

FINAL

**CONTROL TECHNOLOGY ASSESSMENT
FOR
COAL GASIFICATION AND LIQUEFACTION PROCESSES**

**CAN-DO Anthracite Coal Gasification Plant
Hazelton, Pennsylvania**

**Report for the Site Visit
of May 1981**

Contract No. 210-78-0084

April 1982

Submitted to:

**Phillip A. Froehlich, Project Officer
National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati, Ohio 45226**

Submitted by:

**Donato R. Telesca, Manager
Engineering Department
Dynamac Corporation
Enviro Control Division
11140 Rockville Pike
Rockville, Maryland 20852**

FOREWORD

On May 28, 1981, personnel from Enviro Control, Inc. visited the CAN-DO Coal Gasification Plant in the Humboldt Industrial Park outside Hazelton, Pennsylvania. The purpose of the visit was to study the technologies used to control occupational exposure to hazardous chemical and physical agents at the gasification facility. The following people participated in the meeting:

CAN-DO

Mr. W. Kevin O'Donnell, Assistant Director
Mr. John J. Rabbitz, Assistant Plant Manager
Mr. J. Michel, EBECO Engineering Co.

Enviro Control, Inc.

Mr. D. Telesca, Program Manager
Mr. J. Scopei, Chemical Engineer
Mr. J. Engler, Industrial Hygienist
Mr. D. Adler, Industry Analyst

TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	ii
LIST OF FIGURES AND TABLES	v
I. INTRODUCTION	1
A. Contract Background	1
B. History of the CAN-DO Anthracite Coal Gasification Project	1
C. Process Description	2
D. Plant Layout	5
E. Potential Hazards	7
II. ENGINEERING CONTROL TECHNOLOGY	9
A. Introduction	9
B. Coal Storage and Handling	9
1. Process Description	9
2. Control Technology	10
C. Gasification	11
1. Process Description	11
2. Control Technology	15
D. Ash Removal System	17
1. Process Description	17
2. Control Technology	17
E. Hot Gas Cleanup	17
1. Process Description	17
2. Control Technology	18
F. Product Gas Conditioning	18
1. Process Description	18
2. Control Technology	19
III. WORK PRACTICES	21
IV. PROTECTIVE CLOTHING AND EQUIPMENT	24
V. MONITORING PROGRAMS	25

TABLE OF CONTENTS (Continued)

	<u>Page</u>
VI. HEALTH AND SAFETY PROGRAMS	26
A. Employee Education and Training	26
B. Safety	26
C. Industrial Hygiene	26
D. Medical Program	27
VII. CONCLUSIONS AND RECOMMENDATIONS	28
REFERENCES	30

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Simplified Process Flowsheet	3
2	Elevation Drawing of CAN-DO Gasification Building	6
3	Schematic Drawing of Wellman-Galusha Gasifier and Cyclone	12

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
1	Potential Hazards By Process Area: CAN-DO Anthracite Coal Gasification Plant	8
2	Typical Analysis of Gasifier Product Gas	14

I. INTRODUCTION

A. Contract Background

The objective of the "Control Technology Assessment for Coal Gasification and Liquefaction Processes" program is to study the control technologies that are available to prevent occupational exposure to hazardous agents in coal conversion plants. This information is gathered by the Enviro Control Technology Assessment (CTA) team during site visits to engineering firms, gasification plants, and liquefaction facilities. Of particular importance is the industrial use of low-Btu coal gasification processes because of its potential for replacing more expensive and scarcer fuels such as natural gas and oil. One low-Btu gasification process that is commercially available in the United States is based on the Wellman-Galusha gasifier. This report details the control technology and industrial hygiene information gathered on the Wellman-Galusha gasifier and ancillary equipment in use at the CAN-DO Anthracite Coal Gasification Plant, Hazelton, Pennsylvania during a site visit on May 28, 1981.

B. History of the CAN-DO Anthracite Coal Gasification Project

CAN-DO Inc., is a non-profit organization founded twenty-five years ago to encourage industrial development in Hazelton, Pennsylvania, and in the surrounding area. In 1973, natural gas shortages prompted CAN-DO to investigate the possibility of building a gasification plant that would utilize the extensive local sources of anthracite coal to provide gas for the Humboldt Industrial Park. The idea was stimulated by the successful experience of the Hazelton Brick Company which has used a Wellman-Galusha gasifier operating with anthracite coal intermittently since the 1940's. The Appalachian Regional Commission gave CAN-DO a grant to study the feasibility of the project. The conclusion of the study, which was performed by the Stokes Consulting Group and the Gas Machinery Associates, was that the project was feasible technically but not economically.

In 1976, after the oil embargo, the idea of a coal gasifier was revived by the Economic Development Administration which was looking for ways to

revitalize the industrial base in the Northeast. The initial grant of \$2 million dollars was not, however, sufficient to proceed since CAN-DO had no capital of its own available for the project. It was not until other backers agreed to provide financial support that the plan got under way. These other backers included the Appalachian Regional Commission, the Commonwealth of Pennsylvania, and Luzerne County. The Department of Energy (DOE) also agreed to provide support for the plant operations.

A request was issued for engineering proposals. With technical help from DOE, CAN-DO selected a local firm, EBECO Associates, Inc. The project was headed by Hugh Campbell, III who had been closely associated with the Hazelton Brick Coal Gasification Project for many years. A contract for the design of a facility containing two Wellman-Galusha gasifiers was signed in September, 1977. Construction bids were accepted in 1979.

Initial runs were made over a six week period in February and March of 1981 with Gasifier I. Gas was produced but not passed through the scrubbers or any of the gas processing equipment. Runs were stopped when a leak was discovered near the flare. Future activities include re-starting Gasifier I, and commissioning Gasifier II and the downstream gas processing equipment.

C. Process Description

The CAN-DO coal gasification plant has two Wellman-Galusha gasifiers with a combined daily output of 7 million standard cubic feet (scf) of low-Btu gas from 50 tons per day of anthracite coal. The heat content of the gas is 150 nominal Btu/scf. The use of anthracite greatly reduces the gas clean-up requirements and eliminates the need for special tar and oil handling facilities and procedures. The building is large enough to permit the installation of two additional gasifiers should the need arise. The major operations at the plant are coal storage and handling, gasification, ash handling, particulate removal, gas cooling, gas compression, gas drying, gas reheating, and water treatment. A schematic of the process is shown in Figure 1. Most equipment is spared to facilitate servicing and prevent a complete shutdown in case of equipment malfunctions.

