressures - 750 psig • Toxic, explosive, asphyxiating products - Carbon Monoxide - Methane - Char - Hydrogen - Hydrogen Sulfide • Fire • Tri-ethyl aluminum handling
Gas Washing	• Naphthalene
Ash Handling	• Trace metals (skin contact)
CARBON MONOXIDE SHIFT	• High temperatures - 400 to 825 F (204 to 440 C) • High pressures - 1500 to 1650 psig (design) • Toxic, explosive, asphyxiating gases - Carbon Monoxide - Methane - Hydrogen Sulfide - Hydrogen
ACID-GAS REMOVAL	• High pressures - up to 1650 psig (design) • Moderately high temperatures - up to 650 F (343 C) • Toxic, explosive, asphyxiating gases - Carbon Monoxide - Methane - Hydrogen Sulfide - Hydrogen - Phenols (skin contact)
METHANATION	• High temperatures - 650 to 925 F (343 to 496 C) • High pressures - 1650 psig (design) • Toxic, explosive, asphysiating gases - Carbon Monoxide - Methane - Hydrogen • Nickel Carbonyl
SULFUR RECOVERY	• High temperatures - up to 650 F (343 C) • Moderate pressures - up to 115 psig (design) • Toxic gas - Hydrogen Sulfide - Mercaptans

a rod mill, where it is mixed with water and ground to size. A coal cyclone recycles large particles back to the rod mill. The fine coal slurry is fed to a centrifuge, partially dewatered, and sent to the slurry blend tank in the slurry drying area.

The dewatered coal slurry is pressurized (to approximately 750 psig), preheated to approximately 450 F (238 C), and contacted with hot recycle product gas (carbon dioxide) in a spray dryer where the slurry water is vaporized. In the coal cyclone vessel, cyclones separate the solids and vapor. The solids are sent to the gasifier, and the vapor is returned to the recycle gas washer, condensed, degassed, and returned to the coal handling system to be reheated for reuse.

(2) <u>Control Technology Assessment</u>

The 14-day storage pile is routinely watched for possible fires. Storage is located a sufficient distance from the main operating sections of the plant (about 200 feet) so that if a fire does occur, the remainder of the plant should not be exposed to the hazard.

The coal is mixed with water and ground to size by a rod mill. Flux is no longer added to the coal to control ash slagging temperature; as a result, worker exposure to the dust caused by the flux grinding operation is eliminated.

The coal is mixed with additional water to form a 35% solids slurry, then pumped by reciprocating pump (triplex) to the system which is operating at 750 psig. The use of a slurry process stream minimizes the dust exposure throughout the preparation area, and wet operations tend to be quieter then dry operations, thereby reducing exposure to noise. The use of water as the slurry "base allows equipment design at atomspheric pressure without concern for toxic vapor exposure.

Large quantities of fines, which are generated in the coal grinding section, have created a storage problem. At present, dewatering screens lose minus 300 mesh coal, which represents a 30 percent coal loss when using Montana Rosebud coal. Plant personnel attribute the grinding problem to incorrect rod mill specifications - i.e. an incorrect rod-length-to-diameter (L/D) ratio. The present L/D ratio is two; plant personnel estimate a ratio closer to one is needed.

There have been few operating problems in the slurry pressurizing and drying sections. As originally designed, slurry drying was to be accomplished by contacting the slurry with hot recycle gas in the spray dryer vessel. However, the dryer did not have to be operated as designed because plant personnel noted that sufficient heat to dry the slurry was being achieved in the tube inside the spray dryer vessel. Further study of the modified dryer would be needed to determine its effect on the workplace environment.

C. Gasification

(1) Process Description

The heart of the BI-GAS process is a two-stage, high-pressure, oxygen-blown entrained-bed coal gasifier. Figure 3 is a simplified diagram of the gasifier. The pulverized coal from the cyclone is fed to the gasifier which is in an entrained flow mode, through two injector nozzles. Steam, introduced through a separate annulus in the injector, combines with the coal at the injector tip and joins the rising hot synthesis gas from Stage I (750 psig, 2200 F (1200 C)) converting the coal to methane, synthesis gas, and char.

