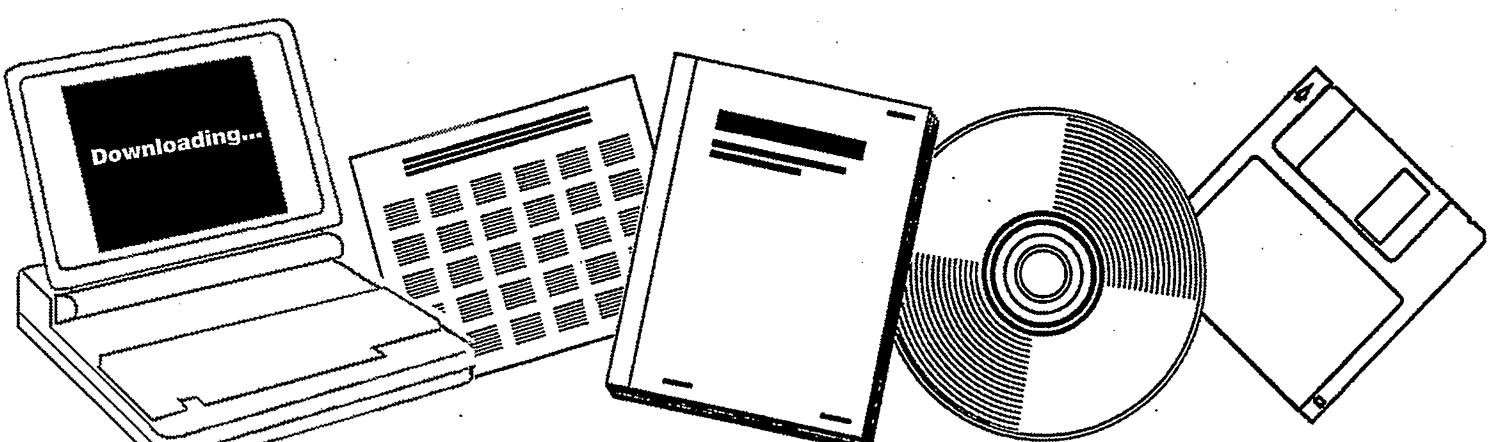
STUDY OF EBULLATED BED FLUID DYNAMICS FOR H-COAL. MONTHLY PROGRESS REPORT NO. 4, DECEMBER 1--DECEMBER 31, 1977

AMOCO RESEARCH CENTER, NAPERVILLE, IL.
RESEARCH AND DEVELOPMENT DEPT

JAN 1978



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MASTER

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MONTHLY PROGRESS REPORT NO. 4
DECEMBER 1-DECEMBER 31, 1977

BY

I. A. VASALOS, E. M. BILD, T. D. EVANS, D. F. TATTERSON,
A. P. VANDER KLAY, AND C. C. WALLIN

DATE PUBLISHED: JANUARY, 1978

CONTRACT EF-77-C-01-2588

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PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY
UNDER CONTRACT EF-77-C-01-2588

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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 monthly progress report is to outline progress in the first three parts during the fourth month of the project.

SUMMARY

Review of Prior Work

The literature search was completed by the end of the month. Summary and conclusions are reported in this monthly progress report. A final report will be issued by March 1, 1978.

Unit Construction

Major emphasis was placed on ordering most of the equipment. Some effort was also devoted to testing critical instruments. Shop construction of reactor pieces is proceeding well. Construction of the support structure started on 12/15. Completion is expected by 1/15/78. During the next month emphasis will be placed on advancing the systems design, completing construction of the reactor pieces, and continuing evaluation of instruments as they arrive.

REVIEW OF PRIOR WORK

Work on this part of the project was completed by the end of the month. A report is under preparation. It is the objective of the next month to prepare a final draft which will be issued by March 1, 1978. Because this report will be issued soon, only the summary and conclusions of the literature search are reported below.

Summary and Conclusions

The area of gas-liquid-solid fluidization has been one of increasing research in recent years. Much of this research has been stimulated by industrial applications of ebullating bed reactors, such as the H-oil, H-coal, and Hy-C processes.

