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STUDY OF EBULLATED-BED FLUID DYNAMICS FOR H-COAL. QUARTERLY PROGRESS REPORT NO. 2, OCTOBER 1-DECEMBER 31, 1980

AMOCO OIL CO., NAPERVILLE, IL. RESEARCH
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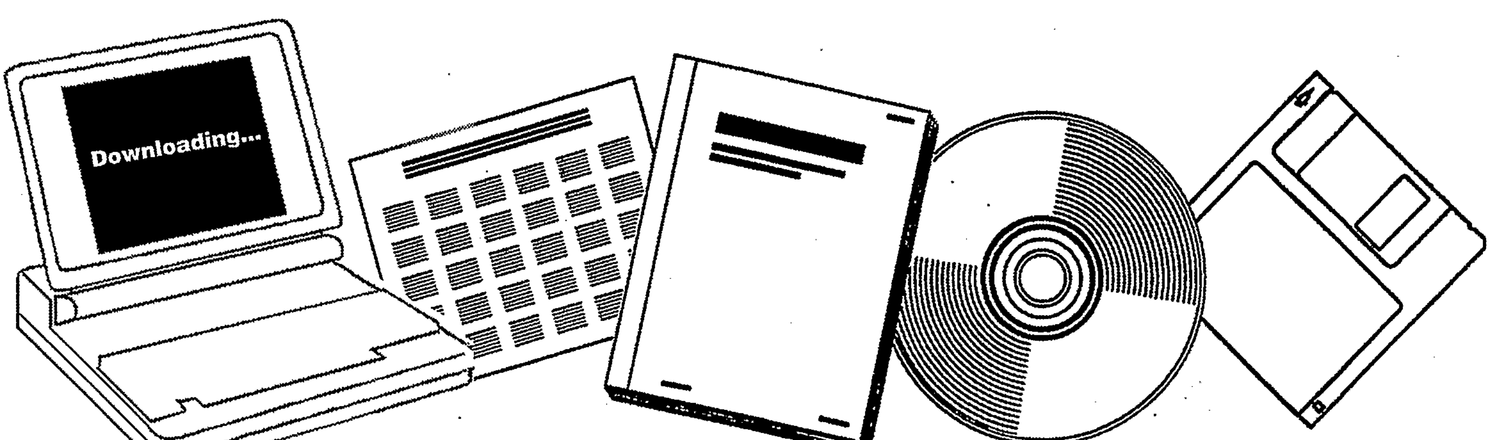

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STUDY OF EBULLATED BED FLUID DYNAMICS FOR H-COAL

QUARTERLY PROGRESS REPORT NO. 2
OCTOBER 1, 1980-DECEMBER 31, 1980

R. J. SCHAEFER, D. N. RUNDELL

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Research and Development Department
Amoco Oil Company
P. O. Box 400
Naperville, Illinois
60566

TABLE OF CONTENTS

TABLE OF CONTENTS
-2-

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 operated next to the Ashland Oil, Incorporated, refinery at Catlettsburg, Kentucky, under DOE 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. One objective of this program is to apply the results of prior cold flow model experiments (2) to the operating H-Coal PDU reactor in Trenton, New Jersey. Studies are also planned to examine the coalescence behavior of gas bubbles in three-phase ebullated beds.

The work to be performed is divided into four parts: fluid dynamics measurements on the PDU reactor, gas bubble coalescence studies at Northwestern University, cold flow and mixing tests at Amoco's Naperville Research Center, and model implementation. The objective of this quarterly progress report is to outline progress in the first three areas.

SUMMARY

Analysis of data from the fluid dynamics tests performed at Hydrocarbon Research, Inc., during Run PDU-10 was started. Data in the computer files were cross-checked with the original notebooks to verify accuracy. Gamma-ray mass absorption coefficients for material in the PDU reactor were calculated using characterization of selected oil and catalyst samples.

Battelle Institute began viscosity measurement of PDU reactor liquid samples.

Northwestern University began shakedown of the 6" diameter test stand. Model fluids were selected and charged to the unit. Optical components were designed and assembly was started.

A paper, "Application of a Bhatia-Epstein Model to the H-Coal Three-Phase Fluidized Bed Reactor," was presented at the 73rd Annual AIChE Meeting in Chicago on November 18, 1980.

INTRODUCTION

The fluid dynamics of the H-Coal reactor have been previously studied in a cold flow unit. Reference 2 provides details of the construction of the unit and results of tests with a variety of gases, liquids, and catalyst sizes. A semi-theoretical model was developed to predict the volume fractions occupied by the gas, liquid, and catalyst phases. The aims of this new contract are fourfold:

1) The model developed using cold flow unit test results will be extended to apply to the operating H-Coal PDU reactor.

2) Because gas bubble dynamics are crucial in determining the nature of the flow, studies of bubble flow will be performed at Northwestern University using optically clear beds.

3) Liquid mixing tests will determine the residence time distribution of liquid in the reactor. Under the previous contract, it was determined that the coal char fines (simulating the unreacted coal and ash) were uniformly distributed throughout the bed. Hence, the measurement of liquid data is essential for modeling the residence time and kinetic parameters associated with the unreacted coal.

4) The model will be implemented into a readily usable format.

DATA COLLECTION

HRI PDU Fluid Dynamics Study

Gamma-Ray Calibration.--The first calibration measurement performed was on 7/11/80. Prior to the PDU run, the reactor traverse scanner was calibrated so that the recorder chart in the control room would span the range of 40 to 60 lb/ft^3 average reactor density. To simulate the material in the reactor, steel plates of varying thicknesses were placed in front of the 500 mc Cs-137 source. Measurement of the gamma-ray count rates under different conditions allows calculation of the mass absorption coefficient for the system.

Shutdown Oil Characterization.--HRI measured the specific gravity of the shutdown oil at several different temperatures which spanned the values observed during the shutdown scans (9/24/80 AM and PM, and 9/25/80).

Amocat I-A Catalyst Characterization.--The density of a sample of used Amocat I-A catalyst withdrawn from the PDU on 8/3/80 was measured.

