STUDY OF EBULLATED BED FLUID DYNAMICS FOR H-COAL. QUARTERLY PROGRESS REPORT NO. 2, DECEMBER 1, 1977--FEBRUARY 28, 1978

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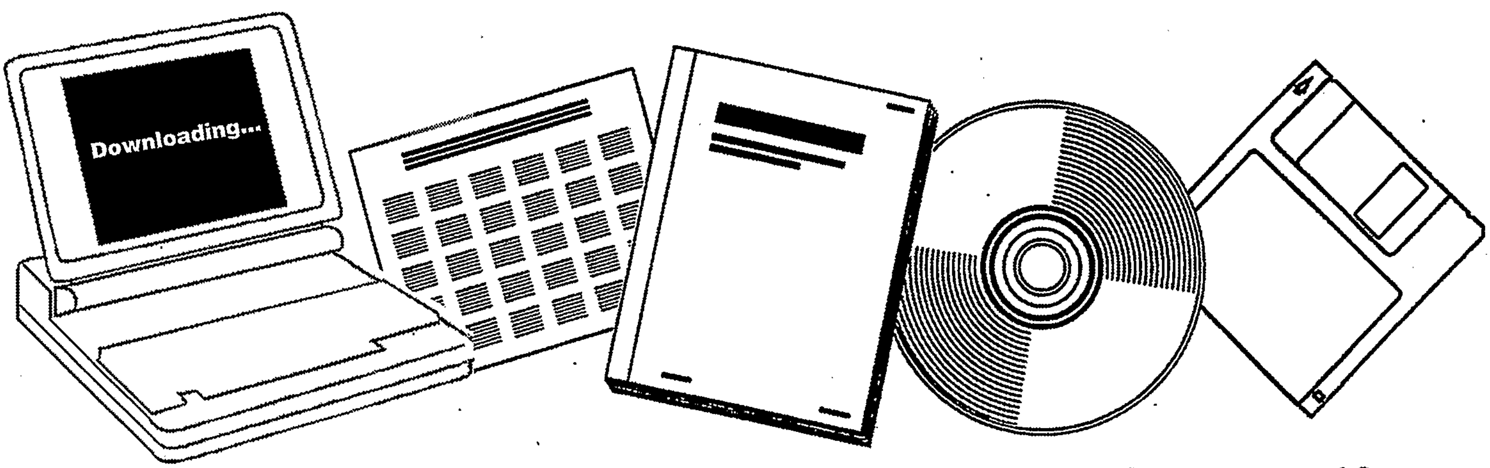

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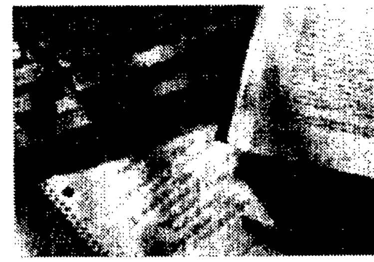

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STUDY OF EBULLATED BED FLUID DYNAMICS FOR H-COAL

QUARTERLY PROGRESS REPORT NO. 2
DECEMBER 1, 1977-FEBRUARY 28, 1978

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FOREWORD

The H-Coal process, developed by Hydrocarbon Research, Incorporated (HRI), involves the direct catalytic hydroliquefaction of coal to low-sulfur boiler fuel or synthetic crude oil. The 200-600 ton-per-day H-Coal pilot plant is being constructed next to the Ashland Oil, Incorporated refinery at Catlettsburg, Kentucky under ERDA contract to Ashland Synthetic Fuels, Incorporated. The H-Coal ebullated bed reactor contains at least four discrete components: gas, liquid, catalyst, and unconverted coal and ash. Because of the complexity created by these four components, it is desirable to understand the fluid dynamics of the system. The objective of this program is to establish the dependence of the ebullated bed fluid dynamics on process parameters. This will permit improved control of the ebullated bed reactor.

The work to be performed is divided into three parts: review of prior work, cold flow model construction and operations, and mathematical modelling. The objective of this quarterly progress report is to outline progress in the first two parts during the second quarter of the project.