Many important contributions to a greater understanding of three-phase fluidization have been made. A large volume of data on bed expansion over a wide range of flow conditions has been generated. Other experiments have aimed at elucidating the interaction between the gas, liquid, and solid phases in the bed. Particle size effects on bubble coalescence and bubble breakup have been observed. Attempts to quantify the effects of bed expansion on the effective viscosity of the bed have been made. The existence of two possible gas-liquid flow regimes in the bed and the importance of particle size and concentration on these flow regimes has been recognized. Two mechanisms have been suggested to explain bed contraction upon the addition of gas. The expansion data plus the information on various phase interactions have been the basis for several significant models which provide formats for correlating three-phase data. The importance of the corresponding liquid-solid and gas-liquid systems has been recognized by some of these models. Validation and modification of these models provide the best basis for future design and control of ebullating bed reactors.

However, many of the studies have their limitations. Many of the experiments were carried out in small-scale equipment. Thus, wall effects may have dominated the flow situation to the point where only the slug flow regime could exist. Much of the data is also limited to fluidization of spherical particles by air and water. Often investigation measured only the solids holdup. In analyzing their data, many investigators did not recognize the importance of the corresponding two-phase systems of gas-liquid and liquid-solid.

This review has suggested several means of further research of value to the H-coal project. Experimentally, more simultaneous measurements of the individual phase holdups, bubble size, and bubble velocity need to be taken. These experiments should be carried out in large-diameter equipment for various liquids and gas covering a wide range of physical properties. The effect of particle shape on bed behavior needs to be determined in both liquid-solid and gas-liquid-solid systems. All of these experiments need to be repeated using slurries to fluidize the bed, rather than liquids.

These data should be used to test and modify existing models and extend their application to slurry systems. Specific problems in the area of model development which should be explored are as follows. Better methods of predicting bubble sizes in fluidized beds are needed. This will allow better prediction of the gas-liquid flow regime in the bed. Better confirmation of the models describing the gas-liquid flow regime in the bed is needed. The correlations for wake size in three-phase systems should be extended to include fluid and particle properties. Finally, the bed contraction criteria proposed separately by Darton and Harrison and by Epstein should be tested.

CONSTRUCTION OF COLD FLOW UNIT AND DATA COLLECTION

Emphasis on various aspects of design and construction of the unit continued this month. Detailed progress in each area includes the following:

Systems Design

Recognizing that the most critical factor for completing the construction of the unit by May 1 is equipment availability, large effort was devoted to ordering equipment. Progress on equipment procurement is reported in Table I. Where possible, costs are also reported.

Laboratory tests were also conducted to evaluate a flow meter (Micromotion) for measuring recycle slurry flow. Since studies by HRI have shown that up to 12 vol% gas may be contained in the recycle steam, these tests are necessary to establish the capability of this instrument with the presence of gas.

In another bench-scale experiment, an in-house gamma-ray system is used to establish the validity of the gamma-ray technique for measuring differences in catalyst densities for the fluid dynamics studies. A system supplied by Harshaw is being considered. Since it is believed that drift or gain in the electronic system can be a problem, experiments are being performed to validate the use of the Harshaw system for this study.

A computer system was also selected during the month. The computer will be purchased by Amoco. However, peripheral hardware and software costs directly applicable to this study will be paid by this contract.

Although the systems design drawing did not proceed to a great extent, another phase of planning proceeded this month. Table II shows a detailed scheduling of the manpower required for unit construction.

Mechanical Design

Shop construction of the various reactor sections started. The construction of the reactor inlet distributor section (Figure 1) proceeded during the month. Work on the reactor spool piece and differential taps (Figure 2) also started. A design of a sample valve was also developed. The design of this valve is shown in Figure 3. Sample valves located in the spool pieces will be used to obtain a gas-liquid-solid-fines sample. Although obtaining a representative gas composition will not be possible, this sampling system will establish the concentration of solids and fines in the liquid slurry along the reactor.

Field Construction

Construction of the support structure started on December 15. Completion of this phase of work is expected by the middle of January.

Future Plans

During the next month the following are planned:

1) Prepare semi-final systems design drawings.
2) Complete fabrication of reactor spool pieces and distributor plate.
3) Complete steel structure.
4) Begin initial piping on the unit.
5) Continue pretesting of system components.
6) Start shop construction of recycle cup.
7) Continue evaluation of γ-ray system to determine holdup in fluidized bed.

