CONTROL TECHNOLOGY ASSESSMENT

FOR

COAL GASIFICATION AND LIQUEFACTION PROCESSES

Report of Site Visit
on
April 6, 1979
to
Bruceton Energy Technical Center
Synthoil Process Development Unit
Bruceton, Pennsylvania

Contract No. 210-78-0084

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Foreword

Enviro Control, Inc., visited the Bruceton Energy Technical Center (BETC), Bruceton, Pennsylvania, on April 6, 1979. The purpose of the site visit was to make an engineering control technology assessment of the Synthoil process development unit (PDU) located at the Center. Because the Synthoil PDU was not in operation at the time of the visit, the Enviro team members were primarily interested in those control technology measures which had been incorporated into the design of the PDU to prevent occupational exposures to potentially hazardous agents in the workplace environment.

The following persons were present:

Synthoil

Thomas N. Torkos, Acting BETC Technical Support Manager, H-Coal Project

Enviro Control, Inc.

James M. Evans, Program Manager
Donato R. Telesca, Principal Investigator
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I. SUMMARY

The purpose of the Bruceton Energy Technical Center Synthoil process development unit was to determine the technical and economic feasibility of the Synthoil process for scale-up to commercial use. Initial data for the process were obtained from two small-scale experimental reactors, after which it was decided to build a 10-ton-per-day PDU.

The basis of the Synthoil process was a hydrogenation step achieved by driving a preheated coal-derived slurry through a packed catalyst bed at high velocity in the presence of an excess of hydrogen, which resulted in high turbulence and mixing beyond anything achieved elsewhere. Experimental work was conducted with several types of coal, at various temperatures and pressures. However, subsequent changes to the operating conditions resulted in a process that was similar to the SRC-II coal liquefaction mode (a process that produces high yields of low-boiling distillates equal to the Synthoil products and more economical to produce).

Although much of the construction of the Bruceton Energy Technical Center Synthoil PDU was completed, it was never operated. Therefore, it is not possible to make a thorough assessment of the control technology for the Synthoil PDU. However, there were certain design specifications, especially in the coal preparation area, which are important to the control technology study. These design specifications are presented for those parts of the Synthoil PDU which were completed at the time of this site visit. References are included in this report for a more detailed study of the Synthoil PDU[2-4].

II. INTRODUCTION

A. History of the Project

The Bruceton Energy Technical Center Process Development Unit, formerly the Synthoil Process Development Unit (PDU), is located in Bruceton, Pennsylvania. Work on the Synthoil PDU was initiated by the U.S. Bureau of Mines, and later by the Department of Energy (DOE) through the Pittsburgh Energy Technical Center (PETC). Although construction of most of the Bruceton Energy Technical Center Synthoil PDU was completed, the unit was never operated because of budgetary reasons. However, data obtained during the testing of the process design are important to the development of coal liquefaction technology.

The objective of the Synthoil project was to determine the technical and economic feasibility of the process for scale-up to commercial use. One of the purposes of the PDU was to obtain data on pressure drop and heat transfer coefficients for the three-phase reactor feed and the effluent streams. Initial data for the process was obtained from two small-scale experimental reactors. The first reactor was 68 feet by 5/16-inch inner diameter with a feed capacity of 48 pounds per day. The second reactor was 14.5 feet by 1.1-inch inner diameter with a feed capacity of 1/2 ton per day. Experimental work was conducted on various coals with both reactors. Based on the results of this early bench-scale work, a 10 ton per day PDU was planned.

PETC was responsible for conducting support research for the design of the unit. Foster Wheeler Energy Corporation was responsible for the overall design, which was completed during 1975, and for construction of the unit, which was begun in the fourth quarter of 1975.

The basis of the Synthoil process was a hydrogenation step achieved by driving a preheated coal-derived slurry through a packed catalyst bed at high velocity in the presence of an excess of hydrogen. This resulted in high turbulence and mixing beyond anything achieved elsewhere. Early work by S. Friedman showed that after the first few hours of operation product yields using inert packing were nearly identical to those using a catalyst packing. Later work at PETC indicated that liquefaction in the SRC-II mode or with a catalyst impregnated onto the coal produced high yields of low-boiling distillates which were not only equal to the Synthoil mode but also more economical. Therefore, in mid-1978 operation of the BETC Synthoil PDU was discontinued by DOE for budgetary reasons.

B. Process Description

The Synthoil process development unit (PDU) was designed to convert 750 pounds per hour of high sulfur, western Kentucky coal to a low-sulfur liquid fuel suitable for industrial use. This quantity of coal is capable of producing approximately 48 gallons of oil per hour (3.05 barrels per ton). A schematic of the Synthoil process is shown in Figure 1.