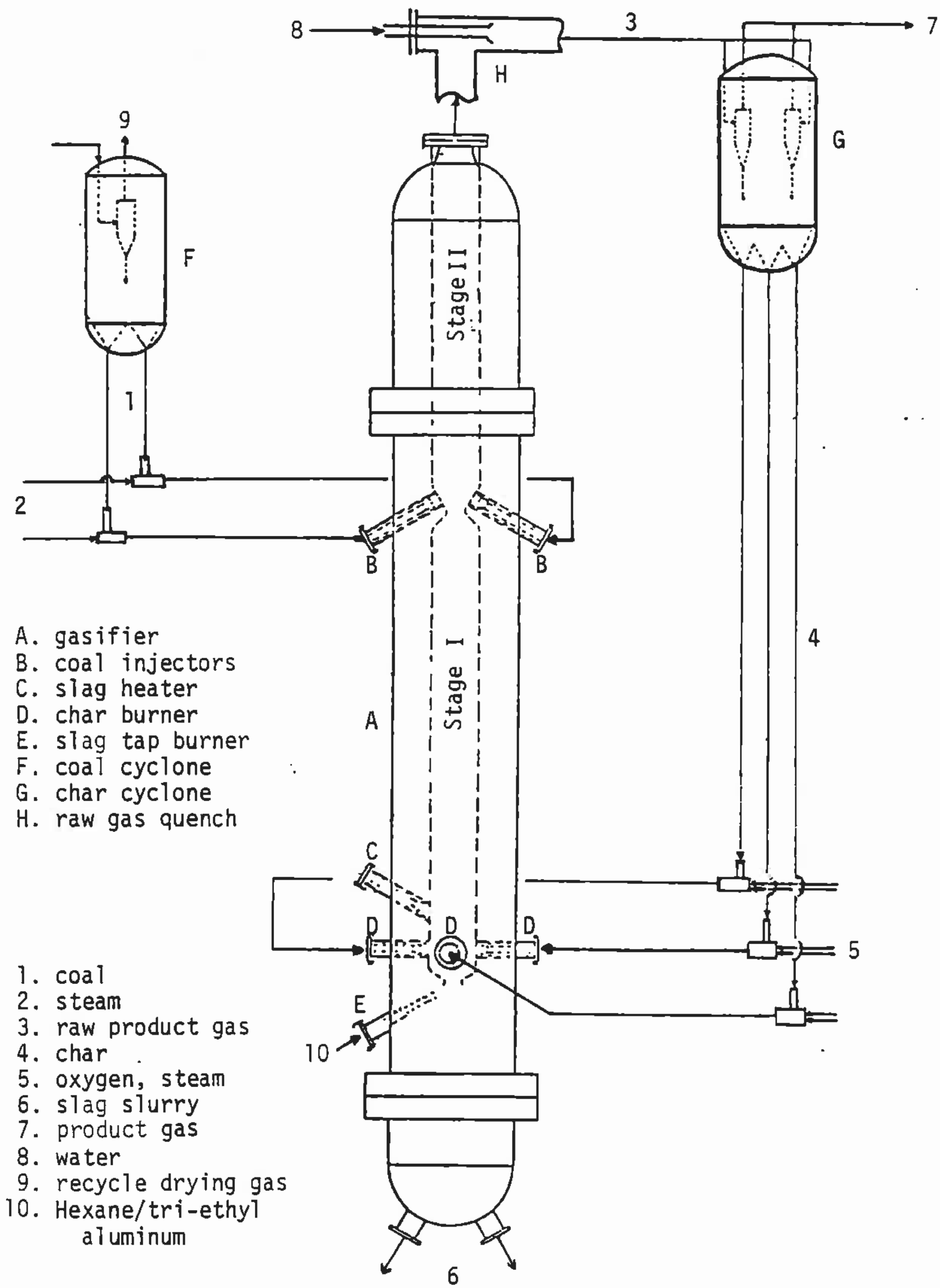

Figure 3. BCR/OCR BI-GAS Gasifier (5 ton/hr).