Viscosity Measurement of PDU Reactor Liquid.--Battelle Institute received the 16 PDU liquid product samples and began viscosity measurements. Their progress report is reproduced in Appendix A.

Northwestern University Bubble Dynamics Study

Northwestern investigators began tests using a model fluid mixture of Dowanol DPM and diphenyl ether. A traversing support for the laser optics (to permit examination of the transparent bed at different elevations) was fabricated. An impedance probe was constructed. Appendix B contains a detailed progress report.

DATA ANALYSIS

HRI PDU Fluid Dynamics Study--Calculation of Mass Absorption Coefficients

Steel Plates.--For two thicknesses, L_1 and L_2, with corresponding intensities I_1 and I_2:

$$\ln I_1/I_o = -\alpha\rho L_1 \quad (1)$$

$$\ln I_2/I_o = -\alpha\rho L_2 \quad (2)$$

$$\therefore \ln I_1/I_2 = -\alpha\rho(L_1 - L_2) \quad (3)$$

$$\alpha = (\ln I_1/I_2)/(\rho[L_2 - L_1]) \quad (4)$$

Table I illustrates this calculation for the steel plate.

Shutdown Liquid.--Table II summarizes the conditions of the PDU for the three shutdown test scans. Average temperatures were obtained from HRI computer reports. Shutdown liquid density data, also obtained from HRI, are plotted in Figure 1.

From Equation 4, average mass absorption coefficients may be calculated. Results of these calculations appear in Table III. Because no clear catalyst bed interface could be seen using the gamma-ray scan data for 9/25/80, this point was excluded from the analysis. The data obtained on 9/24/80 PM (no gas flow) are considered the best for obtaining the liquid mass absorption coefficient; therefore, a value of 0.0271 ft^2/lbm was used for all the test density computations.

Catalyst.--Gamma-ray absorption in the catalyst bed for the 9/24/80 PM test may be used to calculate the catalyst mass absorption coefficient.

In the catalyst bed:

$$-(\ln I/I_o)/L = \rho_L \varepsilon_L \alpha_L + \rho_c \varepsilon_c \alpha_c \qquad (5)$$

Using liquid and catalyst properties obtained from Amoco tests and other published reports (1), the catalyst mass absorption coefficient was found to be 0.0240 ft^2/lbm. The calculation is detailed in Table IV.

Tables V to XX present the individual test data at various elevations. Average densities at each height are calculated by the relation:

$$\rho = (-\ln I/I_o)/(\alpha L) \qquad (6)$$

where an overall mass absorption coefficient of 0.0271 ft^2/lbm was assumed. The ratios R1, R2, and R3 are included in the tables. They may be used later for consistency checks. Density versus elevation profiles appear in Figures 2 through 9. The break points in these profiles were used to obtain expanded catalyst bed heights.

Discussion

The mass absorption coefficients for the HRI PDU calculated in this report are significantly lower than those noted in earlier experiments at Amoco (2). This may be attributed to differences in the construction of the two detector systems. At HRI, the gamma-ray beam must penetrate the steel walls of the PDU; to obtain an adequate signal, the source and detector are not collimated. The beam in the Amoco Pilot plant is strongly collimated by lead shielding. The broad beam attenuation under the conditions at the PDU would be directionally less; therefore, the lower absorption coefficients are judged correct. Qualitatively, the lower catalyst coefficient would also be expected from the lower percentage of hydrogen associated with the catalyst.

Work has been previously performed at ORNL (3) to measure the viscosity, density, and other physical properties of coal liquid slurries. ORNL also uses a gamma-ray apparatus to measure slurry density at process conditions. Several compounds of variable hydrogen content were tested; however, the mass absorption coefficient remained constant. Samples of SRC recycle solvent supplied by ORNL and anthracene will be tested by Amoco, along with the HRI feed slurries, to ascertain if materials in the PDU reactor may be similarly characterized by a single mass absorption coefficient. If this characterization is possible, the analysis of the PDU data will be simplified.

Before the analysis is complete, further fluid dynamics tests will be performed using the catalyst in the Amoco pilot plant. Other Amoco programs have studied the settling patterns of catalyst in a liquid-filled column. In some situations, the catalyst may not settle in the manner that dry, agitated catalyst does. Therefore, the dry bulk density and particle density may not accurately predict the settled volume fraction of catalyst in the reactor. Additionally, the data for this report were obtained for catalyst withdrawn early in the PDU run. Tests will therefore be performed using aged catalyst, which is more representative of material present in the PDU during the fluid dynamics tests.

PLANS FOR NEXT PERIOD

Task 1: H-Coal PDU Reactor Fluid Dynamics

1) Complete analysis of HRI slurry mix tank, SRC recycle solvent, and anthracene samples.

2) Perform Amoco fluid dynamics tests with used catalyst.

3) Continue viscosity measurements at Battelle.

Task 2: Gas Bubble Dynamics (Northwestern University)

1) Continue assembly of optical components.

Task 3: Amoco Fluid Dynamics Tests

1) Begin planning for liquid mixing tests.

Task 4: User Model

1) No work is planned in this area.

REFERENCES

1) "Bench Scale Catalyst Evaluation Program," by E. S. Johanson and A. G. Comolli, Hydrocarbon Research, Inc., Report FE-2547-28, published December 1978.

2) "Study of Ebullated Bed Fluid Dynamics for H-Coal," by I. A. Vasalos, D. N. Rundell, and D. F. Tatterson, Monthly Progress Report No. 26, Contract EF-77-C-01-2588, published November, 1979.

3) "Fossil Energy Program," Quarterly Progress Report for the Period Ending September 30, 1979, Oak Ridge National Laboratory, Contract W-7405-eng-26, Report ORNL-5612, pp 14-33.

NOMENCLATURE

I	Gamma-ray beam intensity.
L	Length of material attenuating gamma rays, ft.
α	Mass absorption coefficient, ft^2/lb.
ρ	Density, lb/ft^3

Subscripts

0	Empty reactor.
1	Reactor, Operating Condition No. 1.
2	Reactor, Operating Condition No. 2.
c	Catalyst.
L	Liquid.
CO	Catalyst (settled).

