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17209

April 1988

ENGLISH

LIQUEFACTION OF COAL

DP/POL/82/002/11-01

Republic of Poland

Expert Report

Prepared for the Government of the Polish People's Republic
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

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SUMMARY

This trip covered the period of April 3-9, 1988, inclusive. The period of April 5-8 was spent in the Katowice area at the Institute of Carbochemistry in Tychy-Wyry. The discussions at the Institute of Carbochemistry dealt with the UNDP-funded project entitled "Liquefaction of Coal", DP/POL/82/002/B/01/37. My duties were covered by two job descriptions, viz., DP/POL/82/002/11-01/32.1c and DP/POL/82/002/11-02/32.1c, and dealt with coal liquefaction technology and plant construction. The objective was to assist the Polish government in these areas whereby they may use their abundant coal reserves to increase their liquid fuel supplies. Discussions concerned the operation of the 80 kg/hr Process Development Unit (PDU). A review was also made of the 5.0 kg/hr unit that provided design data for the 80 kg/hr PDU. The PDU was successfully operated on a long-term basis feeding coal. Mechanical start-up was completed in September 1986, and technical start-up by December 1986. The Polish engineers provided for recirculation of hot separator bottoms, a severe pumping service, but required for their proposed non-catalytic operation in order to obtain adequate conversion. The 80 kg/hr PDU was originally operated with oil and hydrogen, then switched to coal slurry. Several successful runs of 10 days or more were made feeding coal. During 1987, they operated over 1,000 hours feeding coal in a fully integrated operation.

In general, this project was a success story. It was completed on time and under budget. This effort was an excellent example of developing a technology from the bench scale to the process development stage. Many difficult technical problems were analyzed and solved to ensure orderly operations.

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INTRODUCTION

The period covered in this report is April 3-9, 1988, inclusive. I left Pittsburgh on April 3 and flew to London, England, arriving on April 4, 1988. After an overnight stay, I left for Poland on April 5 and remained there until April 8 in the Katowice area. During my stay in Poland, I operated under two (2) job descriptions, viz., (a) DP/POL/82/002/11-01/32.1.c (Process Development Unit (PDU) Construction Expert), and (b) DP/POL/82/002/11-02/32.1.c (Coal Liquefaction Process Technology Expert). The overall purpose of both job descriptions is to assist the government of Poland in their investigations pertinent to direct coal liquefaction. This work is being conducted at the Central Mining Institute in Katowice and the Institute of Carbochemistry in Tychy-Wyry. The latter is a subdivision of the former. To minimize confusion, the organization in Tychy-Wyry will be referred to as the "Institute" in this report, since this is the location of the 80 kg/hr PDU.

The Polish government intends to utilize its ample coal resources to augment its limited liquid fuel supply, which is primarily imported. The present plans call for the operation of a 80 kg/hr (coal feed input) PDU to determine the optimum operating conditions for the liquefaction of several Polish coals. The program also includes the operation of a 5.0 kg/hr bench-scale unit to provide backup R&D for the PDU. In general, I advised on the technical problems associated with the operation of the PDU for direct coal liquefaction. I provided information on what was learned under various U.S. DOE-funded programs, such as SRC (Solvent Refined Coal), H-Coal, and EDS (Exxon Donor Solvent). The discussions centered on the 80 kg/hr (2 t/d of coal) PDU in regard to coal grinding and drying, slurry preparation and pre-heating, hydrogenation, solids separation, and final product distillation.

To simplify the organization of this report, I have written it in a daily journal format. This type of presentation lends itself to a convenient means to express conclusions and make recommendations. The whole period was spent at the Institute of Carbochemistry in Tychy-Wyry, which is in the Katowice, Poland, area. The Institute is composed of about 200 people and has six divisions, viz., (a) Basic Technical Research; (b) Analytical Research; (c) Developmental Units; (d) Process Engineering; (e) General Maintenance; and (f) Management. Each division has about 30 people, except for the Developmental Units Division, which has approximately 50 people.