The products leave the gasifier at approximately 1700 F (926 C), are quenched by atomized water to about 800 F (425 C), and are separated in a char cyclone. The raw gas leaves the char cyclone and passes through a water wash column where it is further cooled and dust is removed. Char (from the char cyclone) and steam enter the gasifier in Stage I through three injection nozzles arranged tangentially to produce a swirl. Oxygen is fed through a separate annulus in the injector and is combined with the steam and char as it leaves the injector tip. The char is gasified completely at rapidly attained mixing temperatures 2700-3000 F (1482-1650 C).

Molten slag (liquefied ash from char) flows to the bottom of Stage I and out of the slag tap hole in the bottom of the section. Two burners assist in keeping the slag molten and free flowing. The molten slag drops into a resevoir of water in the bottom of the gasifier. The rapid quenching causes the slag to shatter into small pieces which fall through the water and, assisted by the recirculating water, exit the gasifier through either one of two bottom openings. The slag slurry is removed through lockhoppers and pumped to a settling pond.

(2) Control Technology Assessment (Gasification)

Coal Feed

A reciprocating pump is used to bring the coal/water slurry to required system pressure. The amount of dust throughout the gasification section, as well as worker exposure to the dust, is minimized by pressurizing the slurry rather than using a dry coal lockhopper feed system.

Reliable flow meters for the coal/carrier gas system are still in the development stage. Currently, coal and char feed rates to the gasifier have to be calculated indirectly by performing a material and energy balance on the gasifier. Problems can arise when the coal flow to the gasifier is stopped due to plugged feed lines. The gasifier sometimes has to be shut-down to unplug the lines. The plugging may be eliminated or reduced by increasing the carrier gas velocity.

A promising method for measuring solids flow at BI-GAS has been the acoustical microphone. However, this is in the development stage and must be integrated with a yet-to-be-designed control system.

The gasifier is operated with a reducing atmosphere. There is concern that an explosion may occur when going from an oxygen-deficient to an oxygen-excess atmosphere. To overcome the solid feed problem of consistency and reliability, BI-GAS uses methane to insure an oxygen-deficient atmosphere.

Char Burners

Rupture of an internal expansion joint (bellow), Figure 4, in a char burner was diagnosed as the most probable cause of a fire which shut down the pilot plant in February 1979. Though no one was injured, extensive instrument damage was incurred on the level on which the char burner is located and on the floor below. Plant personnel reported that a stainless steel expansion joint in the tube used to recycle char, along with steam and oxygen, back into the gasifier had weakened from corrosion cracking and ruptured. The rupture permitted hot fuel gas produced in the high-pressure gasifier to flow back through the rupture and contact oxygen in the air, resulting in the fire. According to plant personnel, further examination of companion char burner expansion joints is being made to confirm this diagnosis. It is believed that by substituting Incoloy 825 for stainless steel 321, corrosion would be eliminated and thus minimize the chance of a similar occurrence.

Additional protective measures to reduce the risk of worker injury and instrument and equipment damage were taken. Channels were built around each of the three char burners to divert blowout from any future ruptures to areas outside the building, thereby minimizing damage