OBJECTIVE AND SCOPE OF WORK

The overall objective of this project is to improve the control of the H-Coal reactor through a better understanding of the hydrodynamics of ebullating beds. The project is divided into three main parts: 1) review of prior work in the area of gas/liquid/solid fluidization; 2) construction of a cold flow model and collection of data; and 3) development of a mathematical model. Progress made in Parts 1 and 2 during the last three months will be presented in this report.

SUMMARY OF PROGRESS TO DATE

Review of Prior Work

Several papers were reviewed in the following areas: 1) hydrodynamics of fluidization; experimental techniques in multiphase systems; and 3) physical properties of coal/oil mixtures. Results from this review are described in a report recently completed. A draft of this report will be sent to H-Coal participants for comments.

Unit Construction and Data Collection

The design of the fluid dynamics unit has proceeded as planned during this quarter. The mechanical and systems design is almost complete, and machine shop and field construction proceeded well. The support structure was built, and utilities have been installed. The reactor has been assembled, and process piping has started. Pretesting of instruments also continued.

REVIEW OF PRIOR WORK

A report was written fulfilling the literature review requirement of the H-Coal fluid dynamics project. The review will serve as a guide for future research in the project on three-phase fluidization. Three areas of literature are reviewed:

1) The hydrodynamics of fluidization.
2) Experimental techniques in multi-phase flow.
3) Physical properties of coal/oil mixtures.

The section on hydrodynamics of fluidization reviews prior work on liquid/solid fluidization, gas/liquid vertical flow, and gas/liquid/solid fluidization. Experimental conditions, data, correlations, and models in these areas are reviewed. Bubble behavior and structure in liquids and liquid fluidized beds are also covered. It is apparent from the review that more experimental work is needed. Few authors made simultaneous measurements of individual phase holdups, bubble size, and bubble velocity. Most data are for fluidization with air and water. Many experiments were performed in small-scale equipment. The effects of fluid properties and particle shape on bed expansion need to be determined. Very little information on fluidization with slurries is available.

In the next section of the report, techniques available for use in this experimental program are reviewed. Techniques using external detectors such as gamma-ray scans, radioactive tracers, and some sonic probes are favored for use in the H-Coal project because they do not disturb the flow. Light, impedence, and conductivity probes which require detectors inside the reactor are also reviewed in this section.

The section on the physical properties of coal/oil mixtures is a review of papers on viscosity measurement of these mixtures. The viscosity of H-Coal slurries is to be determined at H-Coal reactor conditions as part of the project. The literature indicates that the viscosity of these slurries is a function of temperature, solids volume fraction, and solids particle size distribution. Empirical correlations for analyzing the viscosity data are also reviewed.

CONSTRUCTION OF COLD FLOW UNIT AND DATA COLLECTION

Emphasis has continued in designing and building the fluid dynamics unit. Figure 1 puts in perspective the progress made in the various phases of this work. Details on each item are given below. A diagram of the critical path analysis for the construction phase was presented in the January monthly progress report.

Systems Design

Figure 2 shows a schematic diagram of the fluid dynamics unit. Details on sizes of lines and major vessels were reported in the first quarterly report. Major emphasis this quarter was placed on completing the systems design and ordering long delivery items. A final review of the systems design will be held in the second week of March.

Table I reports major items ordered during the quarter. Testing instruments as they arrived continued to receive top priority. The reactor DP cells, Honeywell automatic controllers, Dwyer switches, signal converters, and the Monitronix annunciator were all checked. The Harshaw gamma-ray detection system was evaluated on bench-scale equipment. Results of the study were presented in the January monthly progress report.

Testing of the MicroMotion flow meter was completed. The meter had performed erratically in bench-scale tests at Amoco, so it was returned to the manufacturer for further evaluation. They found that large slugs of gas caused the meter to perform erratically. However, if the gas/liquid mixture was passed through a static mixer before the flow meter, excellent results were obtained. The meter was returned to Amoco for further testing. During these additional tests, the flow meter performed satisfactorily if the gas was well dispersed in the slurry. A static mixer was not required to keep the gas dispersed at the low gas-in-slurry concentrations which are expected in the H-Coal system.

A Nusonic flow meter was selected for the slurry feed stream. Mapco, the manufacturer of the flow meter, evaluated our kerosene/coal fine slurry and found it to be well suited for sonic flow measurement. They prepared calibration curves of sonic velocity versus coal fine concentration and temperature for the kerosene slurry. Calibration curves for the other liquid/coal slurries to be used in the cold flow model are currently being constructed.

