CONTROL TECHNOLOGY ASSESSMENT
FOR COAL GASIFICATION AND LIQUEFACTION PROCESSES

Report of Site Visit
on
April 5, 1979
to
Synthane Pilot Plant
Bruceton, Pennsylvania

Contract No. 210-78-0084

Submitted to

National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
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Date Published: March 1980

TABLE OF CONTENTS

FOREWORD

On April 5, 1979, representatives of Enviro Control, Inc., visited the Synthane Pilot Plant, in Bruceton, Pennsylvania. The purpose of the visit was to discuss the engineering control technology and industrial hygiene aspects of the Synthane process.

Attending the meeting were the following persons:

Synthane Pilot Plant

Robert Lewis, Program Manager
Richard R. Santore, Supervisory Chemical Engineer

Enviro Control, Inc.

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

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 Synthane Coal Gasification Pilot Plant in Bruceton, Pennsylvania, during the site visit on April 5, 1979.

The Synthane Pilot Plant was developed and operated by the Energy Research and Development Administration (ERDA) through the Department of Energy (DOE) to obtain design information for demonstration and/or commercial gasification plants. The high-pressure (1000 psi) deep-injection, fluidized-bed gasification process was designed to convert caking, bituminous coals to a pipeline quality substitute natural gas. Sub-bituminous coal and lignite were also used.

The Department of Energy discontinued operation of the Synthane Pilot Plant in December, 1978. However, the Synthane process was included in the control technology study because certain aspects of the process (such as the ability to process caking coals) are important in the development of coal gasification technology and because process modifications made at Synthane are applicable to similar coal gasification technologies. These modifications to the process include the use of deep bed injection for coal feed instead of the free fall method. This modification reduces the production of tar in the gasifier, thereby reducing worker exposure to this potentially hazardous compound. In addition, numerous modifications were made to the process to reduce the formation of clinkers in the gasifier and the carryover of fines from the gasifier to the gas scrubber.

Because the plant was not in operation, however, a thorough control technology assessment could not be made. This report is therefore limited to those observations made by plant personnel and which were discussed with

Enviro team members during the visit to the plant. References are included for a more detailed study of the process.[1-6]

II. INTRODUCTION

A. History of the Synthane Pilot Plant

The Synthane process, a high-pressure coal gasification technique, was developed by the Bureau of Mines at Bruceton, Pennsylvania. Work was begun in 1961 on methods of pretreating caking coal in fluidized beds. In 1970, a preliminary design contract was awarded to M.W. Kellogg Company to determine if the data were sufficiently complete to proceed with design of the pilot plant. Based on additional gasifier tests and the evaluation of the process, the Bureau of Mines concluded that the process was feasible and that the design work for the pilot plant could begin.

In June 1971, a contract was awarded to C-E Lummus, a subsidiary of Combustion Engineering, Inc., to design the Synthane Coal Gasification Pilot Plant, a 10-ton-per-day unit. The purpose of the Synthane pilot plant was to demonstrate on a pilot plant scale that gasification of caking bituminous coal in a fluidized bed was technically and economically feasible. Construction and detailed engineering were provided by Rust Engineering of Birmingham, Alabama.

On July 7, 1976, the first run with coal feed to the gasifier was made with Montana Rosebud coal, a noncaking, sub-bituminous coal. Early operations, using coal injection above the gasifier bed, resulted in the production of large amounts of tar and oil in the gasifier. In 1977, the gasifier was modified to provide for deep bed injection, which greatly reduced the production of tar and oil in the gasifier. Subsequent operations and modifications to the plant were designed to improve the gasifier operation.

C-E Lummus, under contract to DOE, operated the pilot plant from August, 1975 to December, 1978. The plant was closed down completely in April, 1979.

B. Process Description

The Synthane process is a high-pressure coal gasification process based on the simple concept of a fluidized bed; steam, oxygen and make-gas from the gasification reaction are used as the fluidizing media. A significant feature of the Synthane process is that agglomerating (caking) coal can be processed. A schematic of the Synthane process is shown in Figure 1.