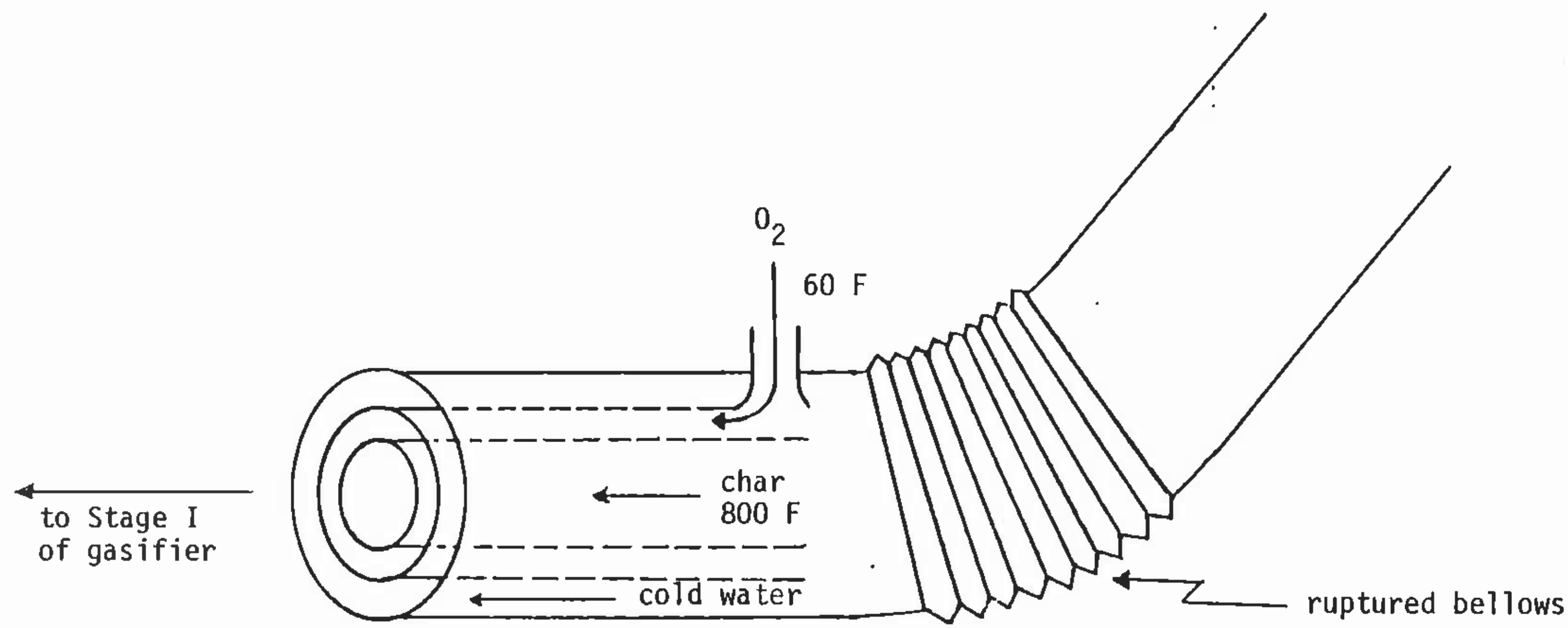

FIGURE 4. Simplified Diagram of the Char Burner Rupture Area.
BI-GAS Gasifier, BI-GAS Pilot Plant.

to equipment and injury to workers. Steel floor plates were installed to minimize exposure on the floor below and above the char burner. Elevators and stairwells were shielded to permit safe escape routes.

On another occasion, char plugging caused the burner to overheat and rupture. This problem was solved by installing a low flow, shut-off device in the char feed line.

Thermocouples

Thermocouple failures in Stage I of the gasifier have been a major problem. The variable performance of the thermocouples are due to erosion of the thermocouples wells by the corrosive slag formed in the gasifier.

Thermocouple wells are changed after each run. To increase erosion resistance, the wells are flame-sprayed chromium oxide molytubes, but thermocouple well life is still unsatisfactory. Radiometric methods have been investigated. The National Bureau of Standards is working on new materials of construction for the thermocouple wells, which are being designed to withstand the severe BI-GAS operating conditions.

Slag Removal

Successful operation of the slag (lockhopper) removal system depends on the ability to produce finely fractured slag beads. There had been slagging problems with the formation of long, thin slag strands, which had to be removed by maintenance people. Maintenance on this system requires termination of the gasifier operations. Since gasifier operations are designed for continuous use, any failure that requires the termination of operation subjects the equipment to harsh shut-down and start-up conditions. The more frequent need for such procedures results in higher chances for equipment failure, additional maintenance and greater exposure of the workers.

The molten slag that flows from the slag-tap hole at the bottom of Stage I of the BI-GAS gasifier must be at a high enough temperature to maintain flow to the quench water. Further, if the temperature of the slag is not high enough, it will not shatter upon contact with the quench water. The temperature of the molten slag is controlled by the operating temperature in Stage I of the gasifier, the size of the slag-tap hole, and the use of a slag-tap burner and slag-heating burner.