TABLE I

EQUIPMENT PROCUREMENT SCHEDULE

Item	Description	Cost	Status
1) Structure	15' x 15' x 30' high. All steel with four platform levels.	Will be paid by Amoco Oil.	Completed by 1/15/78.
2) Vessels			
a) Glass Reactor	Made of four 5' glass pipe sections connected with spool pieces and flanges. Reactor is made of following parts:		
	--Recycle cup (HRI design)		Materials ordered.
	--Bubble cup distributor		In shop.
	--Reactor Corning glass and flange		On order.
	--Spool piece and sample valve		In shop.
b) Feed Tank	100-gallon capacity made of 304 SS. Felker Brothers Manufacturing Company.	$825	On order.
c) Slurry Preparation Tank	60-gallon capacity made of 304 SS. Felker Brothers.	$790	On order.
d) Gas-Liquid Separator	60-gallon capacity made of 304 SS. Felker Brothers.	$715	On order.
e) Gas Saturator	Three stages, multi-stage sparger.	$1000	In progress.
f) Drums for Handling Materials	55-gallon drums.	$500	Available in stockroom.
3) Gas Compressor	Piston reciprocating, manufactured by Corken (3.6 SCFM at 15 psig).	$3623	To be obtained by 1/9/78.
4) Pumps	--March Magnetic Drive (two needed).	$3000	On order.
	--Transfer Pump, Lincoln	$70	Available in stockroom.

(Table Continued)

TABLE I

EQUIPMENT PROCUREMENT SCHEDULE

-2-

Item	Description	Cost	Status
5) Process Piping and Valving	--Pipe, tubing, fittings	$4000	To be ordered as needed.
	--Valves	$4000	" "
	--Check and relief valves	$4000	To be ordered by 1/15/78.
6) Utilities	Electric power to site	$5000	Work to start by 1/15/78.
	100 psi air	$1200	" "
	Cold water and drain	$1500	" "
7) Instrumentation	Total distributive controller Honeywell TDC 2000.	Available by Amoco	On site.
a) Pressure Drop	--Pressure differential (DP) transmitters manufactured by Bournes (8 at $677 each)	$5416	On order.
	--Gould recorder	$7500	On order.
	--Two Texas Instruments recorders ($3570 each)	$7140	On order.
	--Pressure regulator	$130	Available in stockroom.
	--Vutronic DP cells (two)	$1300	On order.
b) Level Detector and Controller Separator	--Flow control valve	$375	On order.
	--Magnetrol Capacitance probe and relay	$1200	On order.
	--Worchester bypass ball valve with actuator	$250	On order.
c) Level Instrumentation (Feed Tank)	--Vutronic DP cell	$650	On order.
	--Flow control valve	$375	On order.
d) Flow Control	--Fresh feed, Nusonic flow transmitter, in-line sonic meter	$650	On order.
	--Recycle, Micromotion 1/2" with digital readout	$3000	Under evaluation.
	--Honeywell integral orifice	$1000	To be ordered.
	--Three control valves	$1150	To be ordered.
	--Load cell	Available by Amoco	
e) Concentration Analyzer	Nusonic Model 5180	$5000	Under evaluation.
f) Heat Exchangers	Single pass, 39 ft^2, manufactured by Norman Engineering (two)	$1000	To be ordered

(Table Continued)

TABLE I

EQUIPMENT PROCUREMENT SCHEDULE

-3-

Item	Description	Cost	Status
g) γ-Ray Scan System	Harshaw detector, amplifier, analyzer, counter, K-ray source.	$1000	To be ordered.
h) Thermometry	--Multi-point temperature recorder	$2098	To be ordered.
	--Temperature indicator	$400	On order.
i) Alarm Station	Monotronics 700 12-point	$800	To be ordered.
8) Control Cabinets		$1179	On site.
9) Computerization	--ModComp computer system (single disk)	To be paid by Amoco	To be ordered.
	--ADC system, Midland	$5526	On order.
	--MCR system (15 inputs)	$2697	On order.
	--Tectronics plotter (includes software driver)	$4320	On order.
	--Decwriter keyboard typer	$1850	On order.
	--Hardware assembled in house	$3900	On order