The Synthane gasifier is designed to operate at 600 to 1000 psig and at 1400 F (760 C) up to 1800 F (980 C). Coal feed size is 100 percent minus 20 mesh. Char from the gasifier is removed either dry (through lockhoppers), or as a slurry. Gas cooling and gas-liquor separation are conventional.

The Office of Coal Research (OCR), Energy Research and Development Administration (ERDA), and the Department of Energy (DOE) have a policy of investigating as many different gas-treating processes as possible. The Synthane Pilot Plant was selected because the gas treatment section is different from other high-Btu pilot plants. Shift conversion is conventional; a cobalt-molybdenum catalyst on an alumina base is used. The Benfield (potassium carbonate) system is used for gas purification (acid-gas scrubbing). For methanation of the Synthane gas, ERDA installed two types of methanation processes, both developed at the BOM Bruceton Center. These were the tube-wall reactor and the hot-gas recycle methanator. Make-gas from the plant is burned in the plant's thermal oxidizer.

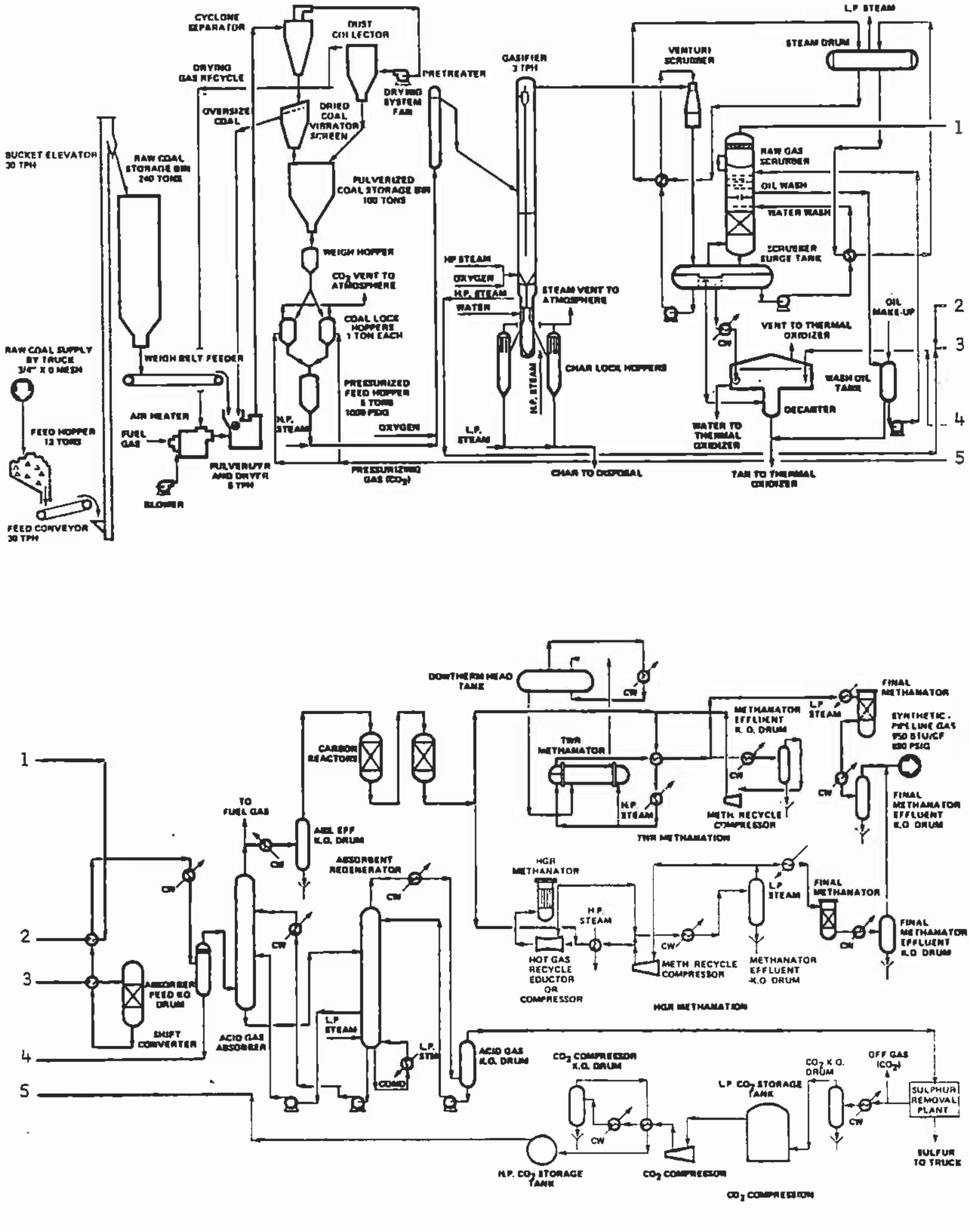

Figure 1. Schematic of Synthane Coal Gasification Process (Adapted from Reference 7).

III. CONTROL TECHNOLOGY ASSESSMENT

A. Coal Pretreatment

(1) Process Description

Washed, 3/4 inch x 0 sized coal is delivered from the mine and dumped into a 12-ton feed hopper. From the feed hopper, coal is conveyed by a belt-and-bucket elevator to a 240-ton raw coal storage bin.

Coal is fed from the raw coal storage bin onto a weigh belt feeder into a Raymond flash-drying hammer mill. In the mill the coal is pulverized to 20 x 0 mesh and dried to 225 F (107 C) with an inert gas stream (containing less than 9 percent oxygen) that carries the coal to a cyclone separator.

The gas separated from the coal passes through a dust collector and is recycled to the flash-drying mill. From the cyclone separator, the coal falls on a vibrating screen where particles larger than 20 mesh are returned to the flash-drying mill for further grinding; particles under 20 mesh drop into a pulverized coal storage bin. Dust is removed from the inert gas stream and falls into the storage bin where it is stored at atmospheric pressure.

(2) Hazards to Health and Safety

Potential occupational health hazards associated with the coal handling and pretreatment process include exposure to coal dust, noise, and fires from possible spontaneous combustion of coal in the storage areas, with the potential inhalation of the products of combustion.