Hydrogenation of the coal takes place in a fixed-bed upflow reactor over catalyst pellets of cobalt molybdate on a silica-alumina base. The turbulence of the slurry, caused by the flow of hydrogen, prevents plugging of the fixed-bed by the mineral matter remaining as the coal is liquefied.[4]

The main product of the Synthoil process is a viscous, heavy oil. The degree of product oil viscosity depends on the severity of reaction pressure. The product oil tends to be more viscous if the reaction pressure is 2000 psia as compared to 4000 psia.[1]

In the Synthoil process, fresh and recycled hydrogen and a slurry of powdered coal, mixed with product oil, are introduced concurrently into the bottom of a reactor packed with catalyst pellets. In the ensuing reaction, which occurs at 420 to 450 C and 2000 to 4000 psig, the coal is desulfurized and hydrogenated, thus producing liquid and gaseous products. The reactor effluent goes to a high-pressure separator where the liquid and unreacted solids are separated from the gases. The liquid

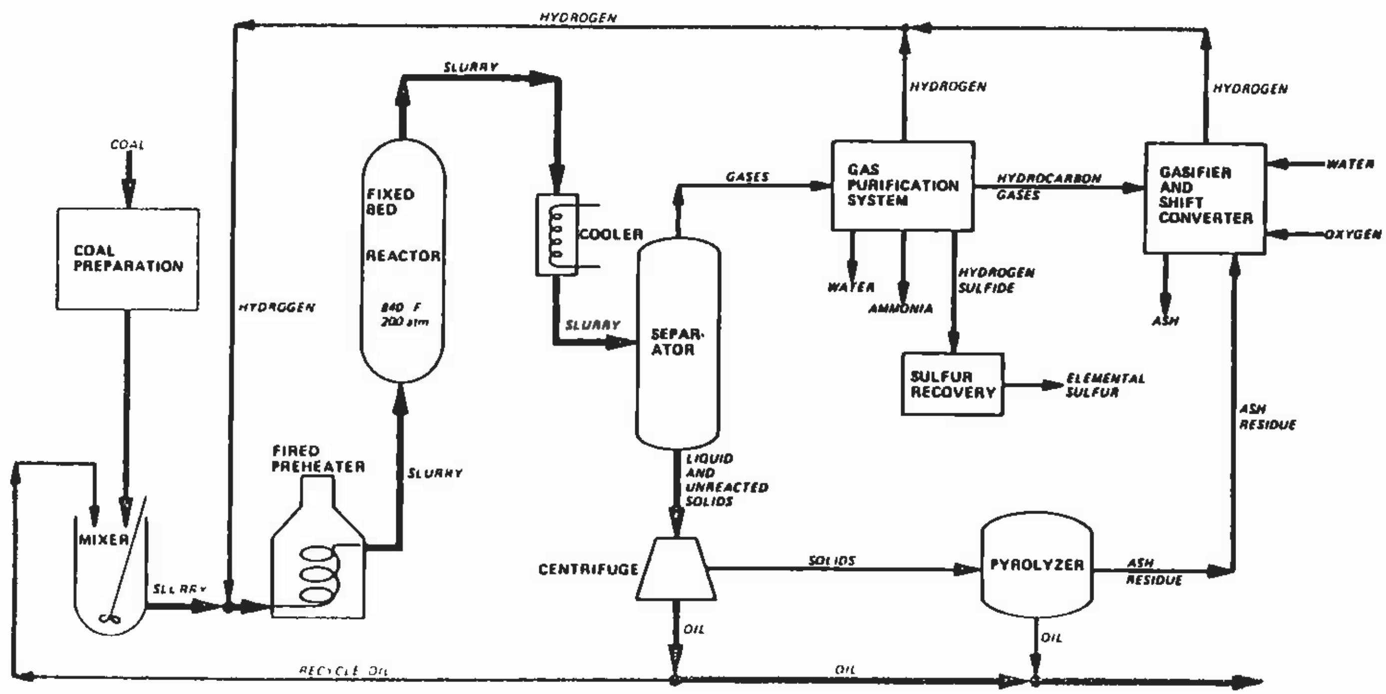

FIGURE 1. Synthoil Process Schematic
(Source: DOE/ET-0026/4)

stream then proceeds to a solid separator (centrifuge, filter, hydroclone, or combination thereof) to remove the unreacted solids in the form of a cake or slurry. Part of the liquid product is recycled for use in the preparation of the feed slurry. Separated solids are pyrolized to recover residual oil, and the residual char can be gasified to produce part of the process hydrogen.