There is a slag-heating burner burning methane and a slag-tap burner, pointing upward. Large radiant heat loss had caused problems with slag flow at BI-GAS but by narrowing the diameter of the slag-tap hole from 6 inches to 2 inches heat loss was decreased and the slag remained in a molten state until it cooled and shattered upon contact with the quench water.

In addition, a slag agitator was installed in the bottom of the gasifier to break-up the slag strands. The agitator uses a 45^{o} rotating (back-forth swishing) motion for this purpose. Grids have been installed over the exit ports to the lockhoppers to prevent plugging in the event that a slag "ball" should form.

To prevent gasifier shut-down due to pluggages in the slag removal system, two slag-lockhoppers are used. These lockhoppers are in service on alternating on-off four-hour schedules.

At the time of the visit, methods to ignite the two burners at the slag hole were being tested. A relatively successful method was to use a mixture of 60 percent tri-ethyl aluminum (TEA) and 40 percent hexane. There is a potential handling problem with the TEA because of its high flammability. A nitrogen blanket must be used at every handling, transfer and storage step to prevent fires.

The molten slag that coats the Stage I gasifier walls is used as a refractory lining. Plugging problems attributable to slag cooling were reduced by removing some Stage I cooling coils and by moving the slag-tap burner to within 6 inches of the slag-tap hole.

D. Mechanical Equipment - General

(1) Process Description

The following assessment of control technology applies to the various mechanical equipment and supporting hardware such as pumps, seals, flanges, and valves not covered in previous sections.

(2) Control Technology Assessment

Pumps

Plant personnel stated that pumps which had been located on the fourth and sixth floors of the gasifier structure had been moved to the ground floor after the February fire. The relocation allows maintenance to be performed more safely during operating runs.

The shafts and seals of some pumps were deteriorating. Although the exact causes were not known, it was noted that improper piping layout design may be the major contributing factor. Engineering has estimated that there was not enough consideration given to structural steel movement when piping was installed. As a result, the piping was overstressed, causing flexure of the pump shaft. This results in rapid pump shaft deterioration and ripped pump seals. The problem was solved by redesigning the piping to include expansion loops.

Spare pumps are provided for critical pumping operations. This allows operations to continue while maintenance work is done to the pump, or, if necessary, allows a controlled shutdown of operations. Either of these generally affords the opportunity to maintain the equipment under relatively unrushed conditions while being exposed to relatively less hazardous chemical and physical agents.

The following details some of the features, and/or problems of pumps used at the BI-GAS facility:

- Slurry pumps are equipped with double mechanical seals with a process stream flush through the seals, which reduces the possibility of solids getting into the surface contact areas.

- For abrasive-type duty, carbon steel shafts are used to reduce wear. Ingersol-Rand pumps are equipped with a sleeve over the shaft. There are problems with process stream solids working back and ruining the sleeves.

- The high temperature (450 to 550 F(232-288 C)), high pressure (1500 psig) gasifier cooling water pumps experienced a seal failure due to case distortion (causing the seal to rub). A redesign of the piping system corrected the problem.

- On the Wilson Snyder pumps, there have been problems with valves. These problems may be reduced by changes in materials of construction. There have been no problems with the seals.

- Problems with the vertical Selexol pump stems from improper motor alignment with the pump.

- There had been plugging problems with cooling and seal flushing water. The problems were reduced by changing the filter from 5 microns to 20-100 micron filters and the tubing size from 1/4" to 3/8" diameter.

Seals

Plant personnel stated that the GRAYLOC fittings used throughout the plant provided satisfactory service. Seal problems were occurring only in sections of the plant that have frequent maintenance and where seals are disassembled during maintenance. This problem exists mainly with the 2½-inch seals (and smaller). The maintenance worker overtightens the seal causing warping because the recommended torque if not used. This distortion from overtightening causes leaks which the worker again attempts to solve by tightening, resulting in seal failure. The problem of overtightening is not a problem with 3-inch or larger seals because the worker cannot apply enough torque to warp the seal. There was seal failure on the high pressure, high temperature cooling water pump for the gasifier. These durametallic seals consisting of either bronze or brass for the stationary parts and tungsten carbide on the rotating part, were failing because of the high temperature of the flushing liquid. The problem was solved by cooling the flushing liquid to 100 F (38 C).