(3) Operations--Control Technology Assessment

The coal preparation area is a completely closed system. Oxygen levels are maintained well below 9 percent to reduce the hazard of spontaneous combustion.

Bags in the baghouse have been designed to filter out material down to 10 microns in size. Despite this close weave, some material does get through during the grinding operation. Blowout panels have been installed in the cyclone and in the baghouse in case the gas mixture gets above the explosive level.

B. Coal Gasification

(1) Process Description

From the storage bin, the dried and pulverized coal falls into a weigh hopper and then alternately into one of the two lockhoppers where it is pressurized with carbon dioxide or inert gas up to an operating pressure of 1,000 psig. From the lockhoppers, the coal falls into a 5-ton pressurized feedhopper.

The coal in the pressurized feedhopper is entrained by high-pressure steam (1,000 psig) and oxygen, and is carried into the bottom of the pretreater. The fluidized bed of coal is maintained in the pretreater at 800 F (427 C) and 1,000 psig to eliminate any caking tendency of the coal. From the pretreater, coal overflows and falls into the middle section of the tall cylindrical gasifier where it meets the upcoming gas from the gasifying coal in the fluidized bed in the lower section of the gasifier. Hot char and product gas are produced in the fluidized bed. Gasifier temperature is maintained with the fludizing gas which consists of oxygen and steam. The char separating out beneath in the fluidized bed of the gasifier consists of ash containing about 35 percent of the original carbon. The char passes down through the center of a cone-shaped distributor into a char-cooling section where it is quenched with water to about 600 F (316 C). The quenched char moves down into a fluidized bed in the char-cooling section where it overflows out of the gasifier into the char cooler. The char is transported pneumatically from the char cooler to a slurry tank and slurried with water at system pressure. The slurry is then throttled to atmospheric pressure through a Willis choke valve. The resulting slurry is filtered on rotary-disc vacuum filters and disposed of as a wet filter cake. The water is recycled.