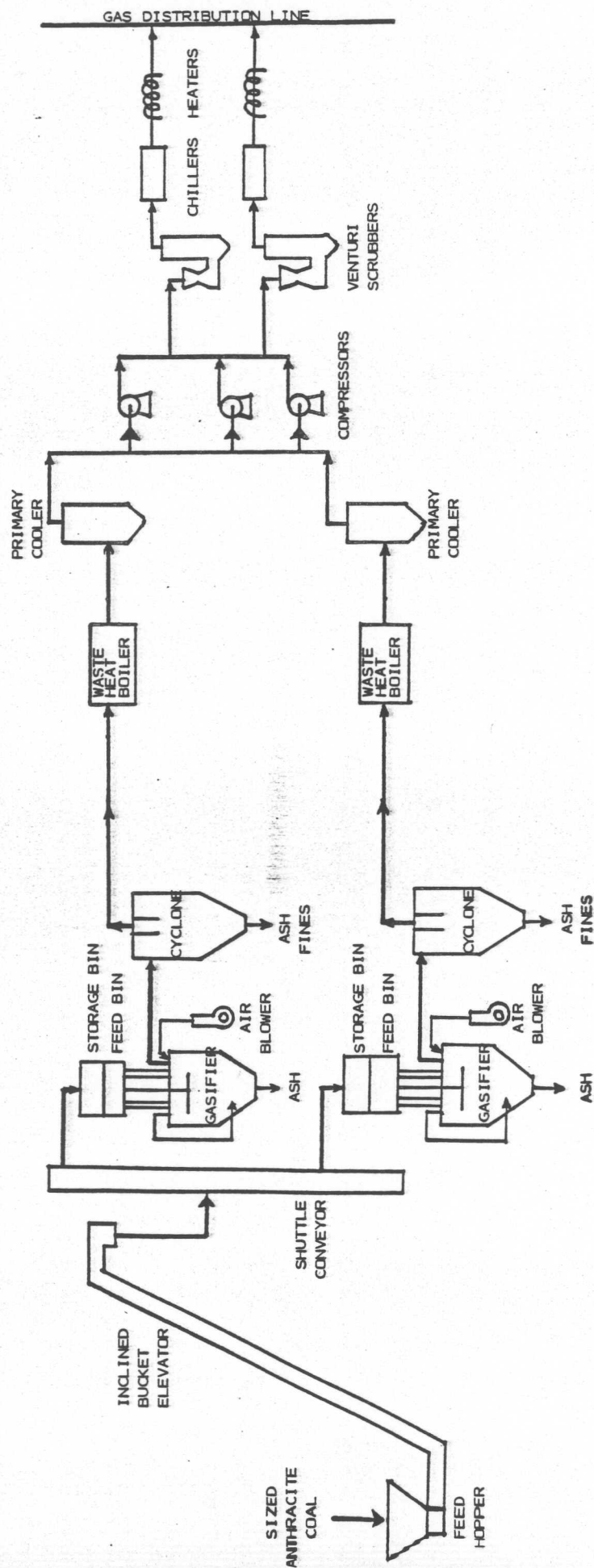


Figure 1. Simplified Process Flowsheet

Pea coal is delivered by truck to the plant. A portion is stored inside and the rest outside in the receiving area. A front loader moves the coal to a hopper. From there it is lifted by an inclined belt conveyor to the fourth level where it is dumped to a reversing shuttle conveyor. The shuttle conveyor distributes coal to two bins directly above the gasifiers on the fourth level.

From the bins, coal is fed to feeding compartments by gravity. Each feeding compartment has two downpipes for feeding coal to the gasifier directly below. Each pipe has two knife valves interlocked so that both cannot be opened at once. Below the valves the coal is channeled into two pipes to distribute the coal evenly into the gasifier. An agitator is used to maintain an even coal bed.

Eight poke holes at the top of each gasifier are used to measure the depth and uniformity of the combustion zone and the ash bed. Two more poke holes are used to break up clinkers and measure the top of the coal bed.

The gasifier is enclosed in a water jacket. Air from primary blowers passes over the water in the water jacket picking up moisture, and then flows through a "saturation" pipe down the side of the gasifier. The saturated air is fed up through a revolving grate to wet the ash and provide the steam needed for gasification. The grate distributes the saturated air and removes the ash to a bin from which it is removed through slide valves two or three times per day.

The product gas passes through a cyclone for removal of char and ash particulates. The ash and char is flushed from the cyclone about twice a month.

From the cyclones the product gas passes to a waste heat boiler which cools the gas and generates steam to drive two refrigeration unit compressors. A third electrically powered refrigeration unit compressor is available as a back-up. The gas flows from the waste heat boiler to the primary direct cooler. After cooling, the pressure of the gas is roughly two inches of mercury. It is then pressurized by three turbo compressors to about

5-6 psig and passes through two Venturi scrubbers. The gas is dried by chilling it to condense out the water. It is then reheated to room temperature, resulting in a product gas with a nominal heat content of approximately 150 Btu/scf.

D. Plant Layout

The CAN-DO gasification plant is housed in an enclosed four-tier structure. Figure 2 is a cross section showing the location of the principal pieces of equipment. Coal, from storage piles outside the building, is brought into a coal storage area on the first level by a front end loader. The front end loader dumps the coal into a bin that feeds a belt conveyor. The conveyor transfers the coal to storage bins above the gasifier located on the fourth level of the structure. Also located on the first level are: the waste heat boilers, the primary scrubbers, and the refrigeration units; an ash disposal area for removal of ash from the gasifier and the particles from the cyclone; a water treatment unit, a coal sample preparation room, a reception area; and a locker room and workshop. A system of underground tanks holds water for recycling.

The second level contains the gasifiers, the primary air system, the turbo compressors and the venturi scrubbers. Also located on this level are the control room and a laboratory. Neither the control room nor the laboratory are positively ventilated with outside air. The cyclones are mounted between the second and third levels.

The third level allows access to the top of the gasifier and the gasifier pokeholes. The raw gas discharge line, the flare bypass valves, and the air saturation pipe are all accessible at this level. Also located on the third level are the heat exchangers and the gas reheater.

The fourth level is only partially enclosed. The enclosed area contains the two bins in which the coal is stored before feeding into the gasifier. A reversible conveyor is used to distribute the coal to either of the storage bins. Water coolers are located on the roof.