TABLE I

STEEL PLATE CALIBRATION OF GAMMA-RAY APPARATUS, 7/11/80

I_1	1654 Counts/Sec
L_1	0.693" of Steel Plate
I_2	1221 Counts/Sec
L_2	0.947" of Steel Plate
ρ	490 lb/ft^3
$\therefore \alpha$	0.0293 ft^2/lbm from Equation 4

DNR/ml
1/15/81

TABLE II

HRI PDU SHUTDOWN CONDITIONS

Amoco Scan Test ID	Date	Start Time	Stop Time	Average Reactor Temp, ^{O}F	Comments
924AM	9/24/80	1:26 PM	2:12 PM	$262^{O}F$	Some flushing oil and N_2 flow.
924PM	9/24/80	7:06 PM	7:52 PM	$203^{O}F$	No gas flow.
925AM	9/25/80	10:22 AM	11:08 AM	$110^{O}F$	No gas flow.

DNR/ml
1/15/81

TABLE III

CALCULATION OF OIL MASS ABSORPTION COEFFICIENT

Amoco Test ID	Average Liquid Temp, °F	Liquid Density, g/cc (1)	I/I_o	α Ft^2/lbm (2)
924AM	262	1.058	0.3013 (3)	0.0256
924PM	203	1.080	0.2743 (4)	0.0271

(1) See Figure 1 for variation of density with temperature.

(2) Calculated from Equation 4, correcting for proper units.

(3) Average between 10.01' and 11.54' elevation. See Table XIX.

(4) Average between 9.49' and 11.55' elevation. See Table XX.

DNR/ml
1/15/81

TABLE IV

CALCULATION OF CATALYST MASS ABSORPTION COEFFICIENT

Variable	Value	Reference
I/I_o	0.221	Table XX; 9/24/80 PM, 5.59' elevation.
L	8.5"	--
ε_c	0.6019	*
ε_L	0.3981	$(1 - \varepsilon_c)$
α_L	0.0271 ft^2/lb	Table III
ρ_L	67.5 lb/ft^3	Table III
ρ_c	97 lb/ft^3	Amoco tests
α_c	0.0240 ft^2/lb	Equation 5

*Calculated using ρ_P = 1.186 g/cc, ρ_B = 0.714 g/cc (Reference 1).

DNR/ml
1/15/81

TABLE V

PDU FLUID DYNAMIC DATA, 7/30/80

DATE	07-30-80
HRI PERIOD	04A
SLURRY FEED LB/HR	822.
RECYCLE . GPM/FT2	47.1
H2 FEED GAS, SCFH	3280.
RECYCLE GAS, SCFH	4178.
BED HEIGHT, FT	13.38

ELEV. FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.17	588.10	2538.01	0.232	76.2	0.824	0.966	0.796
3.67	562.67	2438.64	0.231	76.4	0.788	1.005	0.792
4.17	309.42	1202.73	0.257	70.7	0.433	2.039	0.883
4.50	542.35	2511.25	0.216	79.8	0.759	0.976	0.742
5.08	650.88	2208.21	0.295	63.6	0.911	1.110	1.012
5.58	644.47	2360.40	0.273	67.6	0.902	1.039	0.937
6.08	736.88	2540.70	0.290	64.5	1.032	0.965	0.996
6.58	500.40	2132.77	0.235	75.5	0.701	1.150	0.806
7.17	715.58	2525.52	0.283	65.7	1.002	0.971	0.973
7.67	703.87	2549.74	0.276	67.1	0.986	0.962	0.948
8.17	698.39	2438.98	0.286	65.1	0.978	1.005	0.983
8.67	702.73	2381.20	0.295	63.6	0.984	1.030	1.013
9.00	701.42	2699.65	0.260	70.2	0.982	0.908	0.892
9.50	761.97	2400.55	0.317	59.8	1.067	1.021	1.090
10.00	714.12	2479.30	0.288	64.8	1.000	0.989	0.989
10.50	773.40	2434.95	0.318	59.7	1.083	1.007	1.091
11.00	797.58	2388.20	0.334	57.1	1.117	1.027	1.147
11.58	789.12	2470.06	0.319	59.4	1.105	0.993	1.097
12.08	818.23	2533.45	0.323	58.9	1.146	0.968	1.109
12.58	818.97	2453.65	0.334	57.2	1.147	0.999	1.146
13.08	787.52	2678.29	0.294	63.8	1.103	0.915	1.010
13.67	1124.93	2580.81	0.436	43.3	1.575	0.950	1.497
14.17	1085.45	2747.64	0.395	48.4	1.520	0.892	1.356
14.67	1099.58	2958.71	0.372	51.6	1.540	0.829	1.276
14.67	1102.12	2958.71	0.372	51.4	1.543	0.829	1.279

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE VI

PDU FLUID DYNAMIC DATA, 8/5/80

DATE	08-05-80
HRI PERIOD	10A
SLURRY FEED LB/HR	809.
RECYCLE , GPM/FT2	16.5
H2 FEED GAS, SCFH	3485.
RECYCLE GAS, SCFH	4171.
BED HEIGHT, FT	12.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.17	595.78	2538.01	0.235	75.5	0.789	0.966	0.762
3.67	570.17	2438.64	0.234	75.7	0.755	1.005	0.759
4.17	273.88	1202.73	0.228	77.1	0.363	2.039	0.739
4.50	492.57	2511.25	0.196	84.9	0.652	0.976	0.637
5.08	650.77	2208.21	0.295	63.6	0.862	1.110	0.957
6.08	713.98	2540.70	0.281	66.1	0.945	0.965	0.912
6.58	495.47	2132.77	0.232	76.0	0.656	1.150	0.754
7.17	695.97	2525.52	0.276	67.1	0.922	0.971	0.895
7.67	704.45	2549.74	0.276	67.0	0.933	0.962	0.897
8.17	690.82	2438.98	0.283	65.7	0.915	1.005	0.920
8.67	687.13	2381.20	0.289	64.7	0.910	1.030	0.937
9.00	746.40	2699.65	0.276	67.0	0.988	0.908	0.898
9.50	701.60	2400.55	0.292	64.1	0.929	1.021	0.949
10.00	755.23	2479.30	0.305	61.9	1.000	0.989	0.989
10.50	764.20	2434.95	0.314	60.4	1.012	1.007	1.019
11.00	762.52	2388.20	0.319	59.5	1.010	1.027	1.037
11.58	769.12	2470.06	0.311	60.8	1.018	0.993	1.011
12.08	779.48	2533.45	0.308	61.4	1.032	0.968	0.999
12.58	974.95	2453.65	0.397	48.1	1.291	0.999	1.290
13.08	1071.85	2678.29	0.400	47.7	1.419	0.915	1.299
13.67	1042.83	2580.81	0.404	47.2	1.381	0.950	1.312
14.17	1052.57	2747.64	0.383	50.0	1.394	0.892	1.244
14.67	1065.25	2958.71	0.360	53.2	1.410	0.829	1.169