Valves

The following describes some features and/or associated problems with various valves used at the BI-GAS facility:

- The Rockwell Nordstrom plug valves used for coal slurries have stellite trim and are all specified at 800 psi, in order to simplify repair, maintenance, and parts inventory. The steam valves on the other hand are specified at 50, 150, and 600 psi.

- Rockwell ball valves are used on each slag lock-hopper and have operated satisfactorily. The use of ball valve avoids leakage problems which result when material fills recesses where slide valves are used.

- Silicon carbide Willis Disc valves are used as let-down valves. Although Willis Disc valves were originally designed as control valves the sliding action of discs and the use of abrasive resistant materials results in good shut-off action with no leakage. The plant uses 1 hand-operated and 2 automatic valves in each of two series, which are used in parallel during letdown.

The following describes some of the operating features in use at the BI-GAS facility:

- Orifices are being used to get process stream flow rates.

- Safety valves are on a programmed maintenance system.

- BI-GAS is using a nuclear-type gage to measure the density of the coal slurry. This installation avoids plugging problems inherent in instruments which are immersed in the process stream.

- Most density meters have been installed on vertical lines. This installation avoids the problem of stratification of slurry process streams with subsequent incorrect readings.

IV. INDUSTRIAL HYGIENE

A. Potential Process Hazards and Their Controls

The primary hazard of the BI-GAS pilot plant gasification process is of a safety nature and involves the char burner section of the gasifier. The gasifier is operated under a reducing atmosphere to generate heat and produce synthesis gas. Pure oxygen is fed into the gasifier through a separate annulus to promote the combustion of char. An interruption of char flow through a pluggage of the char feeder line could result in an increase in oxygen concentration in the gasifier. This could lead to the formation of an oxidizing atmosphere and thus increase the risk of fire.

Because of this potential hazard, the sixth floor is off-limits to all personnel during the operation of the gasifier. Worker activity on the higher levels is kept to a minimum by relocating equipment that requires constant monitoring or frequent maintenance to the ground level. All floors are evacuated before the coal burner is ignited. Constant monitoring of the number of people in the gasifier unit building is done by the use of a sign in/sign out system.

The gasifier unit is also believed to be the major site for potential exposure to process contaminants because of the presence of an extensive network of associated piping. Possible contaminants include carbon monoxide, hydrogen sulfide, methane, and monocyclic aromatics such as benzene and toluene. Coal tar is not formed in the gasifier because high temperatures and pressures of operation do not favor their formation. Naphthalene, a low molecular weight polynuclear aromatic component of coal tar is condensed in the naphthalene coolers, which are downstream of the gasifier. Naphthalene has been observed in the cyclone. It is believed that naphthalene formation is inversely proportional to Stage II operating temperature. Exposure to naphthalene would most likely occur during maintenance on the nephthalene coolers.

Plant policy of minimal activity in the gasifier structure is effective in reducing worker exposure to any potential process contaminants from leaks. Other control measures taken include:

- Installing carbon monoxide continuous-monitoring analyzers with audible alarms in the structure;

- Locating self-contained breathing apparatus in the stairwell for emergency use,

- Supplying all personnel entering the structure with a 5-minute escape airpark respirator; and

- Employing the "buddy system" within the structure.

Other sources of exposure to potential process contaminants may occur during the performance of specific process activities, including cleaning the gasifier, product sampling, emptying the coal and char vessels, and dissembling the cyclone. The performance of these activities is governed by standard operating procedures outlined in the plant safety manual and include requirements for insuring a safe workplace atmosphere free of contaminants, and the use of protective clothing and respirators.

Another potential problem area involves the handling of tri-ethyl aluminum which is used in igniting the char burner under high pressure.

Tri-ethyl aluminum is a very reactive reducing agent and presents a potential fire hazard. On direct contact the compound could also cause damage to the skin and eyes. Fire hazard is controlled and worker contact minimized by transporting the compound in high pressure bottles and handling it in a nitrogen atmosphere.