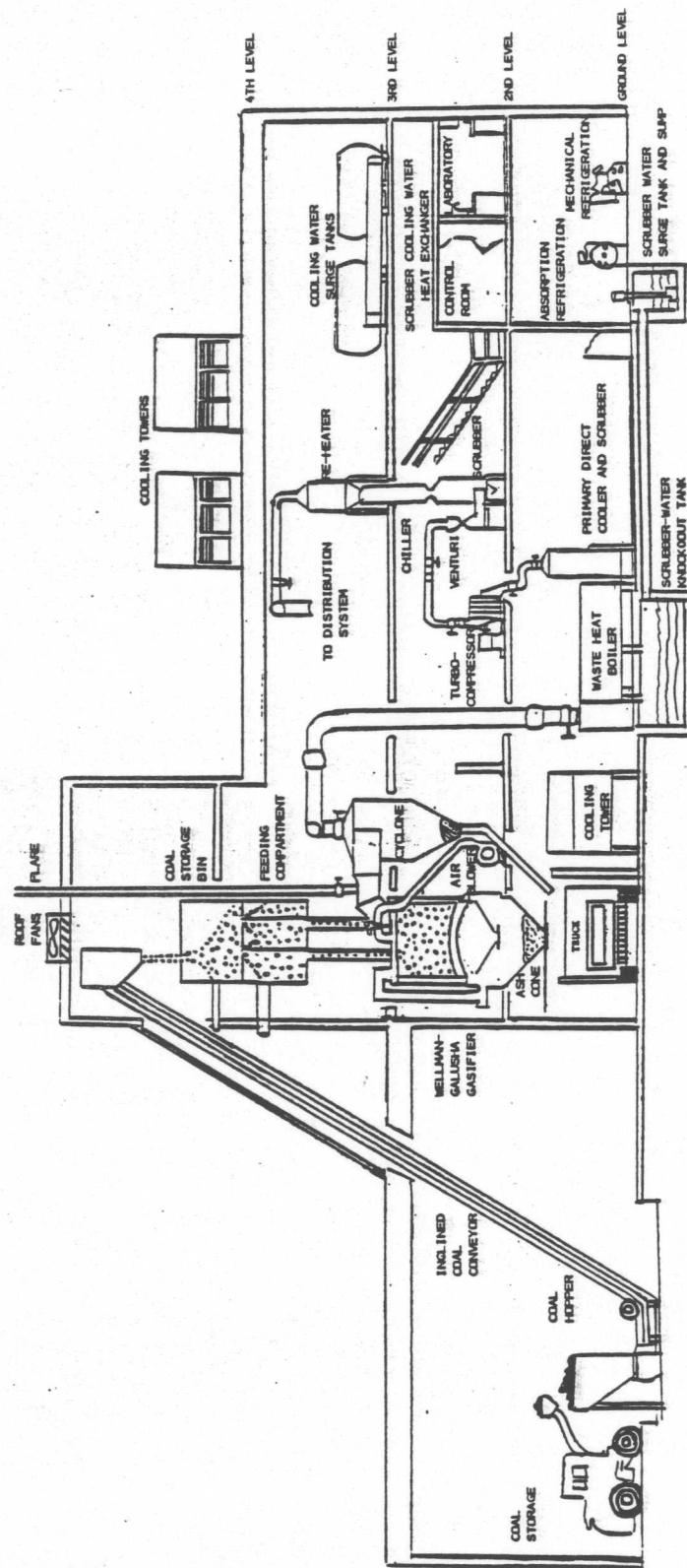


FIGURE 2. Elevation Drawing of CAN-D0 Gasification Building
(adapted from drawing supplied by CAN-D0)

E. Potential Hazards

The potential hazards associated with the CAN-DO Anthracite Coal Gasification Plant are listed in Table 1. The major potential health hazard at this facility is exposure to carbon monoxide (CO). Because low-sulfur coal is gasified, hydrogen sulfide is not expected to be a problem. In addition, because tars and oils are not generated by the Wellman-Galusha gasifier when fueled with anthracite coal, exposure to polynuclear aromatics (PNAs) is not a major concern.

At the time of the site visit (May, 1981) the gasifier had been run, but none of the downstream processing equipment had been operated. All the gas produced has been flared. As a result it is doubtful that all potential occupational safety and health hazards have been identified. Continuing industrial hygiene support activities at the CAN-DO facility are to identify and resolve additional areas of concern.

TABLE 1

POTENTIAL HAZARDS BY PROCESS AREA:
CAN-DO ANTHRACITE COAL GASIFICATION PLANT

PROCESS AREA	POTENTIAL HAZARD
Coal Storage and Handling	Respirable Coal Dust Carbon Monoxide Noise
Gasification	Carbon Monoxide Flammable/Explosive Gases
Ash Removal	Respirable Ash
Hot Gas Cleaning	Carbon Monoxide
Product Gas Conditioning	Carbon Monoxide Flammable/Explosive Gases

II. ENGINEERING CONTROL TECHNOLOGY

A. Introduction

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

B. Coal Storage and Handling

1. Process Description

Pea or buckwheat size anthracite coal with a sulfur content of approximately 0.7 percent is delivered to the facility by truck. The coal is dumped onto a concrete unloading pad. Each load of coal is moved by front end loader to an individual coal pile to await analysis. Each coal pile is flagged for identification purposes. The outdoor storage capacity is approximately 500 tons, or a ten day supply.

After the coal has been analyzed, it is moved to the indoor storage area on the first floor level of the building by a front end loader. Indoor storage capacity is approximately 100 tons, or about a two day supply. The front end loader dumps the analyzed coal into a three ton coal hopper. The coal hopper feeds an inclined belt conveyor that transfers the coal at up to 30

tons per hour to a reversing shuttle conveyor located on the fourth level of the gasifier bay. The control room operator directs the coal to either of two coal feed storage bins. There is space for two additional bunkers if additional gasifiers are installed. The bins are vertical cylindrical vessels, approximately 10 feet in diameter, and 8 feet high. The bottom of the bin is flat, not cone shaped. The storage bunkers are equipped with high level alarms that signal the operators to stop the coal feed conveyors when the bunker is full of coal. The level switches are protected by "dunce cap" shrouds. Coal is fed from the bin to the gasifier feeding compartment through two slide gate valves.