The gas produced in the fluidized bed passes upward, through the gasifier and into an internal cyclone where entrained particles larger than 50 microns fall back into the fluidized bed through a cyclone dipleg. The gas leaves the gasifier at a temperature of approximately 1400 F (760 C) and is quenched with water to a temperature of approximately 450 F (232 C) in a Venturi scrubber. The gas with its entrained liquids and particulate matter enter a scrubber surge tank where the gas is separated from the liquid phase. The entrained materials are removed from the gas in a scrubbing tower which contains a water wash section. The separated liquids and solids from the Venturi scrubber and scrubbing tower are depressurized and collected in a decanter where a tar denser than water is removed from the bottom while the aqueous phase overflows into a wastewater receiver.

(2) Hazards to Health and Safety

Occupational health hazards associated with the coal-feeding process include exposure to coal dust, noise, and gaseous toxicants. There is also a potential for asphyxiation by the inert gases used for lockhopper pressurization. There is also the possibility that tar and oil will be contained in the product that overflows from the pretreater to the gasifier. Occupational health hazards associated with gasifier operation include potential exposure to coal dust, high-pressure hot gases, high-pressure oxygen, trace elements, tar, fire, and noise.

(3) Operations--Control Technology Assessment

During normal operations, the Synthane plant is operated on a lean-phase, closed system. Inert gas, which is generated from propane, and carbon dioxide have been used as the inert gas systems in the process. Carbon monoxide monitors are used in the area to detect carbon monoxide accumulation.

Petrocarb Unit

The Synthane plant uses a Petrocarb lockhopper system. A schematic of this unit is shown in Figure 2. A thorough discussion of the Petrocarb lockhopper system can be obtained in "Coal Pressurization and Feeding, Use of Lockhopper System."[2]

Nuclear level detectors are located on the storage injector and the primary injector to provide reliable level indication for material entering the lockhopper.

Pretreater

In the Synthane process, the caking property of the coal is reduced or eliminated by a mild oxidation of the coal in the presence of oxygen at a temperature of approximately 800 F (427 C). The transport line which conveys the coal to the preheater is electrically heated to initiate coal heat-up. The oxygen is fed into the system at approximately 500 F (260 C). Because of the ignition of the coal in the preheating system, the exit temperature in the preheater is approximately 800 F (427 C).

Gasifier

Initial design of the Synthane process utilized coal feed injection above the gasifier bed. However this operation resulted in formation of tar. In 1977 the gasifier was modified for deep bed injection of coal feed, and the production of tar was significantly reduced.

Temperature control is important in the gasifier (and the preheater) as a means of reducing clinker formation. Temperature fluctuations below 800 F (427 C) or above 2000 F (1094 C) are indications that clinkers have formed or are forming. "Dead spots" also contribute to clinker formation due to poor heat transfer. In the Synthane process, the pretreated coal is fed to the reactor at the same time as fluidizing steam and oxygen are fed to the bottom of the bed through a 45 degree sloping distributor plate. Rate of oxygen addition is used to control