DISCUSSION

As indicated in the Introduction, this report is organized on a daily journal basis.

Day 1 - Sunday, April 3, 1988

After securing my visa, tickets, and DOE approval, I left the United States Sunday evening for an overnight flight to Europe, stopping over in London, England.

Day 2 - Monday, April 4, 1988

Arrived in London to change planes for Poland. Spent the day reading past trip reports and present job description. Spent the night in London.

Day 3 - Tuesday, April 5, 1988

Flew from London to Warsaw and was met by the Katowice personnel who provided transportation from the Warsaw airport to my hotel in Katowice, located in southern Poland about 300 kilometers from Warsaw.

Day 4 - Wednesday, April 6, 1988

This day was spent at the Institute of Carbochemistry at Tychy-Wyry. We talked in general about the 80 kg/hr PDU and the apparent decreased emphasis that the United States is placing on coal liquefaction technology. I explained the DOE role in regard to high-risk, long-range research. This indicated no lack on emphasis, only a shift from large-scale pilot plants to bench-scale research.

At the Institute of Carbochemistry at Tychy-Wyry, the main project is the 80 kg/hr (coal feed) unit. This unit is a modification of their previous 50 kg/hr unit based on the Consol Synthetic Fuel (CSF) process. They use the "natural" catalysts in the coal owing to the lack (and high cost) of Co and Mo in Poland. They have an extensive source of bituminous (Janina) coal with about 20% ash and 3% sulfur, which when cleaned yields an acceptable feed coal containing about 8% ash and 1% sulfur. There is ample material available for a large-scale coal liquefaction plant.

I met with the following people:

- Mr. Walter Matula - Institute Director
- Ms. J. Kulczycka - Assoc. Prof. (UNDP Project Office)
- Mr. Adam Worsztynowicz - Division Director

We reviewed the construction and operation of the PDU in regard to the basic equipment (pumps, vessels, heaters, etc.), instrumentation, and insulation. We discussed the coal grinding, slurry preparation, hydrogen generation, and hydrogen compression (makeup and recycle) and reactor sections. Original operations were with oil and hydrogen on a recycle basis, and featured conditions of 200 atmospheres (3000 psig) and 340°C in the reactor. When coal slurry was processed, the temperature was increased to 415°C. The PDU was operated 24 hours per day on a shift basis, with each shift composed of 12 operators and 4 process engineers.

We spent the rest of the day discussing present DOE work and the effort at the Wilsonville plant on Two-Stage Liquefaction. I outlined the U.S. DOE past and present programs for coal liquefaction (pyrolysis

and indirect and direct liquefaction). I concentrated on direct liquefaction and how it related to the on-going Polish work being funded in part by UNDP. I briefly outlined the new work in two-stage liquefaction of coal.

We reviewed the design of the convection heater processing all feed (coal, slurry oil, makeup hydrogen, and recycle gas) to the reactor. It is a conservative design proven in the early work in the German and United States coal hydro plants. The more recent coal liquefaction plants in the United States used radiant heaters, which are prone to coking and require close operator attention.

We reviewed the design of the pump circulating the Hot Separator Bottoms back to the Reaction Section. This is rather severe pumping service, but the application is very similar to the H-Coal pump that is used to circulate reactor contents to maintain a liquid fluidized bed. This pump had a 100% spare.

We also discussed the design recycle gas composition, which varied between 70 and 80 vol.% H_2. The recycle gas scrubbing system involves only an oil wash, no amine scrubbing for H_2S removal. The overall system was adequate with the high purity makeup hydrogen (99.9 vol.%). Total reactor pressure can be increased to ensure an adequate H_2 partial pressure in the reactor if required.

We next reviewed the mechanical aspects of the 80 kg/hr PDU. The discussion centered around the letdown valves. This was the main area of erosion while the PDU was processing coal. These valves were taken out and thoroughly inspected between runs.