2. Control Technology

The use of presized anthracite coal eliminates the need for coal crushing and sizing equipment, major potential sources of dust and noise. In addition, because anthracite coal is less friable than lower rank coals and lignite, excessive fines generation during coal handling operations is not a problem.

The indoor coal storage area has a water hose for wetting the coal to suppress dust, and for putting out fires that may occur by spontaneous combustion if the coal is stored for a prolonged period of time. The coal hopper is equipped with a water spray for dust suppression.

The inclined belt conveyor is a "Flex-o-Wall" type conveyor. The belt is channel shaped in cross-section with fluted sidewalls and is constructed of rubber. The use of this type of conveyor to elevate the coal results in little coal breakage and dust generation. This conveyor also operates very quietly. Occasionally coal falls from the belt into the process area below. To prevent this, the conveyor was being enclosed in sheet metal during the May, 1981 site visit.

Coal being discharged into the coal bins from the shuttle conveyor damaged the high level alarm switches in the bins. This resulted in the bunkers being overfilled and spilling coal onto the fourth level. Cleaning up the

coal exposed workers to coal dust and to elevated carbon monoxide levels that occur on this level during the coal feeding operation. Protective shrouds constructed over the level switches solved the problem.

C. Gasification

1. Process Description

Coal from either of the storage bins on the fourth level flows by gravity through either of two slide valves into a coal feeding compartment. Another pair of slide valves at the bottom of the coal feeding compartment allows the coal to pass into a set of downlegs. Each downleg is shaped like an inverted "Y" so that the coal is fed into the gasifier at four points to distribute the coal evenly at the top of the gasifier.

The four slide valves control the flow of coal into and out of the feeding compartment. The upper valves open while the lower valves remain closed and the compartment fills. The upper valves then close and the lower valves open, allowing coal to flow into the downlegs. The valve sequencing is timed so that there is coal in the downlegs at all times. This ensures a constant flow of coal into the gasifier. In addition, the coal in the downlegs provides a seal for the gasifier.

The Wellman-Galusha gasifiers are manufactured by the McDowell-Wellman Company. They are fixed-bed, air-blown, low pressure, dry ash, single stage gasifiers. A schematic of the gasifier is shown in Figure 3. Each gasifier has a feed capacity of 25 tons per day of low sulfur anthracite coal and produces approximately 3.5 million standard cubic feet per day of low-Btu gas. The heating value of the gas is nominally 150 Btu per standard cubic foot. The gasifier can be operated in the "banking" mode for an indefinite period of time. In this mode of operation the feed rate is about one ton of coal per week, and the small quantity of gas that is produced is vented to a flare on the roof of the structure.

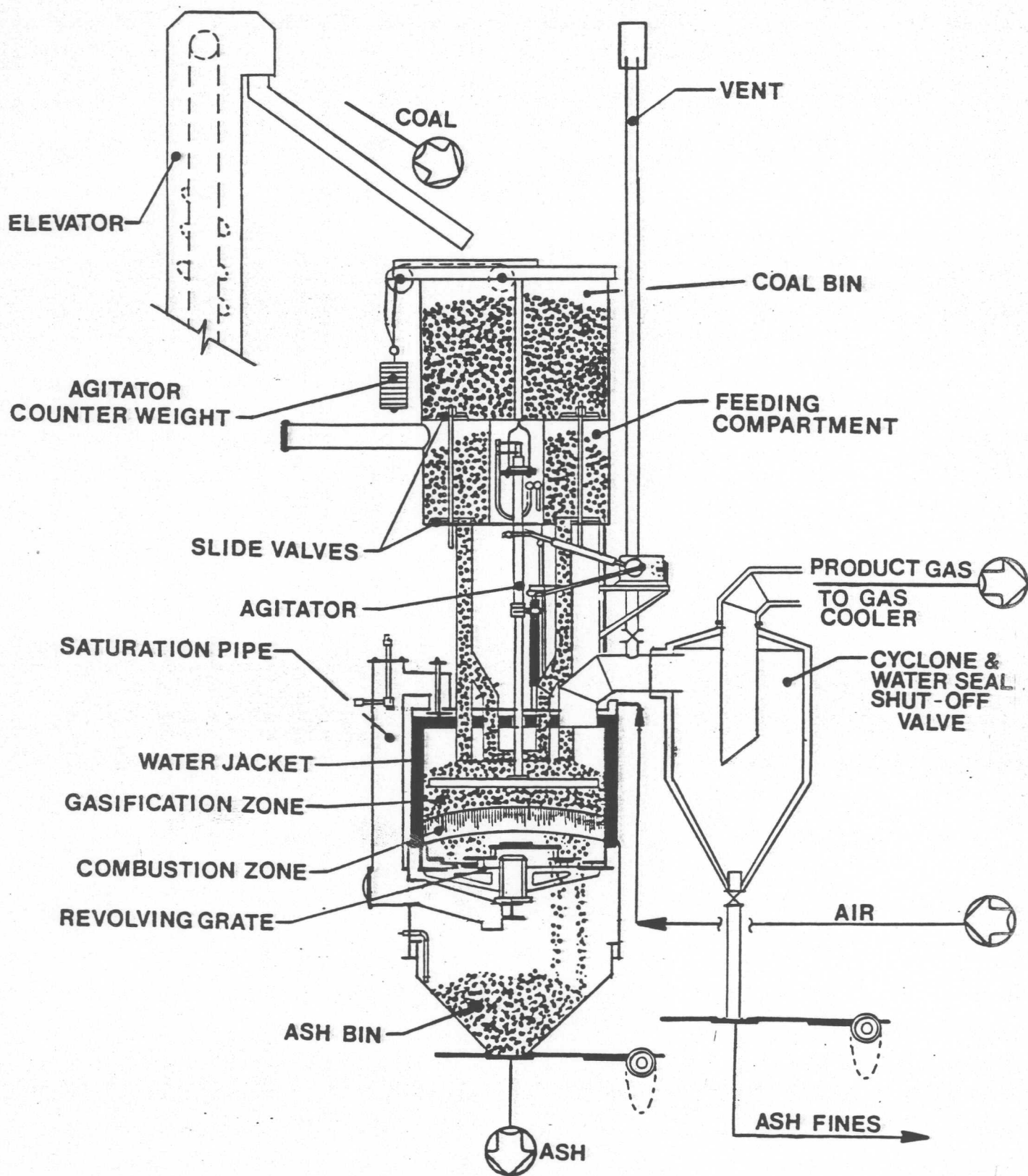


Figure 3. Schematic Drawing of Wellman-Galusha Gasifier and Cyclone (adapted from Reference 2).