A Nusonic concentration analyzer was chosen to monitor the concentration of coal fines in the slurry fed to the reactor.

A computer system was also selected. The computer will be purchased by Amoco. However, peripheral hardware and software costs directly applicable to this study will be charged to this project.

Mechanical Design

Shop construction of the reactor components was completed during the quarter. The spool pieces, reactor inlet distributor section, and the recycle cup are finished. Drawings of these components were shown in past monthly progress reports.

A test sample tap was also constructed. This sample tap will be used to establish the relative concentration of fines, liquid, and catalyst at several locations in the reactor. Modifications to the sample tap are being designed to improve ease of operation.

Mechanical design of the gamma-ray elevator continued. The gamma-ray system will travel along the length of the reactor on the elevator so that the bed density can be continuously monitored.

Design of the slurry preparation tank top and coal fine hopper was completed.

Field Construction

Construction of the steel support structure was completed, and the utilities were installed. Mounting of components into the instrument panel board has started.

During assembly of the glass reactor, one glass section shattered. Following consultation with representatives from the glass pipe manufacturer, several modifications were made to the glass reactor support and assembly procedure. A heavier beam was chosen to support the reactor, and an additional beam was added to support the bottom spool piece. The reactor assembly was completed and approved by the glass pipe manufacturer. DP cells were mounted on the unit and piped to the reactor. Piping of the gas feed system was also started. The entire reactor schematic is shown in Figure 3.

Feed and slurry preparation tanks were installed, and construction of the coal fine feed hopper was completed.

Data Collection

Viscosity and density data for the liquids to be used in the cold flow unit have been measured as a function of temperature. These are reported in Table II. The viscosity was measured using ASTM Test D-445 (kinematic viscosity). The densities were measured with a hydrometer. Coal fines which will be slurried with these liquids have been submitted for particle size analysis.

The length distribution of the HDS-2A catalyst particles to be fluidized in the unit is reported in Table III. The data indicate that the lengths of these particles vary by as much as a factor of 5. American Cyanamid has been contacted to determine if a catalyst can be made with a more uniform length distribution.

During the next month, the surface tension of the various liquids to be used will be determined. A technique will also be selected to measure the viscosities of the slurries to be used in the cold flow unit.

FUTURE PLANS

During the next quarter, the following are planned:

1) Complete systems design.
2) Complete pretesting of system components.
3) Complete gamma-ray elevator design.
4) Complete design of sample tap modifications.
5) Design blowdown drum.
6) Complete demister construction.
7) Complete pilot plant field construction.
8) Debug and start up fluid dynamics unit.
9) Start testing and debugging computer.

COSTS

A summary of cumulative project costs until the end of January is shown in Table IV. Cost projections for the remainder of the year are shown in Figure 4. High projected costs for the period of February to June are due to material and labor costs for constructing the fluid dynamics unit. Completion of the unit will result in lower costs for the second half of the year.

CONCLUSIONS

Progress has been made in the study undertaken for defining the hydrodynamic properties of gas/liquid/solid systems as related to the H-Coal process. The literature search was completed, and a report will be issued shortly. Design and construction of the fluid dynamics unit proceeded as planned. Unit completion is scheduled for May 1, 1978.

TABLE I

EQUIPMENT ORDERED DURING THE SECOND QUARTER

Slurry Pump
Recycle Pump
Transfer Pump
Solenoid, Relief, and Check Valves
Demister
Sonic Flow Meter
Interactive Digital Plotter
Character Generator System
Sodeco Printing Counter
Temperature Trendicator
Oxygen Analyzer
Temperature Controller
Wet Test Meter
Photoelectric Pressure Switch
Level Switches
Integral Orifice Meter
I/P Signal Converter
Heat Exchangers
Recorders
Gamma-Ray Scan Electronics
Dec Writer, ADC, and MCR Systems
MicroMotion Flow Meter
Coal Fine Concentration Analyzer

