THE H-COAL PROCESS - A STATUS REPORT

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ABSTRACT

H-Coal is a catalytic process involving the direct hydrogenation of coal to produce hydrocarbon liquids. Its development was started in 1963 by Hydrocarbon Research, Inc., a subsidiary of Dynalectron. The process has operated at the bench scale level on a wide variety of coals including eastern U.S., western subbituminous and lignites from Texas and North Dakota as well as foreign coals. A three-ton per day process development unit has also been operated extensively, confirming bench scale results and adding substantially to the technical data base. The process affords wide flexibility of operation from "fuel oil" to "syncrude" modes.

A pilot plant now under construction at Catlettsburg, Kentucky is scheduled for completion March 31, 1979. It will be the largest coal liquefaction plant on-line in the U. S., processing up to 600 tpd of coal. Concurrent with the pilot plant, other development activities are being undertaken to provide timely initiation of a commercial project. Assuming successful operation of the pilot plant in 1979, engineering on a 50,000 BPD plant is scheduled to start in early 1980, construction in mid-1931 and operations beginning in late 1984.

I. INTRODUCTION

Recently Ashland has been studying commercialization of the H-Coal process and has had several meetings with Department of Energy personnel concerning such development. The discussion today will address both the status of the H-Coal pilot plant now under construction and the status of a proposal for commercialization of the process.

The pilot plant will be discussed later but just the scope of a project required for commercialization is large by any measure. An installation designed to produce 50,000 barrels per stream day of liquid products would require 18,500 tons per day of bituminous coal or 6,100,000 tons per year. Therefore, the facility would be the largest single point consumer of bituminous coal in the world, equivalent in fuel to a 2,300 MW power plant. It would require 3 relatively large underground coal mines to supply feed to one plant.

Obviously, much careful planning would be required to bring such an undertaking to fruition. Our most optimistic projections for a commercial plant would be on start-up in mid-1984 (as discussed later).

II. BACKGROUND

The H-Coal process developed by Hydrocarbon Research, Incorporated dates back to 1963. The process is a spin-off of the H-Oil technology which is a commercial system used for hydrogenation of residual oil.

H-Coal is a direct, catalytic hydrogenation of coal in an ebullating bed (boiling). The reactor operates at about 3000 psig and 850°F which are relatively severe conditions.

The basic experimental work on the process has been and is still being done on a bench scale unit and a pilot demonstration unit (PDU) at Trenton, NJ operated by HRI. The data base is large including 60,000 hours on the bench unit and 8,000 hours on the PDU. The process has been tested on a wide variety of coals from high volatile bituminous to lignites for domestic coals and on two foreign coals. This indicates the versatility of the processing, that is modifications can be made to accommodate markedly different feed coals.

In 1976 Ashland Synthetic Fuels, Inc., a wholly-owned subsidiary of Ashland Oil, Inc., was awarded the prime contract for construction and operation of an H-Coal pilot plant. Under terms of the contract, Hydrocarbon Research, Incorporated will supply technical advice and support throughout the program.

The plant, now under construction, is located across Interstate Highway 64 from Ashland's Catlettsburg, Kentucky refineries. The refinery will furnish hydrogen and other utility type commodities to the pilot plant which effectively reduces the total capital investment for the installation. The plant is near 40 percent mechanical completion and is a joint government-industry effort. The major portion of the funding for the project is from the Department of Energy. Industrial participants are as follows:

- Ashland Oil, Inc.
- Conoco Coal Development Company
- Mobil Oil Corporation
- Standard Oil (Indiana)

Additional funding is furnished by the Commonwealth of Kentucky and the Electric Power Research Institute, the research arm of the electric power generating industry.

The pilot plant is sized to process from 200 to 600 tons per day of coal, depending on the reactor space velocity. That is, the "mode" of operation determines the capacity of plant as designed. Operating in "fuel oil" mode high space velocity, mild hydrogenation, fuel oil product, the capacity of the plant will be 600 tons per day. Operating in "syncrude" mode low space velocity deep hydrogenation, syncrude product, the capacity of the plant will be 200 tons per day.