The gases from the separator pass through a purification system to remove ammonia, hydrogen sulfide, water, and light hydrocarbons. The purified hydrogen gas is recycled to the reactor. In the Synthoil process, gas must flow at a high rate through the reactor to propel the liquids and solids, and to maintain the necessary turbulence for operability. The hydrogen recycle rate is determined by the linear velocity needed to maintain propulsion and turbulence. The recycle-hydrogen/makeup-hydrogen ratio of 6.7/8.0 was used in both the 1.1" reactor and for the design of the 10 ton per day PDU.[3]

III. CONTROL TECHNOLOGY ASSESSMENT

A. General

Except for the high-pressure reactors, the preheaters, and the coal unloading station, the Synthoil process is enclosed in a single-story structure.

The control room is pressurized and has a three-hour fire wall between the operation section and the control room section. Between the control room and the utilities section, there is a one-hour fire wall.

Control technology features which were designed into the process include:

1. Louvered walls and exhaust fans in the roof for dilution ventilation,

2. Positive-pressure control room with makeup air coming from outside,

3. Use of carbon dioxide and nitrogen (in reactors) as an inert gas,

4. Separation of primary high-pressure separator from other process units by brick and steel walls, with blowout sections to direct any explosion away from the building, and

5. A lock-out system in the reactor unit and primary high-pressure separator, with controlled access during operation to essential personnel.

B. Coal Preparation

(1) Process Description

The coal preparation system was a refurbished and slightly modified version of the coal preparation system used at the FMC Corporation's Char-Oil-Energy Development (Project COED), at Princeton, New Jersey.

Run-of-the-mine coal (3/4" x 0") is unloaded by truck into a ground-level coal receiving hopper. From the coal receiving hopper, feed coal is transported on a belt conveyor, a bucket elevator, and a screw conveyor to the 150-ton coal silo. From the coal silo, the coal is discharged by gravity to a Williams patent roller mill through a rotary feeder. The coal is pulverized to 70 percent through 200 mesh and 100 percent through 60 mesh. This material is simultaneously dried by a stream of hot combustion gas and pneumatically conveyed to a cyclone collector. Pulverized coal is separated from the combustion gas and discharged through a rotary valve into either one of two pulverized coal storage tanks. Pulverized coal from the pulverized coal storage tanks is transported by inert gas to the coal weigh tank located in the feed preparation section.

(2) Hazards to Health and Safety

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

(3) Control Technology Assessment

Carbon dioxide is used to blanket the coal in the coal preparation area, as it moves from the truck unloading pit to the elevators and into the storage bins. This carbon dioxide blanket helps to prevent fire. The belt conveyors, used in the coal preparation area to transport the coal, are enclosed. A carbon dioxide analyzer is installed in the coal storage pit, which is located below grade. An oxygen analyzer is installed on the Williams Patent Crusher to monitor the level of oxygen during operation so that proper action can be taken to eliminate a possible explosion if oxygen level increases.

A portion of the combustion gas is sent through the dust collector where fine coal dust is collected and discharged to the coal feed bins. The filtered gas is subsequently vented under pressure control, and because of the gas temperature, assists in removing moisture from the coal. The balance of the combustion gas is recycled back to the air heater for mixing with hot makeup gas. This recycled gas modulates the gas inlet temperature to the roller mill and limits the oxygen content of the combustion gas to less than nine volume percent. The pulverized coal conveying collector and the area dust collector remove dust particles from the inert gas before it is vented to the atmosphere.

The coal preparation area at the Synthoil PDU is designed such that each of the storage silos is equipped with a blowout panel and piping which will direct any explosion above the roof, away from the work area.

C. Feed Preparation

(1) Process Description

Pulverized coal from the conveying collector in the coal preparation area is loaded into the coal weigh tank through block valves. When the coal weigh tank is filled, the block valves are automatically closed. A predetermined weight of oil is automatically pumped by the oil recycle pump into the paste mix tank from the oil weigh tank. The weighed charge of pulverized coal is then gravity-fed into the paste mix tank.

Pulverized coal and recycle oil are mixed in the paste mix tank by the mix tank agitator and by the mix tank recycle pump which turns the content of the mix tank over, from bottom to top, every ten minutes. Mixing time in the tank is one hour.

The contents of the paste mix tank are pumped to the paste feed tank on a low-level signal. The paste feed tank has its own agitator, recycle pump, and pump around loop with in-line heater. The feed tank recycle pump, in addition to circulating paste through the tank, also provides positive pressure feed to the paste feed pump. Coal oil paste is delivered to the reaction system at the required pressure by the paste feed pump.

(2) Hazards to Health and Safety

Occupational health hazards associated with the feed preparation area include potential exposure to coal dust, noise, and to the coal derived middle distillate used for the slurrying operation.

(3) Control Technology Assessment

Monitoring and controlling of the slurry composition was to be accomplished by the differential weights in the coal weigh tank and in the recycle oil feed tank.