TABLE II

PHYSICAL PROPERTIES OF LIQUIDS TO BE USED IN COLD FLOW UNIT

	70°F	100°F	150°F
Viscosity (CP)			
Toluene	0.56	0.50	0.41
Kerosene	1.39	1.15	0.80
Mineral Oil	22.4	14.6	6.08
Water	1.0	1.0	1.0
Density (gm/cc)			
Toluene	0.86	0.85	0.83
Kerosene	0.79	0.78	0.77
Mineral Oil	0.85	0.84	0.82
Water	0.99	0.99	0.98

TABLE III

LENGTH DISTRIBUTION OF HDS-2A CATALYST

Size (Inches)	Number
0.05-0.075	1
0.075-0.100	10
0.100-0.125	6
0.125-0.150	18
0.150-0.175	15
0.175-0.200	12
0.200-0.225	7
0.225-0.250	4
0.250-0.275	3
0.275-0.300	3
0.300-0.325	1
0.325-0.350	1
0.350-0.375	0
0.375-0.400	1
0.400-0.425	0
0.425-0.450	0
0.450-0.475	0
0.475-0500	1

Diameter = 0.063"

TABLE IV

Summary of cost by 1/31/78

Direct labor and overhead	$53675.
Unit construction--materials	20363.
--craft	22549.
Total	$96587.