We discussed several other subjects, such as:

a. Data Acquisition - Installed in all PDU's and pilot plants in the United States to improve data-gathering accuracy and reliability. The recommended system for the 80 kg/hr PDU to scan, alarm, and compute during operation was installed.

b. V/L Equilibrium Data - This information has been developed and correlated.

c. Coal Science Meeting - The next meeting is in Japan in 1989. The Institute should attend.

At the Tychy-Wyry Institute, we concentrated our discussions on various aspects of the operation of the 80 kg/hr PDU, particularly coal grinding, drying, and transfer. We discussed slurry mixing and the present batch system. Larger plants would use "wet" grinding, pulverizing the coal in the slurry oil. In regard to solids separation, I indicated that we have successfully used vacuum distillation. Present DOE work is concentrating on solvent deashing, but this technique has not been proven to the extent that vacuum distillation has.

We discussed the use of centrifugal pumps versus positive displacement pumps. The former are used for high-volume, low ΔP applications, while the latter are utilized for low-volume, high ΔP. As a result, slurry mixing and transfer generally use centrifugal pumps, and reactor feed pumps utilize the positive displacement type. Both types of pumps are suitable for streams with high (up to 50%) solids content. Recent work in pump manufacture has indicated that some high-volume, high ΔP applications (e.g., amine scrubbing systems) are suitable for centrifugal pumps.

Day 5 - Thursday, April 7, 1988

The Tripartite Review (TPR) Meeting was held on this day at the Institute in Tychy-Wyry. We reviewed operations when the unit at Tychy-Wyry was processing coal at the 80 kg/hr rate, or about 2 t/d. No operating difficulties out of the ordinary were apparent. The reactor was operated at 200 atmospheres and 430°C. At that coal rate (2 t/d), they were using 6 t/d of slurry oil, hence feeding a 25 wt% slurry. Subsequent runs were made at higher slurry concentrations up to 40 wt%. In addition to the combined coal (2 t/d) and slurry oil (6 t/d), they were circulating an additional 24 t/d of hot separator bottoms. Later runs were made at 2.5 t/d of coal. This was a very impressive performance in regard to ease and duration of operation.

We then discussed the method to be used in scaling up the results from the 80 kg/hr PDU to a full-scale commercial plant. Generally the material balance can be set with some degree of accuracy; however, the degree of process and heat integration must be improved upon to obtain favorable economics. The PDU is not suitable for obtaining accurate heat balance data owing to its relatively small size and its inherent high ratio of surface to volume. The Polish workers have most of the current coal liquefaction literature, and I intend to continue sending them pertinent material as it becomes available.

During the week of our TPR meeting, coal was out of the unit, and the PDU was shut down for inspection. The PDU has been operated on coal for about 1,000 hours during the last year. Several runs of 10 days or more were made during this period.

The Director of the Institute at Tychy-Wyry indicated that he may wish to send several people to the United States to survey the latest developments in direct coal liquefaction. They asked for advice on the arrangements and points of contact. I recommended that they write (through UNIDO) to the PETC Director outlining in detail the following:

1. Names and suggested dates
2. Background of visitors
3. Suggested itinerary
4. People they wish to see

The Polish engineers and scientists expressed gratitude for the financial and technical help supplied by UNDP and UNIDO. A project of this magnitude relies on active cooperation of all parties involved. We reviewed the completed work on the 5.0 kg/hr bench-scale unit. It indicated that the design basis of the 80 kg/hr PDU was sound. A review of the 80 kg/hr PDU operating parameters was made based on the results of the 5.0 kg/hr bench scale unit.

Day 6 - Friday, April 8, 1988

This was a travel day, and I left Katowice early to get to Warsaw to catch an afternoon flight to London, England, for an overnight stop.

Day 7 - Saturday, April 9, 1988

The day was spent in travel from London, England, to Pittsburgh, Pennsylvania.