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2.

TABLE VII

PDU FLUID DYNAMIC DATA, 9/4/80

DATE	09-04-80
HRI PERIOD	27A
SLURRY FEED LB/HR	606.
RECYCLE , GPM/FT2	35.9
H2 FEED GAS, SCFH	2949.
RECYCLE GAS, SCFH	4330.
BED HEIGHT, FT	12.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/IO	DENSITY LB/FT3	R1	R2	R3
3.17	554.60	2538.01	0.219	79.2	0.621	0.966	0.600
3.67	691.42	2438.64	0.284	65.7	0.775	1.005	0.779
4.17	377.38	1202.73	0.314	60.4	0.423	2.039	0.862
4.50	793.27	2511.25	0.316	60.0	0.889	0.976	0.868
5.08	854.63	2208.21	0.387	49.5	0.957	1.110	1.063
5.58	822.22	2360.40	0.348	54.9	0.921	1.039	0.957
6.08	930.75	2540.70	0.366	52.3	1.043	0.965	1.006
6.58	857.75	2132.77	0.402	47.5	0.961	1.150	1.105
6.83	892.78	2316.39	0.385	49.7	1.000	1.059	1.059
7.17	886.85	2525.52	0.351	54.5	0.994	0.971	0.965
7.67	863.62	2549.74	0.339	56.4	0.967	0.962	0.930
8.17	892.38	2438.98	0.366	52.4	1.000	1.005	1.005
8.67	894.42	2381.20	0.376	51.0	1.002	1.030	1.032
9.00	901.27	2699.65	0.334	57.2	1.010	0.908	0.917
9.50	832.32	2400.55	0.347	55.2	0.932	1.021	0.952
10.00	892.63	2479.30	0.360	53.2	1.000	0.989	0.989
10.50	859.05	2434.95	0.353	54.3	0.962	1.007	0.969
11.00	817.62	2388.20	0.342	55.8	0.916	1.027	0.940
11.58	796.32	2470.06	0.322	59.0	0.892	0.993	0.886
12.08	740.30	2533.45	0.292	64.1	0.829	0.968	0.803
12.58	900.16	2453.65	0.367	52.2	1.008	0.999	1.008
13.08	1031.00	2678.29	0.385	49.7	1.155	0.915	1.057
13.67	1039.60	2580.81	0.403	47.4	1.165	0.950	1.106
14.17	1073.27	2747.64	0.391	49.0	1.202	0.892	1.073
14.67	1053.50	2958.71	0.356	53.8	1.180	0.829	0.978

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE VIII

PDU FLUID DYNAMIC DATA, 9/11/80

DATE	09-11-80
HRI PERIOD	34A
SLURRY FEED LB/HR	621.
RECYCLE , GPM/FT2	18.5
H2 FEED GAS, SCFH	2935.
RECYCLE GAS, SCFH	4389.
BED HEIGHT, FT	12.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.17	597.05	2538.01	0.235	75.4	0.689	0.966	0.666
3.67	700.52	2438.64	0.287	65.0	0.809	1.005	0.813
4.17	387.57	1202.73	0.322	59.0	0.447	2.039	0.912
4.50	782.40	2511.25	0.312	60.8	0.903	0.976	0.882
5.08	868.43	2208.21	0.393	48.6	1.002	1.110	1.113
5.58	840.12	2360.40	0.356	53.8	0.970	1.039	1.007
6.08	937.00	2540.70	0.369	52.0	1.081	0.965	1.044
6.58	876.72	2132.77	0.411	46.3	1.012	1.150	1.163
6.83	866.43	2316.39	0.374	51.2	1.000	1.059	1.059
7.17	904.72	2525.52	0.358	53.5	1.044	0.971	1.014
7.67	877.03	2549.74	0.344	55.6	1.012	0.962	0.973
8.17	874.37	2438.98	0.358	53.4	1.009	1.005	1.015
8.67	898.35	2381.20	0.377	50.8	1.037	1.030	1.068
9.00	879.22	2699.65	0.326	58.4	1.015	0.908	0.922
9.50	816.37	2400.55	0.340	56.2	0.942	1.021	0.962
10.00	866.43	2479.30	0.349	54.8	1.000	0.989	0.989
10.50	843.73	2434.95	0.347	55.2	0.974	1.007	0.981
11.00	787.37	2388.20	0.330	57.8	0.909	1.027	0.933
11.58	765.77	2470.06	0.310	61.0	0.884	0.993	0.877
12.08	765.27	2533.45	0.302	62.4	0.883	0.968	0.855
12.58	951.73	2453.65	0.388	49.3	1.098	0.999	1.098
13.08	1027.87	2678.29	0.384	49.9	1.186	0.915	1.086
13.67	1033.23	2580.81	0.400	47.7	1.193	0.950	1.133
14.17	1080.45	2747.64	0.393	48.6	1.247	0.892	1.113
14.67	1054.40	2958.71	0.356	53.8	1.217	0.829	1.009