Figure 1

Construction schedule of the FDU

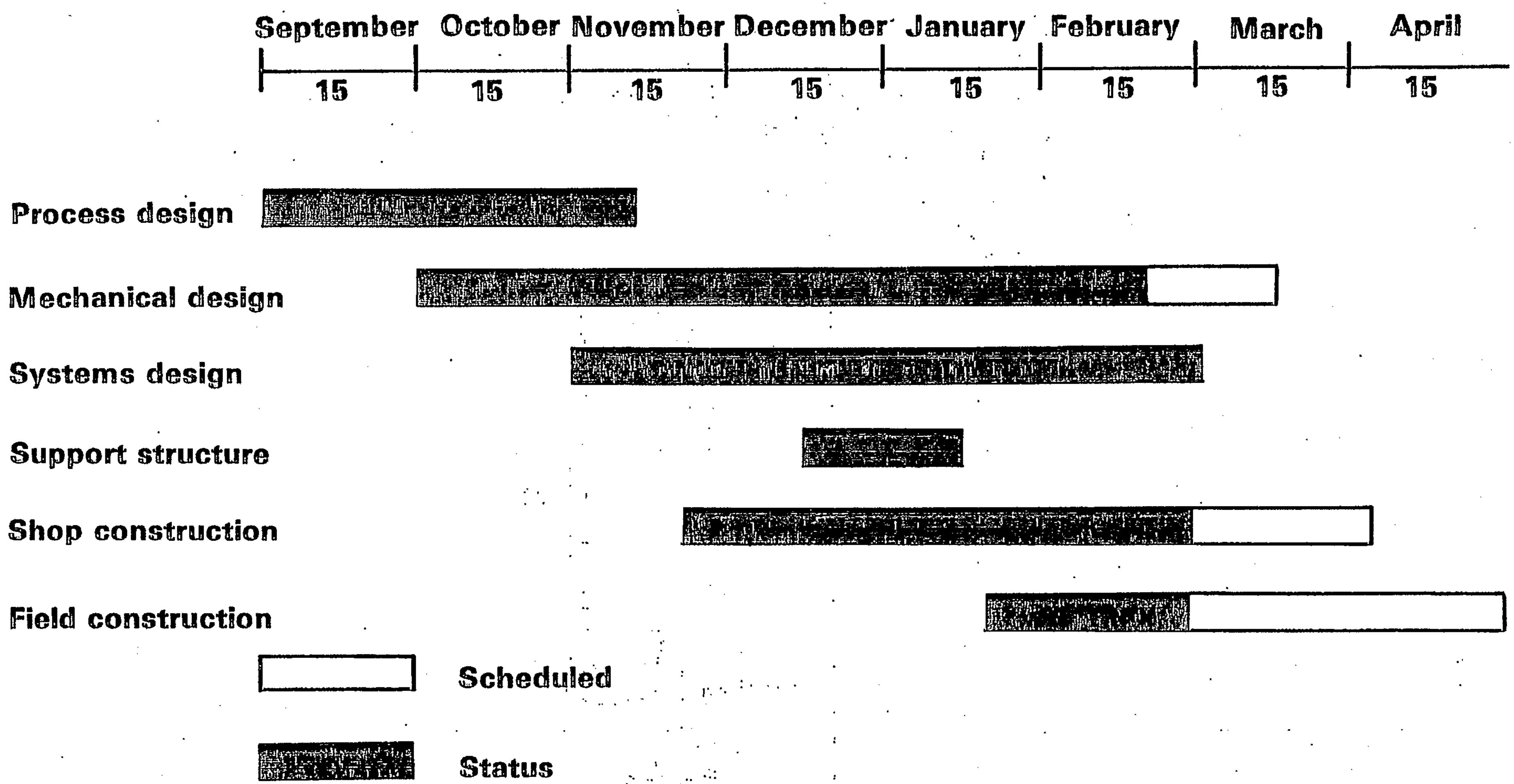


Figure 2