The major physical features of the gasifier include a saturation pipe, revolving grate, water jacket, feed-pipe downlegs, poke holes, agitator mechanism, product gas take-off line, ash bin, and gasifier vessel. A water jacket completely surrounds the gasifier. The inside wall of the gasifier is steel, there is no refractory lining. The agitator mechanism consists of a horizontal arm, vertical drive shaft, gear box, drive, and counter weight (see Figure 3).

The vertical position and speed of the agitator arm can be varied for different coal feed rates. The agitator is suspended in the gasifier by a cable and counterweight. The cable is connected to the agitator at one end. It passes through a hole in the center of the coal bin, exits the top of the bin, passes over a pulley, travels horizontally to another pulley, passes through a hole in the fourth floor and is attached to an 1800 pound counterweight. The drive shaft and horizontal arm of the agitator are water-cooled steel tubing.

The screw shaped grate is mounted eccentrically on a center post to push the ash into the ash bin underneath the gasifier and to distribute the air and steam evenly through the coal bed.

Blowers provide air to each gasifier. The air picks up moisture as it passes over the top of the water in the water jacket. The water temperature in the jacket is maintained in the range of 150 to 180°F (66 to 82°C). A thermostat controls the flow of water to the jacket. Moisture in the air provides steam for the gasification reaction. The air exits the water jacket through the "saturation pipe." Saturated air enters the gasifier through the grate. The moist air cools the ash as it passes through the ash bed, thus preventing clinkers from forming. The rising steam-air mixture then contacts hot char in the fire-bed zone of the gasifier. Here the char burns to provide heat for the endothermic gasification reactions. The rising hot combustion gases and steam then contact coal in the gasification zone.

Finally, the rising gas heats and dries incoming coal and exits the gasifier through the product gas take-off line to the raw gas clean-up system. A typical composition of the product gas is given in Table 2.

TABLE 2

TYPICAL ANALYSIS OF GASIFIER PRODUCT GAS
(MOISTURE AND SULFUR FREE BASIS)

Component	Mole %
CO	27.1
CO ₂	5.0
H ₂	16.6
CH ₄	0.5
N ₂	50.8
Higher heating value (HHV), 150 Btu/scf (nominal)	

Eight poke holes at the top of each gasifier are used to measure the depth and uniformity of the ash bed and combustion zone (fire-bed). Two additional poke holes are used to check for and break clinkers in the ash bed and to measure the distance from the surface of the coal bed to the top of the gasifier. This distance is called the freeboard.

Start-up of a cold gasifier involves placing wooden "wicker boxes" at various locations on the ash grate. Wicks, saturated with fuel oil, are inserted into the wicker boxes with the ends trailing down through openings in the grate so they can be lit from the ash bin. Charcoal, saturated with oil, is loaded onto the ash grate by hand until the wicker boxes are covered. The gasifier is then loaded with anthracite coal and the flow of combustion air is started. The wicks are lighted through the ash bin slide valve and the valve is closed. The gasifier pressure is maintained at about one inch of water column for a few hours with the product gas being

vented to a flare on the roof of the gasifier building. The gasifier is then brought up to operating pressure by partially closing the valve on the exhaust line to the vent. If the fire bed is burning properly, the exhaust valve is closed completely and the product gas is directed to the hot gas clean-up cyclone.

For temporary shutdowns, a "hot standby" condition is achieved by banking the fire, flooding the cyclone with water to close the product gas take-off line, and venting the product gas to a flare. The unit is brought back on stream by increasing the air and coal flowrates, closing the vent valve, and directing the gas to the cyclone.

2. Control Technology

The hazards associated with the gasification area are exposure to carbon monoxide, fires, and explosions. Exposure to hydrogen sulfide (H_2S) is not considered by safety personnel to be a hazard at CAN-DO. The rationale for this is that the concentration of H_2S in the product gas is expected to be below 1000 ppm, whereas CO is almost 30 percent of the product gas stream. Consequently, the presence of CO in the workplace will be detected before H_2S concentrations pose a hazard.

The leakage of product gas through flanges, poke hole covers, and during poking operations is directly proportional to the gasifier operating pressure. Therefore the gasifier is operated at a pressure of approximately four inches of water column, and the product gas is boosted to the pipeline delivery pressure of 5-6 psig after it has been cleaned and cooled.

Ventilation is used to control the build-up of potentially dangerous levels of carbon monoxide in the gasification building. Four exhaust fans are located in the roof of the building over the gasifier bay. The fans operate continuously at low speed; however, when CO monitors on the fourth level of the gasifier bay detect a CO concentration in excess of 50 ppm they automatically switch the fans to high speed.

Although the roof fans appear to be effective in dissipating high CO levels, they have created another concern. Because the number and/or size of outside air intake vents is too small, the building is under negative pressure when the fans operate at high speed. On one occasion while a gasifier was operating in the banking mode, air was drawn down the gasifier vent pipe and into the gasifier. The excess oxygen caused a mild explosion (backfire) in the gasifier. This type of explosion is similar to those that are known to sometimes occur when taking fixed-bed gasifiers from the banking mode to normal operation. Although no damage occurred, the possibility of pulling gases out of the gasifier when in a banking mode and into the workplace when the fans are operating at high speed is an undesirable situation. As of the date of the site visit (May 28, 1981) this situation had not been solved.

In order to prevent over-pressurization of the gasifiers, blow-out vents (openings fitted with a rubber diaphragm) are provided on the gasifier feed compartments and the saturation pipes. Pressure release is through vent lines to the outside of the building.

During a pressure test of one of the gasifiers, leaks were detected at the firedoors, gasifier and cyclone flanges, gasifier body flanges, coal feed downlegs, poke hole covers, and coal feed compartment inlet and outlet slide valves. The following corrective actions have reduced emissions significantly.

- Rough spots on the lip of the firedoors and poke hole covers were filed smooth to make a better seal with the gasifier.
- The faces of the slide valve body were filed smooth to make a better seal with the slide.
- The flange bolts had been tightened unevenly causing a misalignment of the flange faces. The bolts were removed, the gasket aligned, and the bolts retorqued properly.
- The top and middle sections of the gasifier are bolted together with body flanges. Leaks occurred through the joint in these flanges. The gap between the flanges was seal welded to eliminate the leaks.
- The coal feed downlegs are screwed into the top of the gasifier. Gas was leaking past the threads. A seal weld was placed around the downlegs where they enter the gasifier to eliminate the leaks.