Coal is loaded into the coal weigh tank through block valves which open on command from a programmed controller when the coal weigh tank is ready to receive a charge of pulverized coal. The block valves are automatically closed when the coal weigh tank is filled. A preweighed amount of recycle oil is added to the paste mix tank automatically, before the coal is added, to assist in contacting the pasting oil with the pulverized coal.

Proper adjustment of the variable-speed coal feeder is necessary to prevent intermittent high-solids loading during the feed preparation. A small quantity of material is usually left in the paste mix tank to aid mixing of the incoming coal and oil.

A mix tank agitator turns the contents of the tank over, top to bottom, every ten minutes. In addition, a steam-fed mix tank heater capable of heating the contents of the mix tank to 250 F is included in the pump-around-loop to improve mixing qualities.

A flow-through feed system was designed for the paste feed pump. Both the pumps for the mix tank and for the paste feed tank were spared to reduce the possibility of a plant shutdown in the event of pump failure during circulation. The pumps in this area have open impellers; they are rotated below 1800 rpm to reduce the amount of erosion that takes place during the pumping of slurries.

If there were a failure in the slurry preparation and coal sluicing area which necessitated a shutdown, the gross liquid product would, if possible, be diverted to the 3,000 gallon gross liquid product storage drum. All tanks and lines were to be flushed with solvent.

D. Solid-Liquid Separation

(1) Process Description

The solid-liquid separation equipment includes a hydroclone system, two bowl-type centrifuges, a centrifuge oil surge drum, two disc centrifuges, a product oil stripper feed surge drum, and assorted drums and pumps. The hydroclones and the bowl-type centrifuges may be operated continuously, while the two disc centrifuges must be operated batchwise since their processing capacity of approximately 20 gallons per minute exceeds the PDU production capacity of approximately 6 gallons per minute. The flow scheme for the solid-liquid equipment is extremely flexible.

Each centrifuge has its own solids discharge hopper, a 55-gallon collection drum set on a weigh scale. The cake collected in the 55-gallon drums will be disposed of by the Pittsburgh Energy Technical Center. The oil (or filtrate-like material) from the centrifuge will flow by gravity into the centrifuge oil surge drum. A balance line from this drum is connected to the centrifuge vent nozzles and maintains an equilized pressure sufficient to preclude vaporization of the oil. Low-pressure nitrogen is supplied via pressure control to the centrifuge oil surge drum which is designed to operate at 2 psig when the solid-liquid separation system is operating at a temperature up to 250 F, and about 80 psig when the operating temperature can be increased to 600 F. The product oil can either be pumped to the disc centrifuges for further reduction in solids content or bypassed to the product oil stripper feed pump.

(2) Hazards to Health and Safety

Occupational hazards associated with solid/liquid separation include potential exposure to vapors, hot filtrate, contact with solids that are discharged, and burns from the heated Dowtherm solution.

(3) Control Technology Assessment

It was anticipated that the Synthoil process would produce a product oil with up to ten percent solids. This mixture (solids, hydrogenated oil, and solvent) would then have been pumped to the centrifuge to remove solids. Employee exposure at the centrifuge would have been higher than at most areas in the plant because the centrifuge solids product is dropped into a drum and the employee would be exposed while the drum was topped off, capped and removed.

E. Other Areas

The balance of the plant had not been completed. The process technology for these areas can be found in Volumes I, II, and III of the Synthoil Process Development Unit, Operating Manual.[2] Additional information may be found in Engineering Evaluations of Coal Conversion Processes, Part 1,[3] and Evaluation of Synthoil Process, Volume 1,[4] both by R. Salmon.

IV. INDUSTRIAL HYGIENE

The Department of Energy (DOE) financed the building of the Synthoil facility and expected to obtain an outside contractor to run plant operations. The responsibility of this contractor was to train the Synthoil staff and to provide a safe work place environment. In order to evaluate the contractor's capabilities in health and safety, DOE required that all prospective bidders submit a detailed plan of their proposed health and safety program along with their bid for operating the facility.

The proposed program was to describe staffing and training, the medical program, industrial hygiene monitoring, and record keeping. DOE expected an extensive program because the plant was experimental and because DOE hoped to generate a data base for future studies of the process. However, the plant was still in construction when the facility was discontinued and bids had not been requested of the prospective contractors. Therefore, no health and safety program plans were available for review and evaluation.

V. CONCLUSIONS AND RECOMMENDATIONS

Because a large portion of the Synthoil plant was not completed, a thorough assessment of control technology cannot be made. However, data obtained during the testing of the process design are important to the development of coal liquefaction technology, particularly in those process areas where the Synthoil process is similar to the SRC-II process.

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