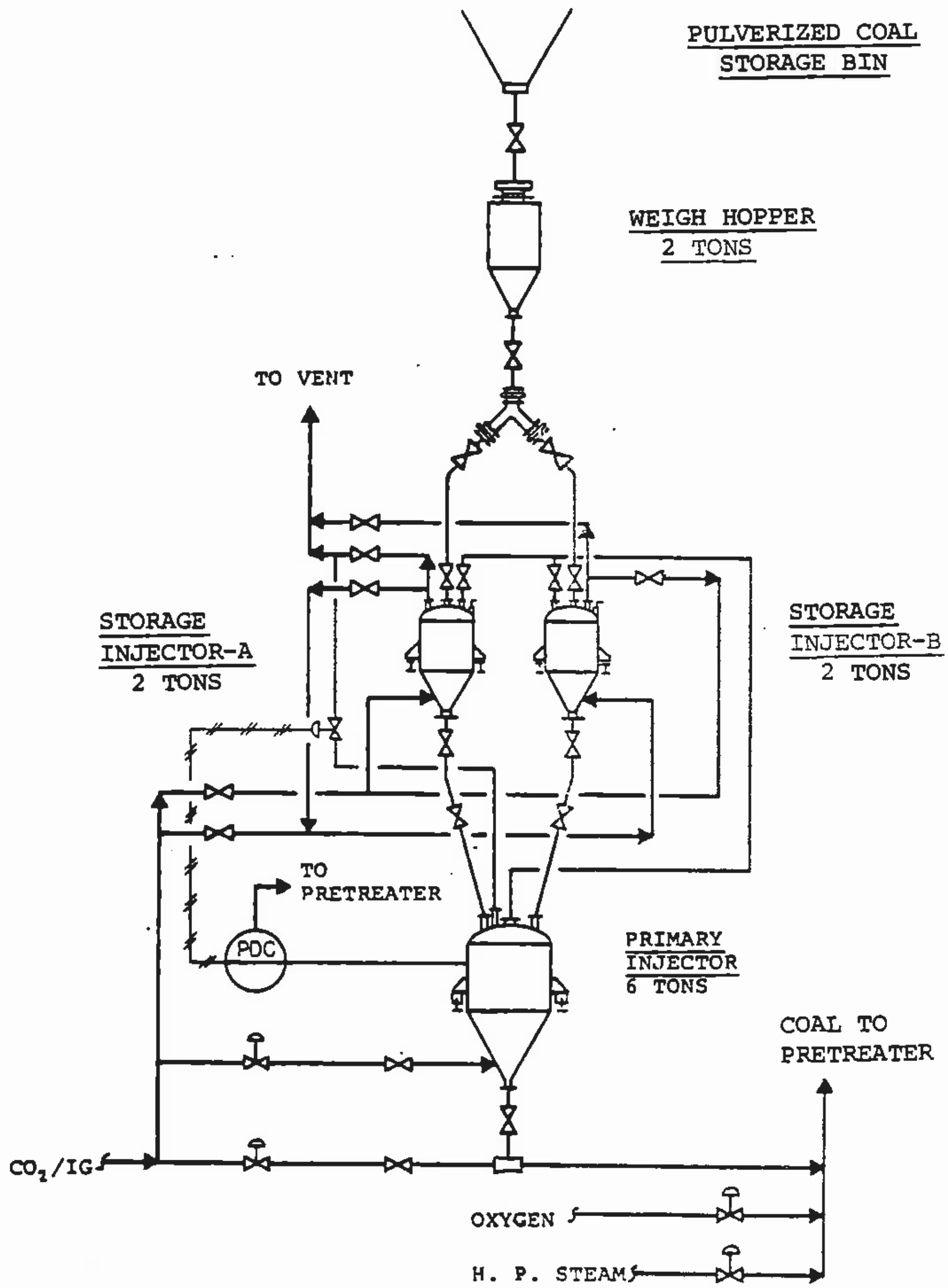

Figure 2. Petrocarb High-Pressure Coal Feed System

(Adapted from Reference 2).

bed temperature. A detailed discussion of temperature control as a means of reducing agglomeration is contained in "Update of Synthane Pilot Plant Status"[3] by R. Lewis, et. al. and in "Synthane Process Update, Mid-'77" by W.P. Haynes.[4]

Discharging char from the gasifier to the char cooler was difficult because of increased loading of fines and a resulting decrease in bed density.[4] Changing the trickle valve to a control valve helped reduce the problem. In addition, the dipleg was increased from two to three inches in diameter.

Char Slurry

To remove dissolved gas from the char slurry, the char slurry is put into a tank at 200 F (93 C). The gases can then be vented and scrubbed.

Valves and Flanges

The char slurry letdown valve was redesigned with a coating of hard-faced material. This increased the life of the valve from 1/2 hour operation to weeks of operation. "Valve Applications at the Synthane Plant in Mixed-Phase Erosive Service"[5] by Desmond B. Bailey, et. al., discusses control valves used at the Synthane plant, and the various materials which were tested to improve the valve life.

Standard flanges and gaskets, such as Flexitallic, are used. Ring joint flanges are used in some instances; it was noted by the Synthane personnel that special care is necessary in assembling these flanges.