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE IX

PDU FLUID DYNAMIC DATA, 9/19/80 AM

DATE	09-19-80AM
HRI PERIOD	418
SLURRY FEED LB/HR	699.
RECYCLE . GPM/FT2	41.5
H2 FEED GAS, SCFH	2850.
RECYCLE GAS, SCFH	4550.
BED HEIGHT, FT	12.58

ELEV. FT.	I-FLOW CPS	I-ZERO CPS	I/IO	DENSITY LB/FT3	R1	R2	R3
3.11	830.30	2488.02	0.334	57.2	0.712	0.986	0.702
3.65	946.25	2458.02	0.385	49.7	0.812	0.998	0.810
4.15	544.50	1204.24	0.452	41.3	0.467	2.036	0.951
4.52	1056.00	2496.72	0.423	44.8	0.906	0.982	0.889
5.07	1150.12	2201.06	0.523	33.8	0.986	1.114	1.099
5.59	1108.78	2360.58	0.470	39.4	0.951	1.039	0.988
6.09	1228.30	2540.72	0.483	37.9	1.053	0.965	1.017
6.61	1132.52	2069.50	0.547	31.4	0.971	1.185	1.151
7.12	1177.45	2528.29	0.466	39.8	1.010	0.970	0.979
7.68	1132.65	2549.62	0.444	42.3	0.971	0.962	0.934
8.15	1151.48	2440.57	0.472	39.1	0.988	1.005	0.992
8.69	1160.58	2428.57	0.478	38.5	0.995	1.010	1.005
8.98	1173.47	2702.61	0.434	43.5	1.006	0.907	0.913
9.48	1095.07	2418.19	0.453	41.3	0.939	1.014	0.952
10.00	1165.93	2479.30	0.470	39.3	1.000	0.989	0.989
10.52	1143.95	2432.94	0.470	39.3	0.981	1.008	0.989
11.02	1085.52	2385.98	0.455	41.0	0.931	1.028	0.957
11.55	1055.00	2481.86	0.425	44.6	0.905	0.988	0.894
12.07	1014.15	2533.73	0.400	47.7	0.870	0.968	0.842
12.59	1103.97	2456.65	0.449	41.7	0.947	0.998	0.945
13.10	1361.66	2675.51	0.509	35.2	1.168	0.916	1.070
13.73	1357.20	2601.79	0.522	33.9	1.164	0.942	1.097
14.15	1393.67	2742.07	0.508	35.3	1.195	0.894	1.069
14.69	1385.22	2968.57	0.467	39.7	1.188	0.826	0.981

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE X

PDU FLUID DYNAMIC DATA, 9/19/80 PM

DATE	09-19-80PM
HRI PERIOD	42A
SLURRY FEED LB/HR	644.
RECYCLE , GPM/FT2	29.5
H2 FEED GAS, SCFH	2900.
RECYCLE GAS, SCFH	4470.
BED HEIGHT, FT	10.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3	D
3.21	660.03	2505.48	0.263	69.5	0.716	0.979	0.701	
3.62	709.57	2492.92	0.285	65.5	0.770	0.984	0.757	
4.14	400.57	1205.14	0.332	57.4	0.435	2.035	0.884	
4.52	822.33	2496.72	0.329	57.9	0.892	0.982	0.876	
5.07	886.42	2201.06	0.403	47.4	0.962	1.114	1.071	
5.60	849.98	2360.85	0.360	53.2	0.922	1.039	0.958	
6.11	976.38	2540.79	0.384	49.8	1.059	0.965	1.022	
6.62	897.98	2045.77	0.439	42.9	0.974	1.199	1.167	
7.13	935.87	2527.69	0.370	51.8	1.015	0.970	0.985	
7.67	919.08	2549.87	0.360	53.2	0.997	0.962	0.959	
8.16	946.77	2439.62	0.388	49.3	1.027	1.005	1.032	
8.69	943.20	2428.57	0.388	49.3	1.023	1.010	1.033	
8.97	947.28	2704.09	0.350	54.6	1.028	0.907	0.932	
9.49	874.47	2409.37	0.363	52.8	0.949	1.018	0.965	
10.02	921.90	2473.05	0.373	51.4	1.000	0.991	0.991	
10.54	1380.82	2430.93	0.568	29.5	1.498	1.009	1.511	
11.04	1305.35	2383.77	0.548	31.4	1.416	1.029	1.456	
11.57	1266.22	2474.78	0.512	34.9	1.373	0.991	1.361	
12.09	1171.52	2533.31	0.462	40.2	1.271	0.968	1.230	
12.61	1111.37	2465.64	0.451	41.5	1.206	0.994	1.199	
13.10	1218.12	2675.51	0.455	41.0	1.321	0.916	1.211	
13.65	1205.12	2583.59	0.466	39.7	1.307	0.949	1.241	
14.15	1247.97	2742.07	0.455	41.0	1.354	0.894	1.210	
14.68	1201.53	2964.35	0.405	47.0	1.303	0.827	1.078	