H-COAL FLUID DYNAMICS FLOW SHEET

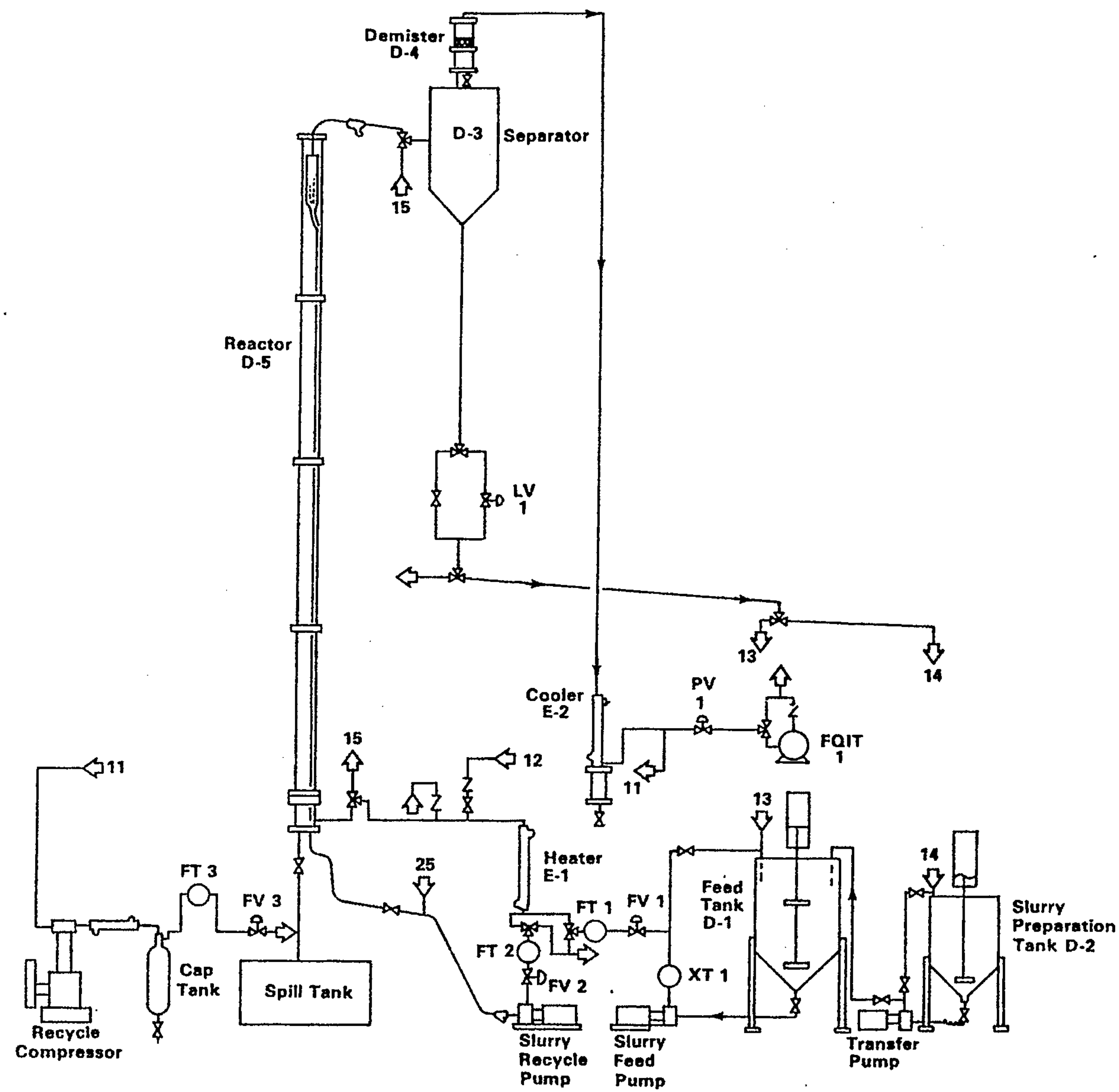


Figure 3.