C. Shift Conversion and Purification

(1) Process Description

The carbon monoxide-to-hydrogen ratio of the cleaned gas is adjusted for methanation in a shift converter. The carbon monoxide is removed in a Benfield unit where hot potassium carbonate is the acid gas absorbent.

The final traces of activated hydrogen sulfide are removed in an active carbon train.

The acid gas from the Benfield unit is separated into its component parts. The hydrogen sulfide is converted to elemental sulfur in a Stretford unit and removed as a byproduct. The remaining gas, which is essentially carbon monoxide, is stored in a low-pressure storage tank. A high-pressure reciprocating pump is used to compress the carbon monoxide to 1,000 psig for use in the plant.

(2) Hazards to Health and Safety

Occupational health hazards associated with the gas-purification process include potential exposure to sulfur-containing gases, methanol, naphtha, carbon monoxide, cryogenic temperatures, high-pressure steam, refrigerant gases, vanadium oxide, and noise.

(3) Operations--Control Technology Assessment

Plant personnel expressed concern about the handling of vanadium oxide, which is used in the Benfield unit. The Benfield and Stretford units were not operated at the Synthane plant, and therefore no assessment can be made.

D. Methanation

(1) Process Description

The mixture of carbon monoxide and hydrogen in the gas is methanated over Raney nickel catalyst. Two methods of methanation were to be tested at the Synthane Pilot Plant. In one method, the coolant is Dowtherm, and the heat collected by the Dowtherm is used to generate low-temperature steam. In the second method, the temperature of the reaction is controlled by diluting the fresh feed gas with recycled gas. The gas leaving the methanator is essentially methane with a heating value of 950 Btu/scf.

(2) Hazards to Health and Safety

Occupational health hazards associated with the methanation process include potential exposure to high-pressure methanated gas, steam, nickel carbonyl, nickel-catalyst dust, carbon monoxide, fire, and noise.

(3) Operations--Control Technology Assessment

This area was not in operation.

IV. INDUSTRIAL HYGIENE

A. Potential Hazards

On the basis of the site visit, information obtained at the plant on operational parameters,[6] and past experience, it is believed that the major hazards of the Synthane gasification process would be hydrogen sulfide and carbon monoxide. The hazard of nickel carbonyl formation in the methanation unit and subsequent worker exposure could also be a major problem because of the high toxicity of the compound. Nickel carbonyl formation should occur primarily during startup and in process upsets. Normal operating conditions are not conducive to the formation of the carbonyl. The gasifier and the lockhopper system are also believed to be potential areas for worker exposure to process contaminants.

Work at other coal conversion plants have shown that aromatic amines are present in the low parts-per-billion range in the workplace environment. Because of similarities in operating parameters with other gasification processes, aromatic amines may also be present at the same concentration in the Synthane workplace environment.

The gasifier, which has an operating temperature of 1800 F (982 C), and the pretreater, which has an operating temperature of 800 F (427 C), would be favorable to the formation of PNAs. Worker exposure to PNAs would, therefore, be likely to occur in these areas.

Operators, maintenance workers, and laboratory technicians are potentially exposed to these hazards. There are 15 operators during normal plant operations with the responsibility of monitoring the process. These duties require time in the process area. Minimal maintenance is performed during normal operations; maintenance activities are performed in the maintenance shop whenever possible.

B. Health and Safety Program

The development and maintenance of a safe and healthful workplace environment is the responsibility of the Safety Supervisor. The supervisor follows the policies and standards set by the plant Safety Committee, of which he is a member. Other members include management and supervisory personnel. There is no worker representation on the Committee.

The safety program developed by the Committee is typical of safety programs in other industries. Safety inspections and accident reporting and investigation are stressed in the Synthane program. Inspections follow program standards adopted from the OSHA regulations.

The Synthane health program is presented in outline form in the appendix. Only certain aspects of this program have been implemented. These include audiometry, indoctrination of new employees, and the use of direct-reading instrumentation for the detection of toxic gases and explosive mixtures. A limited amount of industrial hygiene sampling has been conducted by an outside contractor, but results were not available for review.