IAV/ml
1/9/78

TABLE II

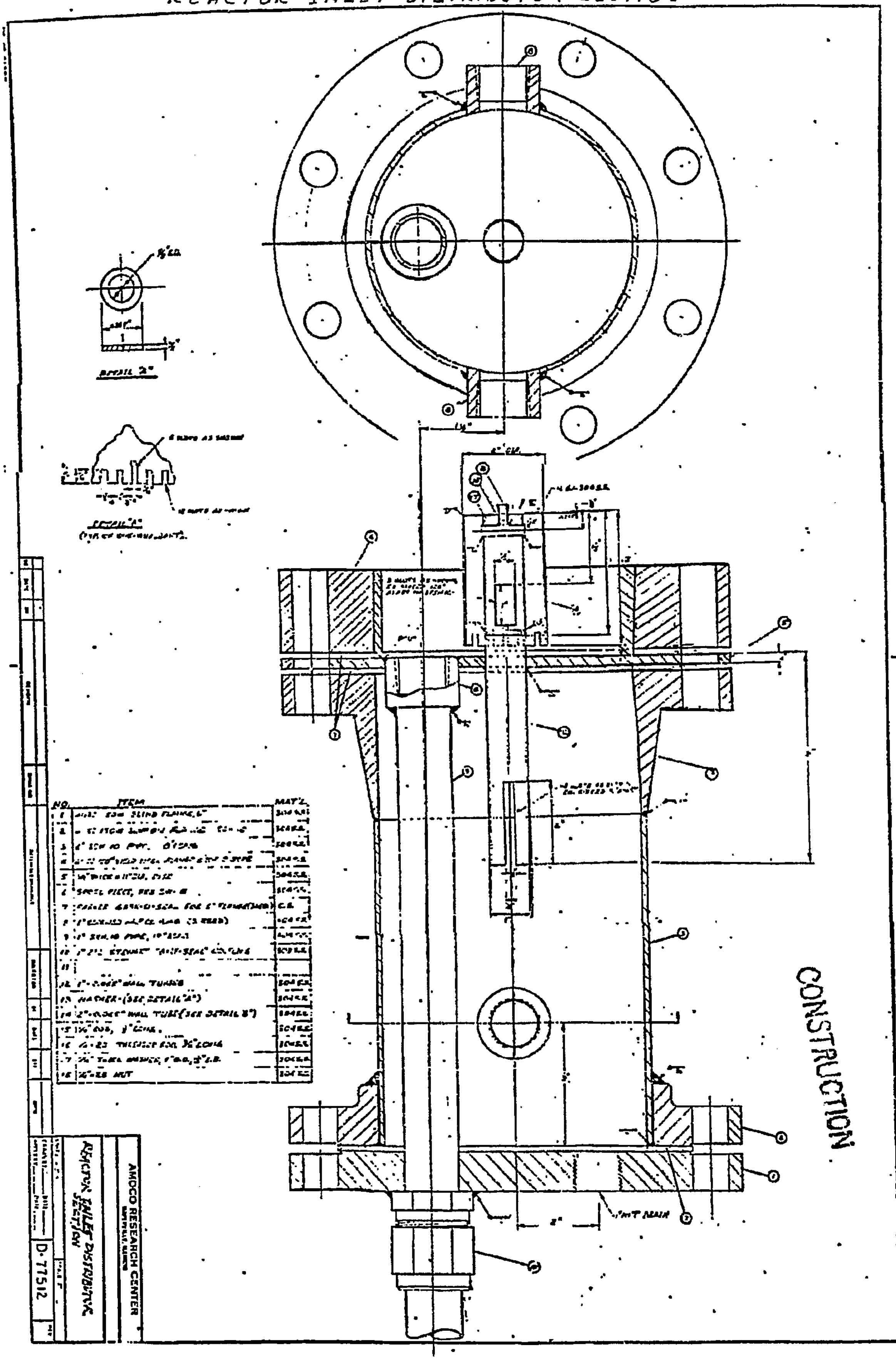
H-COAL HYDRODYNAMICS PILOT PLANT AU-77H
MANPOWER DISTRIBUTION AND SCHEDULING

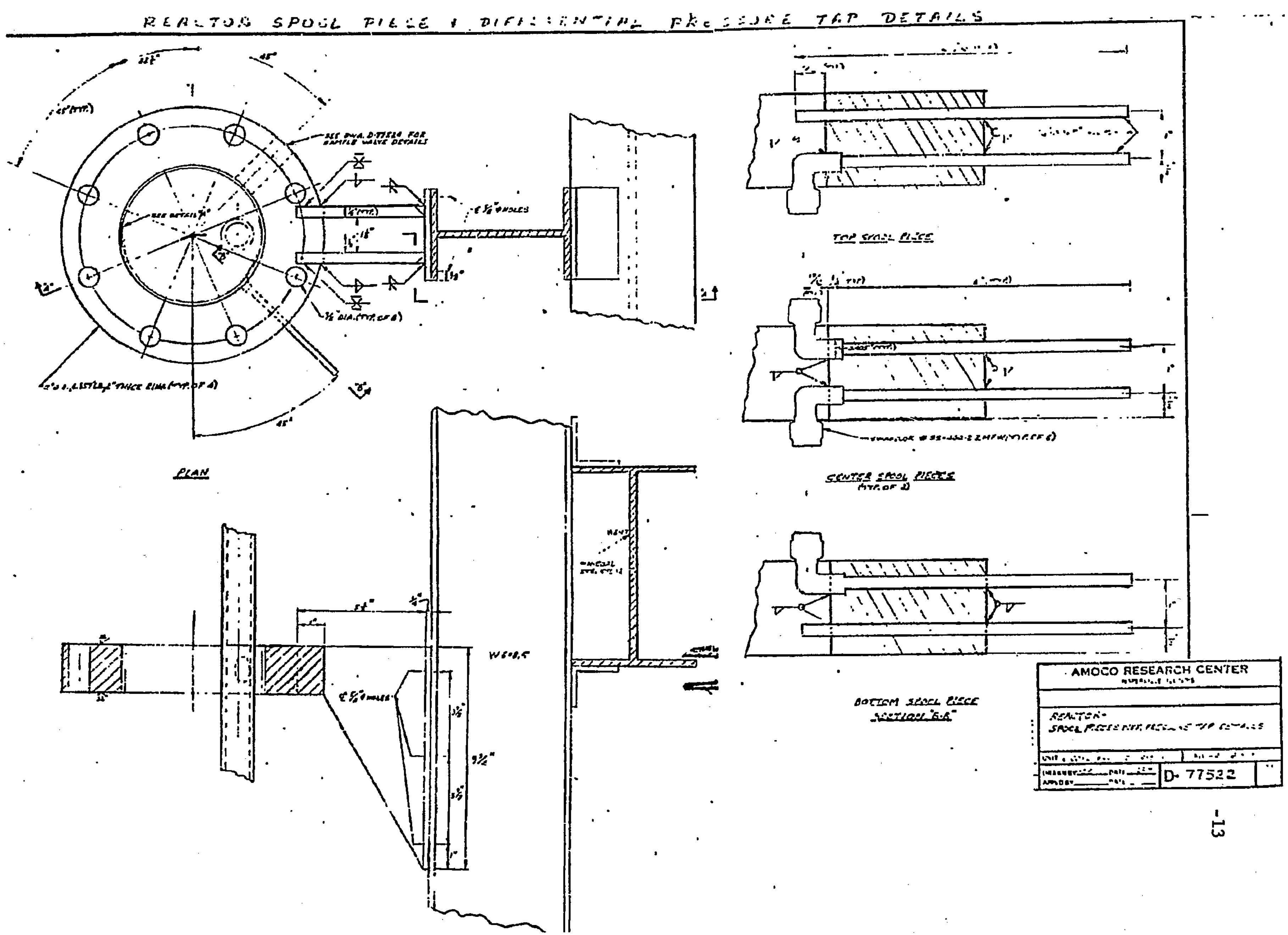
Craftsmen	Tot Man-Weeks	1977 Nov.	1977 Dec.	1978 Jan.	1978 Feb.	1978 Mar.	1978 Apr.	1978 May	1978 June
Shop Construction	30								
Welder	3	1	1	1	-	-	-	-	-
Machinist	15	2	4	6	2	1	-	-	-
Instr/Elec Tech	8	-	1	3	3	1	-	-	-
Pipefitter	4	-	2	2	-	-	-	-	-
Field Construction	112								
Structure[A]	--								
Welder	3	-	-	1	1	1	-	-	-
Pipefitter	44	-	4	6	12	12	10	-	-
Electrician	40	-	6	4	8	10	12	-	-
Sheet Metal	4	-	1	1	1	1	-	-	-
Instr/Elec Tech	20	-	1	1	6	6	6	-	-
Insulator	1	-	-	-	-	-	1	-	-
Design									
Process[B]									
Mechanical[C]	9	3	5	1	-	-	-	-	-
Systems[D]	43	1	6	8	6	6	6	6	4
Construction Guidance/Shakedown									
Process Engr.	0.6	-	-	-	0.2	0.2	0.2	-	-
Mechanical Engr.	3	-	-	1	1	1	-	-	-
Systems Engr.	9	-	-	-	1	4	4	-	-

A. Structure Installation 12/15/77 to 1/15/78.
B. Process Design Finalized.
C. Includes 1 man-week non-pro per month.
D. Includes 50% non-pro per month.