Grinding of coal to the desired size (100 mesh) is achieved using a rod mill located in the coal preparation unit, an enclosed multi-structure building. Exposure to coal dust is controlled in this operation by using a wet grinding operation to reduce dust production. The primary health problem in this unit is expected to be noise; worker exposure is controlled by the use of ear plugs and by regulating the amount of time a worker spends per shift in these areas during rod mill operation.

B. Workforce

The number of workers needed to operate the plant varies depending on plant operational status. During shutdown a crew of ten operators is employed around the clock, 7 days per week on shift duty to maintain process equipment, conduct minor maintenance, keep utilities running, and for housekeeping. A staff of 97 is required during process runs to keep the plant operating 24 hours per day, 7 days per week. Four shift crews are used for operators, process engineers, and chemists. Other workers are on nonshift day duty. See Table 2 for a breakdown of the plant staff.

There are no job descriptions detailing the duties of the operator job categories listed in Table 2. Requirements for these positions are in very general terms and are concerned primarily with the level of experience of the worker. Specific duties are given in writing during job training, which is held prior to each major run.

Table 2

BI-GAS Pilot Plant
Homer City, Pennsylvania

Plant Staff

Operators (Shift)	Laboratory	Maintenance (Nonshift)
4 Shift Supervisors	1 Chief Chemist (Nonshift-Day)	3 Supervisors
4 Process Engineers	8 Chemists (Shift)	37 Craftmen
40 Operators		11 Pipefitters
8 "A" Boardmen (Control Room)		5 Millwrights
8 "B" Operators		5 Electricians
12 "C" Operators		2 Operations Engineers
12 "D" (Laborers)		1 Teamster
		2 Boilermakers
		1 Ironworker
		3 Laborers
		4 Insulators
		2 Carpenters
		1 Painter

Operator assignments by unit operation are:

Operator	Unit Operation
A	Control Room
B	Assist "A" in control room; other areas as assigned, especially coal grinding and utilities
C	One operator is in gas treating/compressor building; two operators are in the main process structure with one being responsible for the first five stories and the second the remaining
D	Assist "B" in grinding operation; training for other positions

On the basis of assigned areas, it is believed that the "C" operators assigned to the process structure and the "D" operators are the primary operator groups with potential exposure to process contaminants. The "C" operators are responsible for all liquid process samples and these activities serve as a major means of exposure. Other activities include general maintenance and selected housekeeping activities such as the cleaning of spills.

The laboratory chemists may be exposed to process contaminants during the collection of gas samples with sample bombs and while handling and analyzing process samples. For maintenance, the groups with the greatest potential for exposure include pipefitters, millwrights, laborers, and insulators. The boilermakers and carpenters may be exposed on occasion to process contaminants during the performance of selected activities.

Worker exposure is controlled through the use of proper protective clothing and equipment and by insuring that workers follow the standard operating procedures given during training. Hard hats and safety glasses are required in the process area; other safety equipment is provided as needed depending on the activity. These include:

- Entering the gasifier and other confined spaces and/or breaking into process lines
  raingear (sealed at cuffs)
  respirator
  chemical goggles and/or faceshield
  rubber gloves

- Cleaning spills
  rubber boots
  rubber gloves
  coveralls
  chemical goggles and/or faceshield

- Handling chemicals
  chemical goggles and/or faceshield
  rubber gloves (caustic/acids)
  respirator

- Taking samples
  respirator
  chemical goggles and/or faceshield
  rubber gloves

Respirators used in these tasks are determined by the expected hazard. The MSA Confo II respirator with appropriate cartridge is used for most of these activities. Available cartridges include organic vapor, paint chemical cartridge, caustic/acid gas, dust, and for specialty chemicals needed in certain support processes. Cartridges are discarded after each use. An MSA powered air-purifying respirator and 3M disposable dust respirator are also available. Scot self-contained or supplied-air respirator are used in emegency situations.

Respirators and other protective equipment are kept in the control room or maintenance shop. The supervisors are responsible for the equipment and for providing workers with the appropriate equipment. Workers, however, are responsible for cleaning equipment after use. The protective clothing and equipment available to the workers are sufficient to control the identified hazards within the facility. However, the overall program can be strengthened by providing more clearly assigned responsibilities for various aspects of the program such as equipment maintenance.