D. Ash Removal System

1. Process Description

Ash is removed from the ash bed by the eccentrically mounted, rotating, screw-shaped grate. The ash falls through the moist air entering the gasifier from the ash bin below. The moisture in the air dampens the ash and causes it to agglomerate slightly. Ash is removed from the ash bins two or three times a day. A truck is positioned under the ash bin and a chain-operated slide valve is opened. The valve is closed when the bin is empty and the ash is transferred to a concrete pad outside the building. The ash, which contains about 0.1% carbon, is used for landfill and for "sanding" roads in the winter.

2. Control Technology

The hazards associated with this process area are inhalation of ash dust and scalding from contact with hot (180°F), moist gasifier feed air.

The potential for inhaling ash dust is very slight because the ash, when it is discharged, is a moist, granular material that tends to agglomerate.

The potential for scalding is also slight because the slide valve is chain-operated, enabling operators to stay clear of any release of hot feed gas.

E. Hot Gas Cleanup

1. Process Description

The temperature of the raw product gas leaving the gasifier is maintained in the 800°F (427°C) to 1000°F (538°C) range. Hot gas cleanup consists of sending the raw gas through a refractory-lined cyclone for particulate

removal. The cyclone is located adjacent to the gasifier between the second and third levels.

During banking operations, the cyclone can be filled with water to cover the opening of the outlet pipe (see Figure 3). This acts as a water seal shut-off valve. When returning to normal gasifier operations, the water level is slowly dropped. To avoid gas flow surges, the cyclone outlet pipe has been cut at an angle; thus as the water level drops, the amount of gas entering the outlet pipe increases gradually.

Three to four cubic feet of fly ash is removed from the hot cyclone twice a month. The fly ash is mostly carbon. To empty the cyclone, an operator opens the upper ash valve in order to fill the cyclone downleg with ash. The upper ash valve is closed, water is injected into the downleg, and a truck or front-end loader is pulled into position under the downleg. The lower ash valve, which is a chain-operated slide valve, is opened and the ash slurry in the downleg drops into the truck. The slide valve is then closed. The cyclone ash is dumped on the pad with the gasifier ash.

2. Control Technology

The hazard associated with the hot gas cleanup area is the inhalation of coal ash dust. This hazard is minimized by injecting water into the downleg of the cyclone to wet the ash and suppress dust generation during removal.

F. Product Gas Conditioning

1. Process Description

In this process area the product gas undergoes additional particulate removal, cooling, demisting, and compression. Desulfurization of the gas is not required because the plant gasifies low sulfur coal. There are two parallel trains of gas conditioning equipment.

Hot product gas exiting the cyclone at 650°F (343°C) goes to the waste heat boiler. The temperature of the gas is lowered to 250°F (121°C), and low pressure steam is produced to drive the chiller/demister refrigeration compressor.

From the waste heat boiler, the gas flows to the primary direct cooler. The primary direct cooler is an impingement type wet scrubber. Here the gas is cooled further and fine particulates are removed. Gas exiting the direct cooler is at 200-250°F (93 - 121°C) and at approximately two inches water column (w.c.) pressure. Turbo-compressors then boost the gas pressure to 5-6 psig. The compressed gas is sent to a venturi scrubber where the gas is cooled and additional fine particulates are removed.

Scrubbing water from the direct cooler and from the venturi scrubber is pumped to a knock-out tank where the particulates settle out. The clarified overflow from the settler collects in a surge tank. Water from the surge tank is pumped through heat exchangers back to the direct cooler and venturi scrubber. To prevent the accumulation of ammonia and fine particulates in the scrubbing water, a slip stream of scrubbing water is continuously removed. The slip stream goes to ammonia removal, and to flocculation and clarification units for fine particulate removal before being reinjected into the recycle stream.

From the venturi scrubber the gas flows to the chiller/demister, where the gas is cooled to 40°F (4°C), and the condensed water vapor is removed. The clean, dry gas is reheated to approximately 70°F (21°C) by an electric resistance heater and is fed to the pipeline for delivery to the consumers.

2. Control Technology

The potential hazards associated with the Product Gas Conditioning area are inhalation of CO, asphyxiation, fires, and explosions due to product gas leaks from process equipment. The engineering controls that will be used to mitigate these hazards are described below.

Product gas leakage is reduced by pressurizing the system with nitrogen before start-up and soap bubble testing valves, valve stems, flange joints, and other gasketed joints for leaks. Leak testing reduces, but does not eliminate product gas emissions. Consequently, general dilution ventilation is used to control potentially toxic concentrations of CO and flammable or explosive concentrations of product gas. In addition, explosion-proof motors and electrical equipment are used in this process area.

The carbon dioxide and hydrogen sulfide present in the product gas dissolve in water to form carbonic acid and hydrosulfide species. As a result, scrubbing water and wet product gas are very corrosive. In order to prevent equipment and piping leaks due to corrosion, the materials of construction in this process area are primarily stainless steel and polyvinyl chloride (PVC). The vessel shell, trays, and demister pad of the primary direct cooler are fabricated from type 316 stainless steel. The scrubbing water piping is schedule 80 PVC. The product gas turbo-compressors have internal bearings, consequently the bearings will be exposed to wet corrosive product gas. The bearings, which are now carbon steel, will be replaced with stainless steel bearings.

Because equipment in this process area had not been operated as of the date of the site visit, additional hazards may be discovered once integrated operation of the facility is achieved. One of these hazards may be the accumulation of PNA containing tars and oils in the scrubbing water of the direct cooler and the venturi scrubber. Another potential hazard is the absorption and subsequent release of ammonia and hydrogen sulfide from the scrubbing water into the workplace.

III. WORK PRACTICES

When the gasifiers are operating, three shifts are used to monitor the process 24 hours a day, seven days per week. Three men will be assigned to each shift, but only two of the three will be on site at the same time. These two men, presently referred to as the operator and operator's assistant, will eventually be referred to as the leaderman and the leaderman's assistant.