The pilot plant is scheduled for mechanical completion March 31, 1979. Although it is a pilot plant, it will be the largest coal liquefaction plant ever built in this country. Since the pilot plant will be on-line next year, it should furnish sufficient data to allow early design and engineering of a commercial scale H-Coal plant.

III. PROCESS DESCRIPTION

A process description of a 50,000 barrel per day commercial plant is outlined in the following paragraphs and graphically presented in Figure 1.

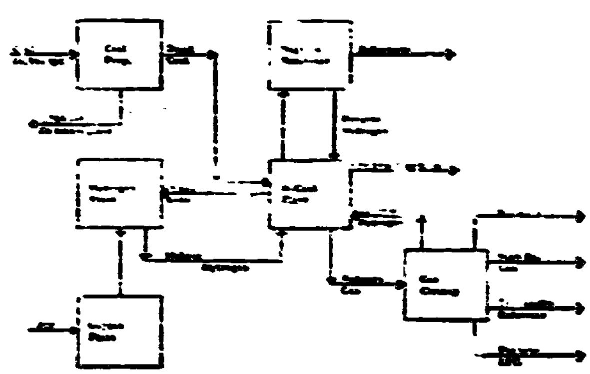

Figure 1. Block diagram. H-Coal process

A. COAL HANDLING AND PREPARATION

The run-of-mine coal is received at the plant and crushed to minus 3/4 inches in a hammer mill. From the mill the coal is fed through a transfer house to the coal storage pile, the steam plant, or crushed coal storage bins.

Coal from the bins is transported to a fluid bed drying system where the moisture content is reduced to about 2 percent by weight. The dried coal is then fed to a closed loop crushing system where the size is reduced to minus 14 mesh. The coal is then pneumatically conveyed to the slurry preparation feed bin.

B. HYDROGENATION PLANT

The coal is then mixed with recycle oil in the slurry mix tank. The recycle oil is made up of hydroclone overflow, fractionator bottoms, and some middle distillate from the fractionator. The mixed coal-oil slurry is then pumped ... reactor feed tank.

Each reactor is equipped with two direct-fired feed heaters, one of which heats the feed slurry and 50 percent of the makeup and recycle hydrogen and the second is used to heat the remaining hydrogen. From the slurry feed tanks the slurry is pumped to reaction pressure (about 3000 psig) and then is mixed with recycle hydrogen and heated to reaction temperature (about 850°F) before entering the reactor. The other hydrogen (not mixed with the slurry) is also heated to 850°F prior to introduction to the reactor. The dual heater arrangement offers excellent temperature control of the feed streams. The mixing of recycle hydrogen and slurry before heating is advantageous because the hydrogen lowers the slurry viscosity and improves heat transfer.

The charge in the reactor is maintained in an ebullated state (boiling action) by an internal liquid recycle. This assures adequate catalyst contact and facilitates catalyst addition and withdrawal during operation.

The products from the reactor are taken overhead and flow to the primary separator where the light products are flashed off and the oil, unconverted carbon, and ash flow through a pressure letdown valve to a high pressure flash drum operating at 1200 psig. The light gases and oils overhead are heat exchanged with the makeup and recycle hydrogen and cooled and flashed in a series of drums each operating at lower pressures and temperatures than the preceding one to recover unreacted hydrogen for recycle back to the reactor. The gases and light oils recovered during the flashing are sent to gas cleanup and fractionation respectively.

The heavy oil, unconverted carbon, and ash stream from the bottom of the primary separator is also flashed in a series of drums to separate oil and gases from the heavy residue. The gases and oil recovered are again sent to gas cleanup and fractionation respectively. The heavy fraction containing almost ... the unconverted carbon and ash flows to hydroclones for a partial concentration of the solids into the underflow stream. The hydroclone overflow is recycled to slurry preparation and the underflow flows to the atmospheric and vacuum towers operating in series which concentrate the solids. The oils recovered from the towers are sent to fractionation and the bottoms from the vacuum tower are used for feed to the partial oxidation gasifiers in the hydrogen plant.