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XI

PDU FLUID DYNAMIC DATA, 9/20/80 AM

DATE	09-20-80AM
HRI PERIOD	428
SLURRY FEED LB/HR	636.
RECYCLE , GPM/FT2	19.1
H2 FEED GAS, SCFH	2860.
RECYCLE GAS, SCFH	4500.
BED HEIGHT, FT	9.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.12	647.95	2496.84	0.260	70.3	0.393	0.982	0.386
3.62	777.55	2492.92	0.312	60.7	0.472	0.984	0.464
4.25	429.05	1236.15	0.347	55.1	0.260	1.984	0.517
4.53	889.97	2489.45	0.357	53.6	0.540	0.985	0.532
5.05	972.43	2195.69	0.443	42.4	0.590	1.117	0.659
5.60	947.78	2360.85	0.401	47.5	0.575	1.039	0.598
6.10	1063.57	2540.76	0.419	45.4	0.646	0.965	0.623
6.61	987.93	2069.50	0.477	38.5	0.600	1.185	0.711
7.13	1022.63	2527.69	0.405	47.1	0.621	0.970	0.602
7.76	1042.07	2547.60	0.409	46.6	0.633	0.962	0.609
8.16	1023.95	2439.62	0.420	45.2	0.622	1.005	0.625
8.69	1030.60	2428.57	0.424	44.7	0.626	1.010	0.632
8.97	1028.62	2704.09	0.380	50.4	0.624	0.907	0.566
9.48	1541.87	2418.19	0.638	23.4	0.936	1.014	0.949
10.00	1647.42	2479.30	0.664	21.3	1.000	0.989	0.989
10.53	1624.68	2431.93	0.668	21.0	0.986	1.008	0.994
11.03	1532.52	2384.88	0.643	23.0	0.930	1.028	0.956
11.55	1479.28	2481.86	0.596	27.0	0.898	0.988	0.887
12.08	1418.40	2533.52	0.560	30.2	0.861	0.968	0.833
12.59	1323.55	2456.65	0.539	32.2	0.803	0.998	0.802
13.11	1405.20	2673.84	0.526	33.5	0.853	0.917	0.782
13.65	1427.62	2583.59	0.553	30.9	0.867	0.949	0.822
14.14	1462.97	2738.73	0.534	32.7	0.888	0.895	0.795
14.76	1436.60	2998.16	0.479	38.3	0.872	0.818	0.713

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XII

PDU FLUID DYNAMIC DATA, 9/20/80 PM

DATE	09-20-80PM
HRI PERIOD	43A
SLURRY FEED LB/HR	637.
RECYCLE , GPM/FT2	18.8
H2 FEED GAS, SCFH	3610.
RECYCLE GAS, SCFH	6010.
BED HEIGHT, FT	10.33

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.11	566.13	2488.02	0.228	77.1	0.719	0.986	0.708
3.62	629.72	2492.92	0.253	71.7	0.799	0.984	0.786
4.14	347.47	[illegible]5.14	0.288	64.8	0.441	2.035	0.897
4.52	751.88	2496.72	0.301	62.5	0.954	0.982	0.937
5.07	775.50	2201.06	0.352	54.3	0.984	1.114	1.097
5.61	745.00	2361.13	0.316	60.1	0.946	1.038	0.982
6.10	859.77	2540.76	0.338	56.4	1.091	0.965	1.053
6.62	803.15	2045.77	0.393	48.7	1.020	1.199	1.222
7.12	820.95	2528.29	0.325	58.6	1.042	0.970	1.011
7.66	799.58	2545.52	0.314	60.3	1.015	0.963	0.978
8.17	808.62	2438.94	0.332	57.5	1.027	1.005	1.032
8.69	818.32	2428.57	0.337	56.7	1.039	1.010	1.049
8.97	815.32	2704.09	0.302	62.5	1.035	0.907	0.939
9.48	738.80	2418.19	0.306	61.8	0.938	1.014	0.951
10.02	787.73	2473.05	0.319	59.6	1.000	0.991	0.991
10.55	1113.00	2429.92	0.458	40.7	1.413	1.009	1.426
11.03	1117.07	2384.88	0.468	39.5	1.418	1.028	1.458
11.55	1055.05	2481.86	0.425	44.6	1.339	0.988	1.323
12.00	1008.05	2535.20	0.398	48.0	1.280	0.967	1.238
12.60	967.17	2461.14	0.393	48.7	1.228	0.996	1.223
13.10	1044.22	2675.51	0.390	49.0	1.326	0.916	1.215
13.65	1033.83	2583.59	0.400	47.7	1.312	0.949	1.246
14.15	1078.98	2742.07	0.393	48.6	1.370	0.894	1.225
14.68	1059.25	2964.35	0.357	53.6	1.345	0.827	1.112

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XIII

PDU FLUID DYNAMIC DATA, 9/21/80 AM

DATE	09-21-80AM
HRI PERIOD	43B
SLURRY FEED LB/HR	628.
RECYCLE . GPM/FT2	19.1
H2 FEED GAS, SCFH	2830.
RECYCLE GAS, SCFH	2200.
BED HEIGHT, FT	9.33

ELEV. FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.12	693.40	2496.84	0.278	66.7	0.445	0.982	0.437
3.62	714.43	2492.92	0.287	65.1	0.458	0.984	0.451
4.14	398.73	1205.14	0.331	57.6	0.256	2.035	0.520
4.52	831.93	2496.72	0.333	57.3	0.533	0.982	0.524
5.07	912.78	2201.06	0.415	45.9	0.585	1.114	0.652
5.59	882.38	2360.58	0.374	51.3	0.566	1.039	0.588
6.09	1003.37	2540.72	0.395	48.4	0.643	0.965	0.621
6.63	920.42	2022.04	0.455	41.0	0.590	1.213	0.716
7.14	956.43	2527.10	0.378	50.6	0.613	0.970	0.595
7.75	956.15	2547.85	0.375	51.1	0.613	0.962	0.590
8.17	970.67	2438.94	0.398	48.0	0.622	1.005	0.626
8.68	1014.93	2407.89	0.422	45.0	0.651	1.018	0.663
8.96	1057.75	2705.57	0.391	48.9	0.678	0.906	0.615
9.48	1511.53	2418.19	0.625	24.5	0.969	1.014	0.983
10.01	1559.72	2476.17	0.630	24.1	1.000	0.990	0.990
10.53	1530.05	2431.93	0.629	24.1	0.981	1.008	0.989
11.06	1382.30	2381.55	0.580	28.3	0.886	1.030	0.912
11.55	1381.13	2481.86	0.556	30.5	0.886	0.988	0.875
12.07	1288.12	2533.73	0.508	35.2	0.826	0.968	0.799
12.59	1193.55	2456.65	0.486	37.6	0.765	0.998	0.764
13.09	1285.12	2677.18	0.480	38.2	0.824	0.916	0.755
13.73	1267.57	2601.79	0.487	37.5	0.813	0.942	0.766
14.14	1303.43	2738.73	0.476	38.7	0.836	0.895	0.748
14.69	1256.00	2968.57	0.423	44.8	0.805	0.826	0.665