Representatives for the Department of Energy will initially be working with employees on each shift instructing them on how to properly monitor gasifier activities. Management indicates this training will continue for one year, and will include instruction on the proper sampling of ash and product gases, and the use of laboratory equipment for analysis of the samples.

Activities performed by the operators and their assistants include such tasks as taking temperature and pressure readings, determining fire-bed depth and free board height (poking), loading and transferring coal, dumping ash and providing routine maintenance on the gasifier. Additional tasks will be added to these after training is completed. These tasks will include collection and analysis of product gas samples, ash, etc. In the interim, specific tasks performed by these employees include:

- Poking Procedures (twice per shift or as required)
 - Check coal flow to the gasifier
 - Turn grates off
 - Check agitator position (or turn off)
 - Insert poke rods (three minutes)
 - Pull rods and check ash height
 - Observe color of rods and fire bed conditions
 - Start grates
 - Start agitator (if required)
 - Log all conditions and average ash depth
 - Check free board depth
 - Be certain all poke holes are closed
- Gasifier Operating Procedures (done hourly)
 - Log U tube pressures - saturation and off take temperatures
 - Make sure water is coming from jacket overflow
 - Make sure water is coming from agitator and main bearing
 - Check agitator position, height, speed
 - Check grate drive speed

● Gasifier Operating Procedures (each shift)

- Adjust grates and saturation as required
- Grease fittings as instructed on lube chart
- Set oil drops for main grate bearing; 6 drops per minute
- Take fire tests every four hours
- Make sure upper bins are full before end of shift
- Dump ash approximately 5:00 a.m. and 5:00 p.m.
- Dump fly ash Tuesday and Saturday, change charts daily 6:00 a.m.
- Flush water jacket

Gaseous emissions from the open poke holes may expose the operator to high levels of carbon monoxide during the poking operation. In addition, the operator may be severely burned by the hot poke rod or by flames from the open poke hole. Because of the potential hazards associated with the poking operation, a second operator is always present during the procedure. During the poking operation the control room may be unattended; however, annunciators will sound an alarm if there is a process upset requiring operator attention.

Maintenance workers are not assigned to the gasifier facility. When maintenance is to be performed on the gasifier, it will be completed by one or both of the operators working on that shift. A "buddy system" is used on hazardous tasks, such as working inside the gasifier for cleaning or maintenance, or any work requiring entry into a confined space. Because of the potential for the accumulation of product gas from system leaks, no smoking is permitted in the facility when the gasifiers are in operation. Cuffed trousers are not allowed in the facility to minimize the chance of employees being burned by catching the hot poke rod in their cuff when removing it from the poke hole.

To control entry, the facility and surrounding yard is enclosed with a cyclone fence topped with barbed wire. All gates and doors are locked to limit access to the gasifier building. The flare located approximately 100 yards behind the gasifier building is also enclosed within a barbed wire fence.

All visitors to the plant must register at the main desk and are required to wear hard hats. When touring the facility, an employee who works at the facility must be present.

The building may be exited via either of two stairwells. Exits to both stairwells are provided on all levels of the gasification plant. The exits are clearly marked and the exit doors are equipped with panic bar hardware.

IV. PROTECTIVE CLOTHING AND EQUIPMENT

Employees working at the gasification plant are required to wear hard hats and steel toed safety shoes. Safety glasses are not required. The company provides each employee with seven clean work uniforms (shirt and trousers). The present work practice is to provide each employee with three of the seven uniforms per week. The uniforms are made of 65 percent polyester and 35 percent cotton.

No gloves are worn by employees unless they are checking the fire bed depth with rods at the poke holes. When performing this task, insulated gloves with a heat reflective exterior surface are used by the employees to remove the hot rods from the poke holes.

Respirators are available for use at the gasification facility. These respirators include:

- Disposable non-toxic particulate dust respirators.
- Two MSA 30-minute, demand type, self-contained breathing apparatus (SCBA) respirators. These respirators will soon be replaced with two MSA 30-minute pressure demand type respirators. The SCBAs are located in the stairwells on the first and second levels of the facility. The SCBAs are located at these levels for easy access in the event that emergency evacuation of, or re-entry to the gasification facility is required. Both SCBA respirators have a spare 30-minute air tank available. Presently, employees have not been trained in the proper use and maintenance of these respirators. However, on the site survey date, plans were being made with a local supplier of this equipment for a training a program for the gasification plant employees.
- Four demand type, supplied-air line respirators that can be connected to the central compressed air supply system on all levels of the gasifier. These respirators will be replaced with the pressure demand type supplied-air line respirators. Present plans are for all air line respirators to be located in cabinets at hook-up locations to facilitate clean storage and easy access. The respirator training and maintenance program mentioned above should include the use, repair, and maintenance of these respirators.
- The air compressor used to supply fresh air to the air line respirator system is located on the ground level near the flocculator tank. The compressor is oil lubricated and equipped with a multi stage compressed air purification system. There are no high temperature or carbon monoxide alarms installed in the air supply line to warn supplied-air respirator users of potentially contaminated air. Nor are there any CO monitors adjacent to the air intake of the supplied-air respirator compressor to warn of contaminated air.

V. MONITORING PROGRAMS

In February and March of 1981, gasifier plant workers were monitored for exposure to air contaminants by a private consulting firm under contract to the U.S. Department of Energy. Monitoring was performed during start up of the number one gasifier. Background noise measurements were also made throughout the facility by the same firm. The results of these surveys are not yet available. No other monitoring has been performed.

To protect employees from exposure to high levels of carbon monoxide, two CO alarm systems have been installed to monitor CO levels throughout the gasification facility. The centralized control panel for the primary alarm system is located in the control room. Detector alarm units tied into the central monitoring system are located on all levels of the facility. Exhaust fans located on the roof of the facility above the gasifier bay run constantly, but increase in speed when CO levels reach 50 ppm. An alarm also sounds when 50 ppm of CO is detected. Two additional CO alarm units, one located on the second and the other one the fourth level of the facility, operate independently of the central alarm system. The highest CO levels (20 to 50 ppm) are found on the fourth level during the opening of coal feed compartment valves. However, employees rarely work on this level.

The carbon monoxide alarm systems were calibrated approximately one month before this survey with the assistance of an outside consulting firm. At the time of the survey, plans for periodic calibration of the systems were not made.