The fractionator separates the plant ... various fractions, gases, naphtha, light oil, and bottoms. The gases flow to the gas cleanup system, the naphtha is stabilized and sent to storage, the light oil represents distillate fuel oil product and the bottoms from the fractionator, along with some of the light oil, are recycled to slurry preparation.

The fc regoing description is based on the "syncrude" mode of operation. However, it should be noted that the H-Coal process does afford flexibility as to product distribution and may indeed be operated in a "fuel oil" mode. It follows that some of the processing described above would require modification for the "fuel oil" mode of operation.

C. NAPHTHA REFORMING

The processing proposed by Ashland for a commercial plant includes reforming of the highly naphthenic naphtha to form an aromatic gasoline blending reformate. The hydrogen produced by dehydrogenation of the naphthenes will be recycled to the H-Coal reactor; this effectively reduces the size of the hydrogen plant as well as increases the value of the product.

At this time, we have assumed that the phenols can be fed to the reformer guard case. If this proves to be unacceptable, the phenols could be removed prior to reforming. The research octane number of the reformate is estimated to be 101.

The guard cases will use a nickel-moly catalyst to reduce both the sulfur and nitrogen concentrations to acceptable levels for the platinum-type reformer catalyst. The reforming would be relatively mild because of the highly naphthenic feedstock which would not require isomerization or hydrocracking to form a desirable gasoline blending stock.

D. GAS CLEANUP AND COMPRESSION

The refinery-type gases collected from the hydrogenation system are mixed and compressed to 215 psig and flow to a light oil wash where all of the naphtha and much of the butane entrained in the gas streams are recovered. The gases from the light oil absorber are compressed to 600 psig and flow to the hot potassium carbonate (Benfield) acid-gas scrubbing system for removal of H_2S and CO_2. Trace quantities of CO_2 and H_2O are removed by molecular sieves prior to the cryogenic cold box. The cryogenic system produces a hydrogen recycle stream (95% purity), a fuel gas stream, and a mixture of propane and butane. The propane and butane are separated into the final products in a debutanizer.

The naphtha from light oil stripping is sent to naphtha reforming and the butane is taken as gasoline blending stock. The acid gas from the Benfield regenerators flows to a Claus unit. The cryogenic fuel gas stream is compressed for pipeline transmission, the propane is sent to the LPG product, and the hydrogen is compressed and recycled to the hydrogenation plant.

E. THE HYDROGEN PLANT

The gasification system presently contemplated will be based on the Texaco partial oxidation system. Vacuum tower bottoms or other more concentrated resid from the H-Coal process will be used for feed and supplemented as necessary with coal to meet the hydrogen requirement. The heavy liquid bottoms and coal have each been tested successfully by Texaco in pilot plant operations. This type unit is being considered for both high Btu gas plants and methanol plants now under investigation so design data is likely to be available in time for H-Coal development.

Every effort will be made to maximize the solids content of the H-Coal resid prior to gasification. Any reduction in oil content will be replaced by coal at a significant economic advantage. Several ongoing projects are focusing on solids-liquid separation and should provide technical and economic data within a time frame compatible with the proposed H-Coal schedule.

The hydrogen plant, after synthesis gas generation, is a conventional processing system for hydrogen production. That is, two stages each of shifting and acid-gas scrubbing to get 95% plus purity product.

The gasification system, including the supporting oxygen plant and the substantial steam requirement, is an expensive part of the total plant, both from an operating and capital cost consideration.

There are no gasifiers in operation today in the world of the size proposed here but much development work on such units has been done and it appears feasible to build such a unit.

F. SUPPORTING PLANTS AND TANKAGE

All of the processing required for hydrogen sulfide recovery and sulfur manufacture, ammonia recovery and tankage are of conventional design and afford no unique problems as applied to H-Coal processing.

IV. IN-HOUSE COMMERCIAL PLANT STUDY

The foregoing process description was based on an in-house Ashland study for commercialization of the H-Coal process operating in the "syncrude" mode to produce about 50,000 barrels per day of liquid products.