CONCLUSIONS

Considerable progress has been made in the construction and operation of the 80 kg/hr PDU at the Institute of Carbochemistry at Tychy-Wyry, Poland. The plant was completed and operated on schedule. The attainment of full integrated operations by December 1986 followed successful mechanical start-up in early 1986 and technical start-up in late 1986.

The budget was adequate for this project, and expenditures were closely controlled. The UNDP Fellowship program has greatly helped this project. Several Polish engineers each spent six (6) months at PETC to improve their access to technical literature in the field of direct coal liquefaction. I will continue as in the past to send pertinent literature directly to the Institute in Tychy-Wyry.

Operation of the 80 kg/hr PDU was a success, including coal grinding, slurry preparation, hydrogen production and compression, the preheater and reaction system, and the hot separator with the hot circulation pumps. The hydrogenation section was the most critical area of the PDU. The completion of the electrical and instrumentation areas was given top priority. The section completed last was the product distillation area. All projected completion dates were attained.

Finally, we concluded this trip with yearly Tripartite Meeting. At this time a great deal of actual operating data on processing coal slurries was available. The Polish workers successfully developed a process for direct hydrogenation of a particular type of coal. Their long-range goal is to make use of their vast coal deposits, which, although accessible, contain high amounts of sulfur. Deposits in the Janina region (at 250-300 meters) have been estimated at 7 billion tons. The high-sulfur coals from these shallow mines are cheaper than most other European coals but cannot be burned in power plants owing to pollution. Direct hydrogenation of these coals has given encouraging results. The integrated operation of the PDU has yielded technical data to serve as a basis for the design of a demonstration plant having a capacity of 8-20 t/hr coal throughput.

The final conclusion relates to the success of this project which is due to the hard work of the Polish engineers and scientists. The project followed the agreed-upon schedule and was completed on time. Many problems of a technical and/or mechanical nature were recognized, analyzed, and solved on-site by the Polish workers. Cost management was given top priority, and the project was brought in under budget. Owing to careful planning and attention to detail, the start-up was safe, error-free, and proceeded smoothly. Subsequent integrated operations proved out the basic design upon which the plant was based. All in all, this project could be considered a model for developing a complex technology under less than favorable conditions.

RECOMMENDATIONS

Based on my stay at the Tychy-Wyry Institute of Carbochemistry during the period of April 5-8, 1988, the following recommendations are pertinent relative to the Polish coal liquefaction effort (DP/POL/82/002/B101/37):

1. Outstanding progress was made in the operation of the 80 kg/hr PDU. Concentrated efforts were required to keep this project on schedule, but the projected date for attaining full integrated operation (December 1986) was attained. The Institute members should advise UNIDO of operating progress in detail on a monthly basis.

2. There is a continual need to ensure that the members of the Institute keep abreast of the latest developments in coal liquefaction. I will continue to send pertinent material. The UNDP Fellowship program has proven very valuable.

3. Physical property data obtained at PETC aided the design of the 80 kg/hr PDU. Mr. E. Jedrysik spent 6 months at PETC on a UNIDO Fellowship to work in this area.

4. The use of a pump to recirculate a portion of the hot separator bottoms to the inlet of the preheater was critical to the operation of the 80 kg/hr PDU. This pump provided a means of obtaining sufficient coal conversion without costly catalysts. Recognition should be given to the Polish team for developing this pump.

5. Information exchange should be continued. I would recommend that Polish progress reports be sent to me when they are available. I will continue to periodically send pertinent coal liquefaction literature to them.

6. The Polish engineers and scientists should be considered as a UNIDO source of technical expertise on the design, construction, and operation of direct coal liquefaction plants. They could serve as "experts" in future UNIDO projects.

7. The Institute of Tychy-Wyry should be considered as a training facility for short- and long-term visitors from other countries interested in this technology. UNIDO fellowships should be used to send engineers from other countries to Poland for training in the design, construction, and operation of direct coal liquefaction process development units.

J.J. Lacey

J.J. Lacey
April 15, 1988