The gasification facility is equipped with a closed circuit TV system. This enables the control room operator to visually monitor process operations and the activities of the field operators. Activities monitored include coal conveying and feeding on the fourth level of the gasifier bay, coal hopper loading, ash removal, and gasifier poking. The control room operator uses the camera at the coal storage bin loading area to inspect the equipment in the event of a high CO alarm without having to enter the area. The operator can also determine when and which of the coal storage bins needs filling without visiting the area.

VI. HEALTH AND SAFETY PROGRAMS

Presently there is no formal safety and health program at the CAN-DO Anthracite Coal Gasification Facility. As part of the technical support for plant operations, the Department of Energy, through Oak Ridge National Laboratory and a private contractor, is providing an industrial hygiene support program. The objective of the support program is to assist in protecting the safety and health of the employees and to characterize employee exposures to potential health hazards during the start up of the Wellman-Galusha gasifier and ancillary operations.

A. Employee Education and Training

On an informal basis, the assistant plant manager provides new employees with on-site training in the operation of the gasifier. In addition, he is also responsible for familiarizing them with the work practices and engineering controls used at the plant to minimize employee exposure to potential health hazards.

B. Safety

First aid kits are located in the employees locker rooms, control room, and laboratory. Management voiced an interest in having their employees trained in first aid and CPR as added safety measures.

ABC type, all-purpose, 10-pound dry chemical fire extinguishers are located throughout the facility. These extinguishers are to be serviced at least once a year by the same company that currently services the SCBA respirators. Employees currently receive no training in the use of the fire extinguishers.

C. Industrial Hygiene

A locker room is provided on the ground level of the gasifier building for employees to change clothes; however, employees are allowed to change clothes at home and to store their clean and dirty uniforms there as well.

Employees return their dirty uniforms to the plant for professional laundering by an outside service weekly. Showers are provided in the locker room for the employees' use.

D. Medical Program

All employees working at the gasifier are given a pre-employment physical examination to establish a baseline with regard to their physical condition. In addition to developing a medical history, the pre-employment physical examination includes:

- Chest X-ray
- Skin examination
- Blood pressure testing
- Electrocardiogram
- Hearing test
- Eye examination
- Blood tests
- Rectal examination

Management plans to have these physical examinations repeated annually on all workers.

VII. CONCLUSIONS AND RECOMMENDATIONS

Although there is no formal safety program in effect at this plant, management is concerned with providing a safe working environment for the plant workers. This concern is evident from conversations held with the Plant Director and Assistant Director and from the work practice controls that are already in effect at this facility.

In order to aid plant management at CAN-DO, and management at similar facilities, the following recommendations for improving the engineering controls and work practices already in place are presented.

- Management's policy regarding safety and health appears to be clearly set. The assistant plant director makes sure employees are familiar with potential hazards as well as the safe work practice procedures and engineering controls that have been established.

In addition, periodic safety meetings should be held to inform employees of new safety and health concerns, to review existing hazards, and to train workers in the proper use of personal protective equipment, emergency procedures, fire fighting equipment and any other precautions that need to be taken when dealing with special hazards, such as carbon monoxide.

- An emergency procedure should be developed for handling injuries, transporting ill or injured workers, and notifying medical facilities with a minimum of confusion. Emergency numbers should be posted. Medical facilities near the plant should be contacted and arrangements made to familiarize them with any injuries or illnesses that may be unique to the gasification plant.
 - Documentation should be expanded to include training sessions for management and employees in safety and health-related activities, emergency medical procedures for treating injured employees, injury reporting procedures, and emergency evacuation procedures which are understood by all employees.
 - To encourage employee participation and acceptance of a safety program, management should display safety pamphlets on the workplace bulletin board, use safety and health related posters, and other information devices to maintain awareness of these concerns.
- Management should include employees in the formulation of safety plans and solicit their suggestions for a safer workplace.
- A safety committee should be formed.

- Employees should not be permitted to eat their lunches in the maintenance room or other areas where food could become contaminated from surrounding plant operations. A clean eating room or area should be designated.
- Five-minute escape pack respirator should be located on each level of the gasifier building for use in emergency evacuation of the facility. The respirator maintenance program discussed earlier should include proper use and maintenance of these respirators.
- A larger ventilation intake opening should be provided so that the exhaust fans do not cause a negative pressure and pull gases from the gasifier into the building when the fans operate at high speed.
- The control room should be positively ventilated with outside air.
- An exhaust hood should be installed over the grinder in the Coal Analysis Lab to prevent exposure to respirable coal dust.
- Welded joints, rather than flanged joints, should be used to the maximum extent practicable to reduce the potential for leaks.
- The indoor coal storage area should be ventilated to prevent the accumulation of toxic levels of CO from the front end loader diesel exhaust.
- The poke hole covers should be hinged, gasketed doors with latches, rather than sliding covers, to reduce gasifier emissions.
- In order to prevent flames and/or toxic gases from escaping, steam injectors should be installed in the gasifier pokeholes so that air is pulled into the gasifier through the poke holes during the poking operation.
- Gasifier gases that leak into the coal feed compartments should be vented through an exhaust fan to the outside. Alternatively these gases may be reinjected into the gasifier.
- The CO detectors should be calibrated and tested periodically.

REFERENCES

1. Enviro Control, Inc., September 1978. Criteria for Recommended Standard....Occupational Exposures in Coal Gasification Plants. DHEW (NIOSH) Publication No. 78-191. National Institute for Occupational Safety and Health, Cincinnati, Ohio.
2. Dravo Corporation, February 1976. Handbook of Gasifiers and Gas Treatment Systems. FE-1772-11. U.S. Energy Research and Development Administration, Washington, D.C.
3. Bolez, C.A. and Patterson, D.R., A New Look at Low and Medium BTU Gas for Industrial Applications. Presented at AIChE 85th National Meeting and Chemical Plant Equipment Exposition June 4-8, 1978, Philadelphia, Pennsylvania.
4. Hahn, O.J. et al; A Mass and Energy Balance of A Wellman-Galusha Gasifier, Institute for Mining and Minerals Research, University of Kentucky and National Lime and Stone Company. (no date)
5. Enviro Control, Inc., Trip Report of Site Visit to Glen-Gery Corporation, Colonial Plant, York Pennsylvania, December 6, 1977. Work performed under NIOSH contract no. 210-76-0171.
6. Enviro Control, Inc. Trip Report on Site Visit to National Lime and Stone Company, Carey, Ohio, May 5, 1977. Work performed under NIOSH contract no. 210-76-0171.