The processing as visualized produces salable products and ash. The system produces no heavy oil (boiling above 600°F) because it is recycled to extinction or comes off the bottom of the vacuum towers mixed with the ash and unconverted carbon. The vacuum tower bottoms are fed to the partial oxidation unit for synthesis gas production and subsequent hydrogen manufacture. The result is a plant that produces commercial products and ash, an important feature of the processing worked out at Ashland.

The commercial plant is sized to process 18,541 tons per day of "as received" coal to produce 49,741 barrels per day of hydrocarbon liquids, 29.52MM standard cubic feet per day of high Btu gas, 567.5 long tons per day of sulfur, and 118.8 tons per day of anhydrous ammonia. The coal requirement and product slate are shown in the following slide.

Table I. Product slate - commercial plant

Coal Required "As Received"	18,541 tpd
Products	
Reformate	15,182 BPD
Distillate (400-600°F)	27,792 BPD
Butane	3,276 BPD
Propane, LPG	3,491 BPD
Total	49,741 BPD
By Products	
Sulfur	567.5 LT/D
Ammonia	118.8 ST/D
High Btu Gas	29.5 MMscfd

V. ECONOMIC EVALUATION

An economic study of the commercial plant, sized as described previously, has been completed by Ashland.

"The state of the art" of coal liquefaction dictates that an economic evaluation at this time be of a preliminary nature. That is, our evaluation is based on a "factored" type estimate. This type estimate requires materials and energy balances on the flow sheets, preliminary engineering, sizing and costing of major equipment items but piping, structures, instruments, etc. are taken as a percentage of the bare equipment costs and thus arriving at a total installed capital cost.

Our primary interest at Ashland has been the syncrude mode of operation and our economic projections have been made on a plant operating in this mode only.

Obviously, economic projections require the preparation of schedules and Figure 2 is a phased schedule for commercial development of the H-Coal process. The preliminary and cost estimate is being initiated now and should be completed by the end of March 1979. Also, concurrently, preliminary site selection work is under way with particular emphasis on Illinois basin reserves as possible feed for the first H-Coal commercial plant. Ashland is actively seeking out partners to form a consortium for industrial support of the commercial project. Initial environmental work is being done in that the scope and nature of work required is being planned and defined leading to an environmental assessment which is required for an impact statement. Also during Phase I, permit requirements will be determined and defined so that an action plan for acquisition of same can be instigated.

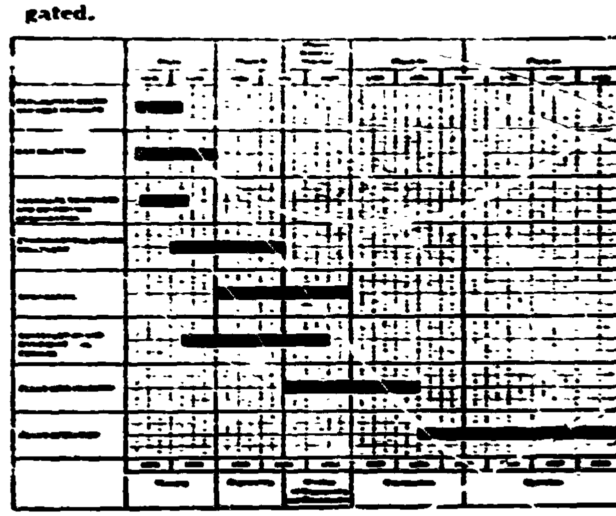

Figure 2. H - Coal commercialization schedule

Phase II starts in January 1980 when commitment is made to plant engineering. Plant engineering includes detailed plant engineering, preparation of equipment specifications, preparation of a construction bid package, and selection of an erection contractor. Environmental studies will be continued through the first half of the engineering phase culminating in the approval of the environmental impact statement in mid-1981. Then Phases II and III would overlap as engineering would extend into the construction phase.

Phase III construction would start in mid-1981 and extend to mid-1984 (3 years). This is an ambitious schedule for such a large complex plant and will require meticulous planning to maintain.