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XIV

PDU FLUID DYNAMIC DATA, 9/21/80 PM

DATE	09-21-80PM
HRI PERIOD	44A
SLURRY FEED LB/HR	639.
RECYCLE , GPM/FT2	30.5
H2 FEED GAS, SCFH	3940.
RECYCLE GAS, SCFH	6360.
BED HEIGHT, FT	13.08

ELEV. FT.	I-FLOW CPS	I-ZERO CPS	I/IO	DENSITY LB/FT3	R1	R2	R3
3.21	558.20	2505.48	0.223	78.2	0.673	0.979	0.658
3.63	653.48	2481.28	0.263	69.5	0.787	0.988	0.778
4.14	361.22	1205.14	0.300	62.8	0.435	2.035	0.885
4.53	758.33	2489.45	0.305	61.9	0.914	0.985	0.900
5.09	809.98	2211.79	0.366	52.3	0.976	1.109	1.082
5.60	778.45	2360.85	0.330	57.8	0.938	1.039	0.974
6.10	883.63	2540.76	0.348	55.0	1.065	0.965	1.027
6.62	823.27	2045.77	0.402	47.4	0.992	1.199	1.189
7.13	845.82	2527.69	0.335	57.0	1.019	0.970	0.989
7.67	834.67	2549.87	0.327	58.2	1.006	0.962	0.967
8.17	834.20	2438.94	0.342	55.9	1.005	1.005	1.010
8.70	844.02	2449.26	0.345	55.5	1.017	1.001	1.018
9.01	839.27	2690.63	0.312	60.7	1.011	0.911	0.922
9.49	771.80	2409.37	0.320	59.3	0.930	1.018	0.946
10.01	829.97	2476.17	0.335	56.9	1.000	0.990	0.990
10.55	817.25	2429.92	0.336	56.8	0.985	1.009	0.994
11.05	762.80	2382.66	0.320	59.3	0.919	1.029	0.946
11.58	726.20	2471.24	0.294	63.8	0.875	0.992	0.868
12.10	691.47	2533.10	0.273	67.6	0.833	0.968	0.806
12.61	672.90	2465.64	0.273	67.7	0.811	0.994	0.806
13.10	852.33	2675.51	0.319	59.6	1.027	0.916	0.941
13.75	930.95	2608.47	0.357	53.7	1.122	0.940	1.054
14.15	970.23	2742.07	0.354	54.1	1.169	0.894	1.045
14.69	945.27	2963.57	0.318	59.6	1.139	0.826	0.941

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XV

PDU FLUID DYNAMIC DATA, 9/22/80 AM

DATE	09-22-80AM
HRI PERIOD	448
SLURRY FEED LB/HR	641.
RECYCLE , GPM/FT2	30.5
H2 FEED GAS, SCFH	2790.
RECYCLE GAS, SCFH	2350.
BED HEIGHT, FT	9.75

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.12	604.63	2496.84	0.242	73.9	0.407	0.982	0.400
3.64	706.32	2469.65	0.286	65.2	0.476	0.993	0.472
4.15	525.77	1204.24	0.437	43.2	0.354	2.036	0.721
4.53	825.65	2489.45	0.332	57.5	0.556	0.985	0.548
5.07	883.25	2201.06	0.401	47.6	0.595	1.114	0.663
5.60	848.98	2360.85	0.360	53.3	0.572	1.039	0.594
6.10	956.93	2540.76	0.377	50.9	0.644	0.965	0.622
6.61	895.80	2069.50	0.433	43.6	0.603	1.185	0.715
7.13	924.55	2527.69	0.366	52.4	0.623	0.970	0.604
7.67	914.32	2549.87	0.359	53.4	0.616	0.962	0.592
8.16	968.53	2439.62	0.397	48.1	0.652	1.005	0.656
8.69	987.93	2428.57	0.407	46.9	0.665	1.010	0.672
9.07	993.69	2636.55	0.377	50.8	0.669	0.930	0.622
9.49	918.57	2409.37	0.381	50.2	0.619	1.018	0.630
10.02	1484.85	2473.05	0.600	26.6	1.000	0.991	0.991
10.55	1408.25	2429.92	0.580	28.4	0.948	1.009	0.957
11.04	1330.45	2383.77	0.558	30.4	0.896	1.029	0.922
11.56	1277.95	2478.32	0.516	34.5	0.861	0.989	0.852
12.08	1192.08	2533.52	0.471	39.3	0.803	0.968	0.777
12.60	1118.62	2461.14	0.455	41.1	0.753	0.996	0.751
13.10	1213.75	2675.51	0.454	41.2	0.817	0.916	0.749
13.74	1199.12	2605.13	0.460	40.4	0.808	0.941	0.760
14.16	1226.83	2745.41	0.447	42.0	0.826	0.893	0.738
14.69	1195.25	2968.57	0.403	47.4	0.805	0.826	0.665

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XVI

PDU FLUID DYNAMIC DATA, 9/22/80 PM

DATE	09-22-80PM
HRI PERIOD	45A
SLURRY FEED LB/HR	660.
RECYCLE , GPM/FT2	37.1
H2 FEED GAS, SCFH	3690.
RECYCLE GAS, SCFH	6390.
BED HEIGHT, FT	13.42