C. Health and Safety Program

The BI-GAS Pilot Plant is under the management of a corporation in the construction field. Because the hazards associated with construction activities are generally of a safety nature, construction firms tend to be more safety-oriented in their concern for the health and safety of the employees. This safety consciousness is refelcted in the BI-GAS Health and Safety program.

The BI-GAS program, and its policies, procedures, and priorities are set by the plant Safety Hazards and Review Committee, following corporate policies. The Committee is composed of management and supervisory level personnel; there is no worker representation. The implementation of the program is the responsibility of the safety supervisor, who is also a committee member.

Workers are kept appraised of the program through the Safety Policies and Procedures Manual, safety training sessions, and monthly meetings. The manual, which is issued to each employee, emphasizes safety, stressing items such as:

- Fire prevention;
- Prevention of accidental injuries;

- Handling of chemicals to prevent accidental injuries;
- Emergency procedures, and
- First aid.

Training sessions involve the education of new employees on job hazards with emphasis on safety and safe work practices. Sessions usually run about two hours. The monthly meetings, which are scheduled to last one hour, are used to obtain worker input on the safety program and its policies and to highlight selected safety topics.

Because of the emphasis on safety, the industrial health aspects of the BI-GAS program have not been fully developed. Health concerns covered the training of personnel in the handling of common chemicals such as solvents and caustics and in the health effects of overexposure. Monitoring activities were limited to detector tube measurements for hydrogen sulfide, sulfur dioxide, carbon monoxide, and carbon dioxide. None of these compounds was detected.

There is no systematic program of industrial hygiene monitoring to determine the type of hazards to which workers are exposed and the level of exposure. Of particular concern is worker exposure to the polynuclear aromatics, which are potential skin carcinogens. Steps however, are being taken to implement an in-depth industrial hygiene program to identify potential hazards and to determine quantitative exposures to these hazards.

Because of OSHA regulations, the Department of Energy requested sampling for arsenic, benzene, coal dust, and noise. For arsenic, four area samples were taken in the gasifier area during plant operations on November 14, 1978, and on December 13, 1978. Reported air concentrations were less then $1 \mu g/m^3$.

Four area samples and 11 personal samples were taken between April

1978 and December 1978 and analyzed for benzene. Area samples were taken at the gasifier and in the laboratory with reported results ranging from less than 0.1 ppm to 0.2 ppm. Personal samples were taken of the chemist and operators and gave a maximum exposure level of 0.1 ppm for a 4-hour sample.

Coal dust exposure levels were determined using 2 area samples and 6 personal samples taken between September 1977 and March 1978. All samples were taken in the coal grinding area and personnel assigned to this area. Area and personal samples showed respirable dust levels well below $1 mg/m^3$.

Noise survey results indicated two potential problem areas, the coal grinding facility which is enclosed and the utilities building where recorded noise levels were above 90 dBA. The other process areas had levels below 90 dBA and in most cases below 85 dBA. Worker exposure in the two potential problem areas is controlled by the use of ear muffs and by regulating the amount of time a worker can spend in these areas. If strictly enforced these controls could prove effective in preventing occupational hearing losses.

The medical program consists of an annual examination which includes chest X-rays, pulmonary function tests such as forced vital capacity and one-second forced expiratory volume, and audiometry. These tests are conducted at the plant by an outside company. Testing is performed in a mobile van. About 90 percent of the workers participate in these exams.

The major weakness of the medical program is the absence of a pre-employment physical examination, which is needed to provide a baseline for the tests given at the annual examination. BI-GAS does not provide this examination because its employees are considered to be temporaries and corporate policy does not provide for this service for temporaries. An examination of the OSHA accidental injury records (Form 200) for 1978 and the first six months of 1979 indicate the presence of skin irritation problems among operators and maintenance workers who were exposed to NALCO water treatment chemicals. The personnel was educated on the necessity of wearing protective equipment when handling irritating chemicals.

Because of skin irritation problems and becuase of the possible presence of polynuclear aromatics, which are potential skin carcinogins, periodic skin examinations to potentially exposed workers should be made.

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