A concise statement of work will be prepared discussing in detail the work to be accomplished by the construction contractor. A complete construction schedule will be prepared including a "Critical Path Model" so as to assure procurement and logistics can be adequately planned and coordinated.

The schedule will include all on-site activities from site preparation to mechanical completion including "milestones" which are important construction goals and which will allow evaluation of the project at instances of attainment.

Phase IV will be the start-up and operation of the plant.

The economic projections shown in Table 2 assumes 75 percent debt, 25 percent equity capital, with the discounted cash flow rate of return on equity only. The interest on debt is taken at 8.75 percent or 1 percent above the prime interest rate.

The operating costs are determined using $20 per ton for coal and normal costing procedures to arrive at a total estimated annual operating cost.

The by product credits taken were sulfur at $25 per ton, high Btu gas at $2 per million Btu's, and ammonia at $110 per ton.

The projections were made using constant 1977 dollars and projected current dollars for capital determination.

The DCF ROI was based on the value of products listed previously corrected for entitlements which gave an average value of the liquid products at $16.50 per barrel. If the values were not corrected for entitlements the product values would be $14.02 per barrel.

The DCF ROI was then calculated three ways: first using constant dollars, secondly inflated to start-up only, and thirdly using full inflation.

Table 3 shows the identical sets of numbers on a 100 percent equity capital base. Obviously, high debt has a profound effect on DCF ROI.

Table 2. Commercial plant

Economic Projections

Capital Investment	1977 Dollars	Current Dollars
Total	582.7	[illegible]
Debt	453.6	790.2
Equity	175.2	265.2

Equity DCF ROI	
Constant Dollars	14.8%
Inflated to Start-up	17.9%
Full Inflation	31.8%

Table 3. Commercial plant

Economic Projections

Capital Investment	1977 Dollars	Current Dollars
Total	582.6	896.0

Project DCF ROI	
Constant Dollars	9.1%
Inflated to Start-up	10.5%
Full Inflation	19.8%

The next table shows the inflation rates used in the preceding economic analysis. Making such prognostications has been a precarious occupation in recent history but extended forecasting requires some predictions of inflation rates.

Table 4. Projected inflation rates

Year	Crude Oil Price (Product Values)	Coal Price	General Inflation	Construction Inflation
1977-1979	4.6%	6.6%	4.6%	6.9%
1980-1984	7.0	5.0	5.0	[illegible].0
1985-1989	10.0	4.0	4.0	
1990-1994	7.0	4.0	4.0	
1995-2005	2.0	3.0	3.0	

It is obvious from the above that Ashland contends that oil prices will begin to escalate more rapidly than either coal prices or general inflation in 1980 and continue at a more rapid inflation rate through 1994. Therefore, applying the above inflation rates to a coal based synfuels plant improves the economics over a constant dollar case as was indicated in the tables.

VI. GOVERNMENT SUPPORT

When one considers the constant dollar economics which are marginal, the projected capital intensiveness of the proposed project one must conclude that development by the industrial community without economic incentives from the government are unlikely. In fact, action will be required in both the economic sector and the environmental area if an accelerated schedule is to be maintained.

The economic incentives which have been suggested include guaranteed non-recourse government loans with various industrial buy-back provisions, accelerated investment tax credits, tax credit allowance for each barrel of product, government grants for the initial development, and combinations of the above. It will be necessary in any event to require sufficient funding from the industrial consortium to indicate their commitment to the success of the project.

To meet the schedule outlined previously, unreasonable delays must be eliminated from the environmental program which is on the critical path. Obviously, one can not commit to construction without reasonable assurance that the environmental impact statement is acceptable. Since an environmental assessment is required for the preparation of an EIS, any unusual delays would extend the schedule because of time requirements for baseline data and other time constraints inherent in the assessment work.

VII. SUMMARY AND CONCLUSIONS

1. We believe at Ashland that coal liquefaction development in the United States is inevitable.

2. The H-Coal program is underway now and should be accelerated.

3. We are now preparing a formal proposal to the Department of Energy for H-Coal development.