REACTOR DESIGN

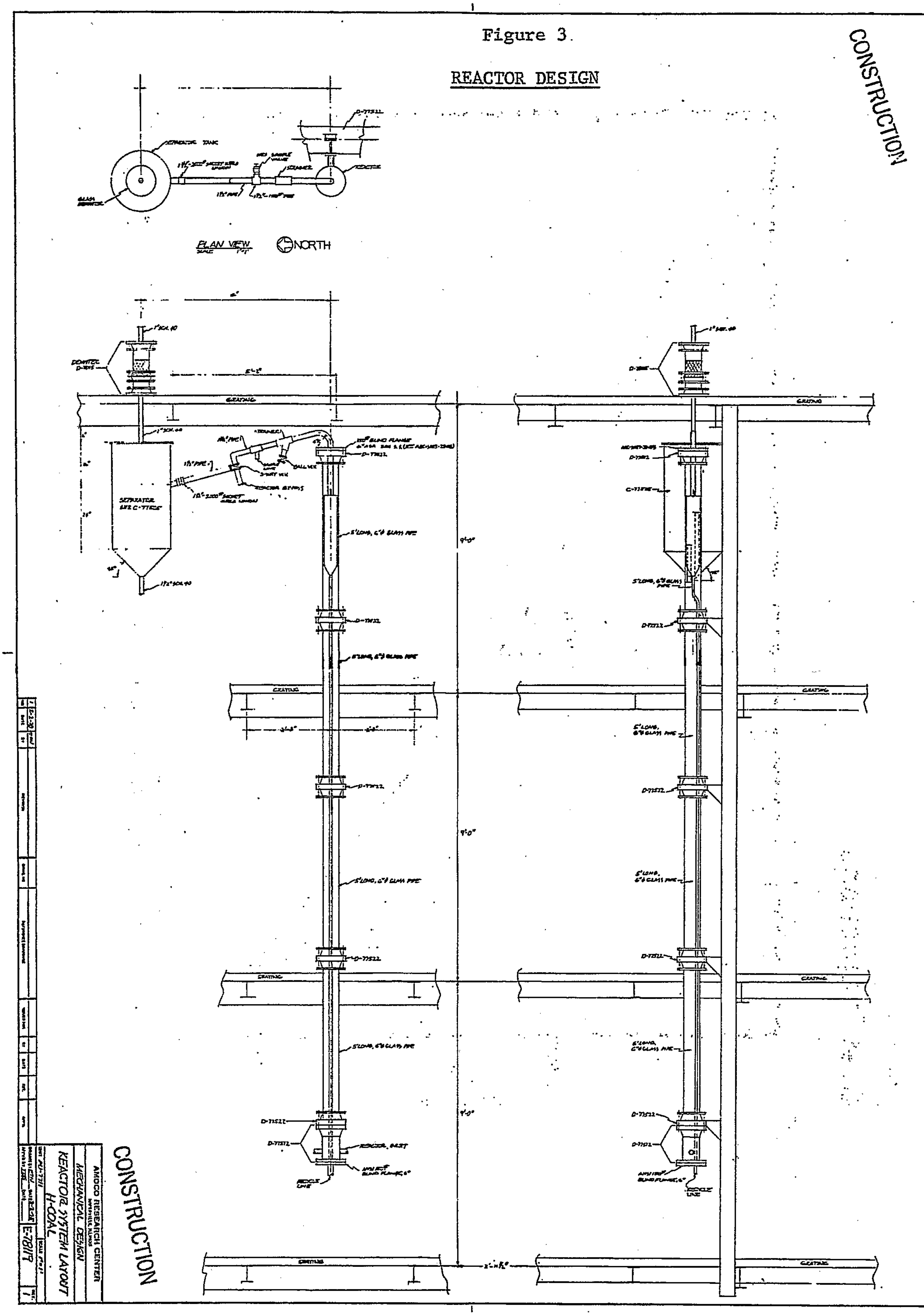
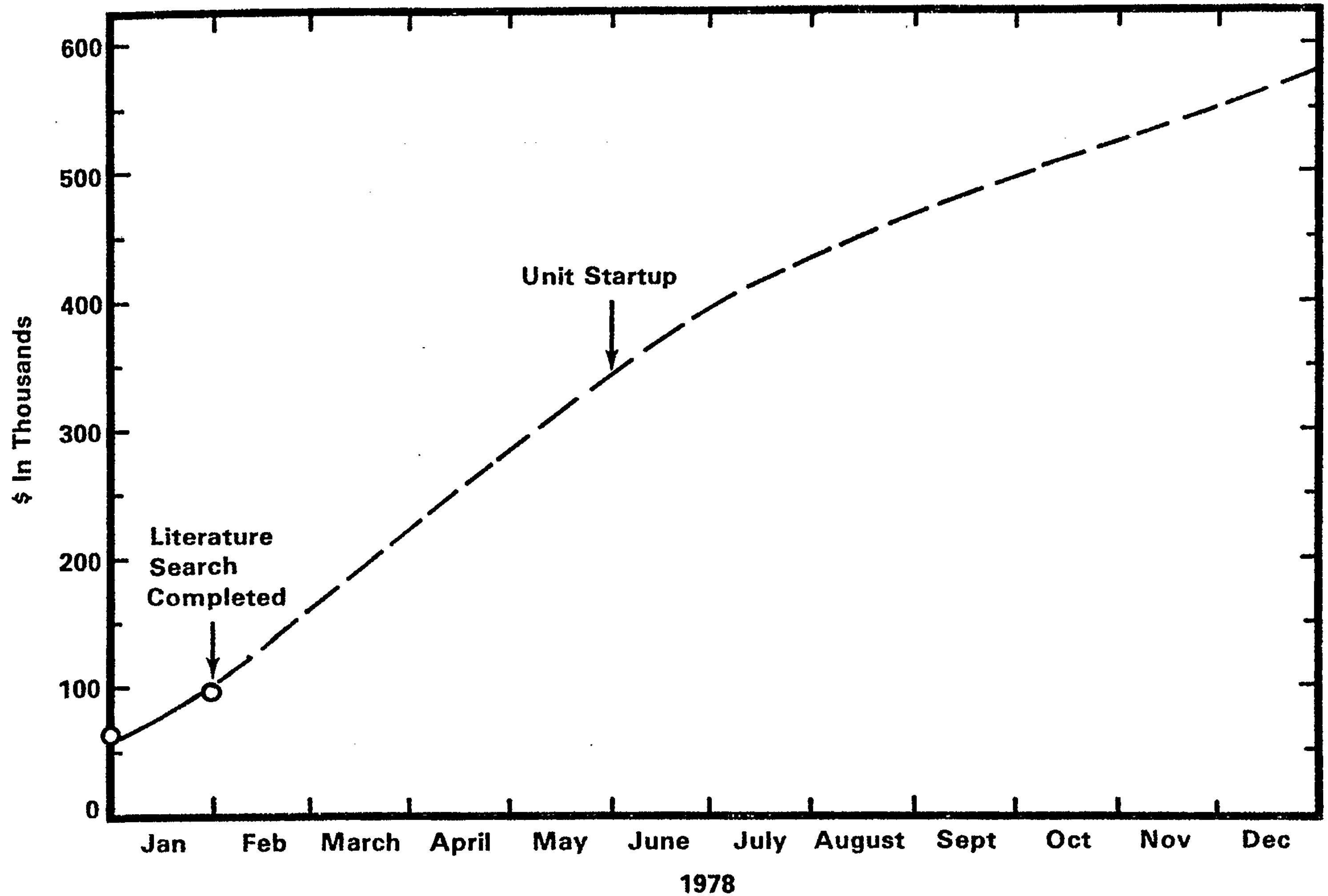


Figure 4

Cost Projections



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