SES/IAV/APVK/sgj
11/8/77

Figure 1
REACTOR INLET DISTRIBUTOR SECTION

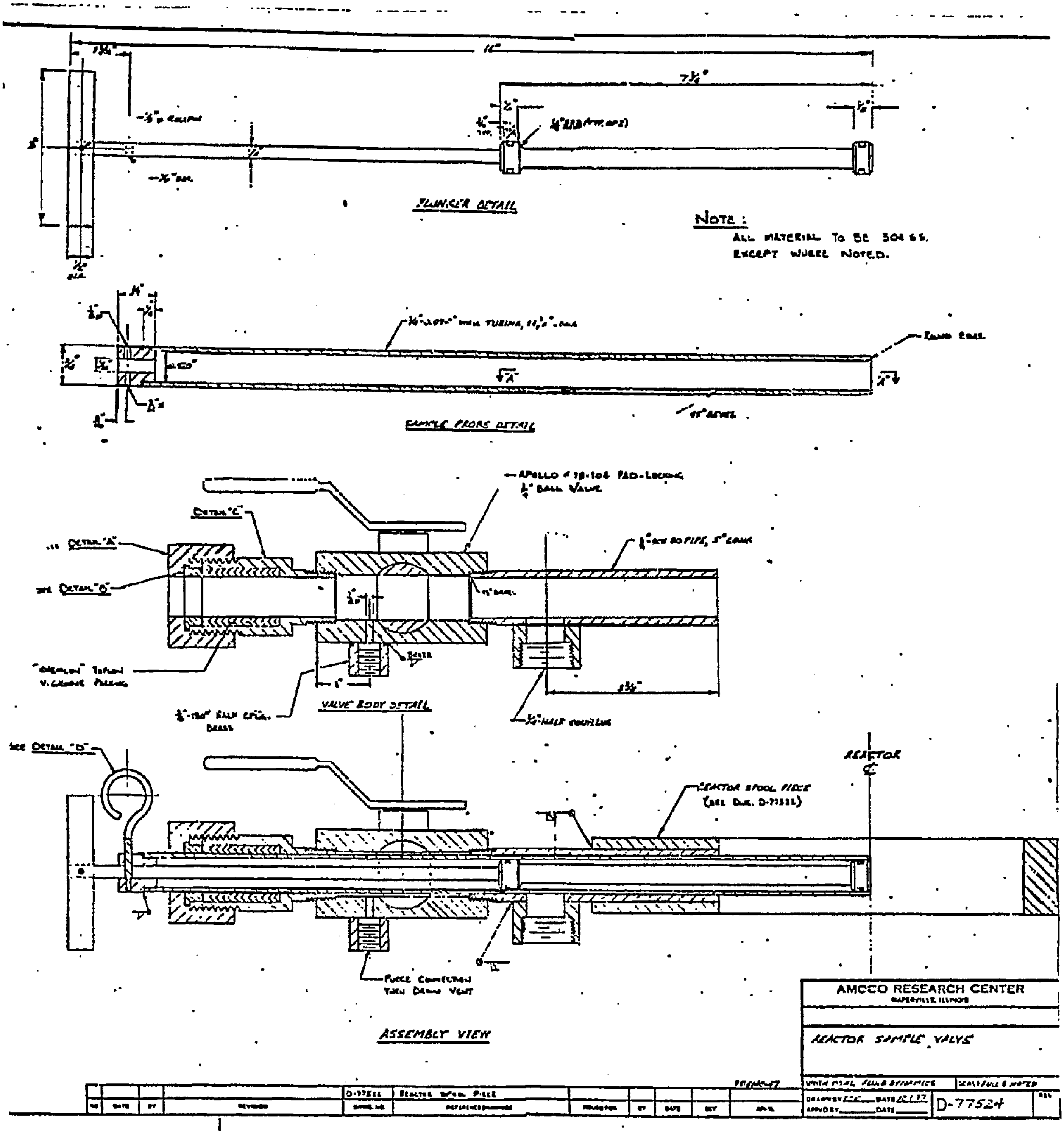



REACTOR SPOOL PIECE & DIFFERENTIAL PRESSURE TAP DETAILS
PLAN
TOP SPOOL PIECE
CENTER SPOOL PIECES
(TYP. OF 2)
BOTTOM SPOOL PIECE
SECTION "B-B"
AMOCO RESEARCH CENTER
D- 77522

-13

Figure 3

Reactor Sample Valve



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