C. Medical Program

Synthane maintained a medical office at the plant staffed by a full-time nurse. A physician was at the plant two days a week for a total of 4 hours per week. At other times, patients were sent to the emergency room of a nearby hospital. The office served as a site for general first aid and for employee examinations performed by the physician. The analyses of patient specimens were performed by an outside laboratory. The office was equipped for pulmonary function testing, audiometry, vision testing, and cardiography.

Three types of examinations were provided by the medical staff: preemployment, annual, and termination. All examinations were provided on a voluntary basis and were the same for all employees, regardless of age. The three examinations were essentially the same and consisted of a full 12-screen testing which included laboratory analysis for hemoglobin, uric acid, blood/urea nitrogen, cholesterol, triglycerol, and glucose. Pulmonary function tests, audiometry, vision testing, cardiography, and chest X-rays were also performed to establish a baseline at preemployment for comparison with results from the annual and termination physical examinations. Additional tests were performed as needed at the discretion of the physician.

The medical tests provided in the Synthane medical program are extensive and can be considered the equivalent to that provided in industrial firms with very good medical programs. However, because steps have not been taken to identify the hazards within the Synthane workplace environment, the selected tests may not be adequate in diagnosing potential occupational illnesses. For example, workers may be exposed to PNAs in the process areas. Since these compounds are potential skin carcinogens, there is the risk of exposed workers developing skin cancer. However, none of the tests are geared toward the identification of skin cancer or precancerous lesions.

D. Industrial Hygiene Summary

Because of the limited operating time of the Synthane Pilot Plant, the hazards associated with the process and the effectiveness of the plant health and safety program in controlling these hazards can not be adequately assessed.

If fully implemented as planned, the Synthane health and safety program should be effective in providing for a safe workplace environment.

However, the program should be expanded to increase its flexibility. The current program only provides for worker protection against solvents and physical agents such as noise and heat stress. The potential existence of other toxic agents such as hydrogen sulfide is overlooked.

A sampling protocol should be designed which includes area and personal monitoring to allow for the identification of chemical hazards present in the workplace environment and to determine exposure levels and the workers at risk. Once these hazards and the workers at risk are identified, the necessary engineering controls and work practices should be implemented to control exposures.

V. CONCLUSIONS AND RECOMMENDATIONS

Because the Synthane Pilot Plant was not in operation at the time of the site visit, a thorough assessment of the control technology at the plant is not possible.

Specific recommendations by the Synthane personnel include the following:

(1) Complete the additional design work required at the baghouse to reduce the amount of material sifting through the bags.

(2) Increase the surge tankage to prevent process upsets.

(3) Install remote control valves to shut off lines where there is danger from fumes, hot water, etc., in order to protect plant personnel.

References are included with this report for a more detailed study of the Synthane process.

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6. Jewell, J.D. "Quality Assurance Summary Report for the Synthane Coal Gasification Plant." C-E Lummus, Bloomfield, New Jersey (no date).

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APPENDIX

HEALTH PROGRAM OUTLINE

I. Industrial Lighting

   A. Factors affecting seeing tasks
   B. Age and subnormal vision
   C. Factors of good illumination

II. Industrial Noise Exposure

   A. Audiometric testing
   B. Personal protection

III. Industrial Ventilation

   A. Sources of exposure
   B. Methods of control

IV. Industrial Exposure to Heat

   A. Work practices
   B. Acclimatization
   C. Environmental measurements
   D. Medical
   E. Appraisal of employees
   F. Warning signs
   G. Recordkeeping

V. Industrial Sanitation

   A. General requirements
   B. Water supply
   C. Toilet facilities
   D. Washroom
   E. Change rooms
   F. Retiring rooms
   G. Lunchrooms

VI. Industrial Solvent Exposures

   A. Classification of solvents
   B. Control measures
   C. Factors which determine severity of exposure
   D. Guidelines for selection of solvents

APPENDIX (Continued)

VII. Ionizing Radiation

- A. Radiation exposure limits
- B. Personnel monitoring
- C. Radiation area
- D. Posting requirements
- E. Notification of incidents

VIII. Employee Training

- A. Responsibilities
- B. Indoctrination of new employees
- C. Job safety analysis