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.12	649.67	2496.84	0.260	70.1	0.701	0.982	0.688
3.63	764.33	2481.28	0.308	61.3	0.824	0.988	0.815
4.16	416.28	1203.33	0.346	55.3	0.449	2.038	0.915
4.53	863.53	2489.45	0.347	55.2	0.931	0.985	0.917
5.07	922.82	2201.06	0.419	45.3	0.995	1.114	1.109
5.60	890.22	2360.85	0.377	50.8	0.960	1.039	0.997
6.10	993.52	2540.76	0.391	48.9	1.072	0.965	1.034
6.62	923.17	2045.77	0.451	41.5	0.996	1.199	1.193
7.13	961.28	2527.69	0.380	50.4	1.037	0.970	1.006
7.68	930.48	2549.62	0.365	52.5	1.004	0.962	0.965
8.17	951.02	2438.94	0.390	49.1	1.026	1.005	1.031
8.69	950.52	2428.57	0.391	48.9	1.025	1.010	1.035
9.00	946.95	2699.65	0.351	54.6	1.021	0.908	0.928
9.51	882.08	2398.15	0.368	52.1	0.951	1.022	0.973
10.02	927.20	2473.05	0.375	51.1	1.000	0.991	0.991
10.55	905.88	2429.92	0.373	51.4	0.977	1.009	0.986
11.05	848.30	2382.66	0.356	53.8	0.915	1.029	0.942
11.58	820.60	2471.24	0.332	57.4	0.885	0.992	0.878
12.10	786.82	2533.10	0.311	60.9	0.849	0.968	0.821
12.61	751.13	2465.64	0.305	61.9	0.810	0.994	0.806
13.11	828.65	2673.84	0.310	61.0	0.894	0.917	0.820
13.75	999.30	2608.47	0.383	50.0	1.078	0.940	1.013
14.16	1059.57	2745.41	0.386	49.6	1.143	0.893	1.021
14.70	1042.67	2972.80	0.351	54.6	1.125	0.825	0.928

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XVII

PDU FLUID DYNAMIC DATA, 9/23/80 AM

DATE	09-23-80AM
HRI PERIOD	458
SLURRY FEED LB/HR	623.
RECYCLE , GPM/FT2	41.2
H2 FEED GAS, SCFH	2850.
RECYCLE GAS, SCFH	2100.
BED HEIGHT, FT	10.75

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.10	587.18	2479.20	0.237	75.0	0.595	0.989	0.589
3.62	709.77	2492.92	0.285	65.4	0.720	0.984	0.708
4.15	399.82	1204.24	0.332	57.4	0.405	2.036	0.825
4.53	838.15	2489.45	0.337	56.7	0.850	0.985	0.837
5.07	921.42	2201.06	0.419	45.4	0.934	1.114	1.041
5.60	886.65	2360.85	0.376	51.0	0.899	1.039	0.934
6.10	1002.82	2540.76	0.395	48.4	1.017	0.965	0.981
6.61	919.65	2069.50	0.444	42.3	0.932	1.185	1.105
7.13	943.58	2527.69	0.373	51.3	0.957	0.970	0.928
7.67	903.05	2549.87	0.354	54.1	0.916	0.962	0.880
8.16	965.70	2439.62	0.396	48.3	0.979	1.005	0.984
8.70	1029.20	2449.26	0.420	45.2	1.043	1.001	1.045
8.97	1000.02	2704.09	0.370	51.8	1.014	0.907	0.919
9.49	920.85	2409.37	0.382	50.1	0.934	1.018	0.950
10.01	986.37	2476.17	0.398	48.0	1.000	0.990	0.990
10.54	956.77	2430.93	0.394	48.6	0.970	1.009	0.978
11.03	1184.40	2384.88	0.497	36.5	1.201	1.028	1.235
11.56	1152.62	2478.32	0.465	39.9	1.169	0.989	1.156
12.08	1083.35	2533.52	0.428	44.3	1.098	0.968	1.063
12.60	1023.73	2461.14	0.416	45.7	1.038	0.996	1.034
13.10	1105.08	2675.51	0.413	46.1	1.120	0.916	1.027
13.70	1114.93	2591.77	0.430	43.9	1.130	0.946	1.069
14.16	1087.65	2745.41	0.396	48.2	1.103	0.893	0.985
14.69	1081.73	2968.57	0.364	52.6	1.097	0.826	0.906

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XVIII

PDU FLUID DYNAMIC DATA, 9/23/80 PM

DATE	09-23-80PM
HRI PERIOD	46A
SLURRY FEED LB/HR	696.
RECYCLE , GPM/FT2	41.2
H2 FEED GAS, SCFH	2820.
RECYCLE GAS, SCFH	4340.
BED HEIGHT, FT	12.08

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.08	617.88	2464.81	0.251	72.1	0.665	0.995	0.662
3.63	770.15	2481.28	0.310	60.9	0.829	0.988	0.819
4.14	430.77	1205.14	0.357	53.6	0.464	2.035	0.944
4.53	881.78	2489.45	0.354	54.1	0.949	0.985	0.935
5.08	954.42	2206.42	0.433	43.7	1.028	1.111	1.142
5.61	897.88	2361.13	0.380	50.4	0.967	1.038	1.004
6.10	1008.68	2540.76	0.397	48.1	1.086	0.965	1.048
6.61	942.75	2069.50	0.456	41.0	1.015	1.185	1.203
7.15	958.40	2526.51	0.379	50.5	1.032	0.970	1.001
7.66	946.23	2545.52	0.372	51.6	1.019	0.963	0.981
8.17	943.08	2438.94	0.387	49.5	1.015	1.005	1.021
8.71	972.88	2469.94	0.394	48.5	1.047	0.993	1.040
8.97	956.28	2704.09	0.354	54.2	1.030	0.907	0.934
9.49	886.20	2409.37	0.368	52.1	0.954	1.018	0.971
10.01	928.83	2476.17	0.375	51.1	1.000	0.990	0.990
10.54	908.25	2430.93	0.374	51.3	0.978	1.009	0.986
11.04	846.97	2383.77	0.355	53.9	0.912	1.029	0.938
11.56	837.03	2478.32	0.338	56.5	0.901	0.989	0.892
12.08	921.68	2533.52	0.364	52.7	0.992	0.968	0.960
12.61	984.78	2465.64	0.399	47.8	1.060	0.994	1.054
13.09	1080.30	2677.18	0.404	47.3	1.163	0.916	1.065
13.74	1059.52	2605.13	0.407	46.9	1.141	0.941	1.074
14.15	1104.60	2742.07	0.403	47.4	1.189	0.894	1.063
14.69	1083.43	2968.57	0.365	52.5	1.166	0.826	0.963

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XIX

PDU FLUID DYNAMIC DATA, 9/24/80 AM

DATE	09-24-80AM
HRI PERIOD	46B
SLURRY FEED LB/HR	0.
RECYCLE , GPM/FT2	0.
H2 FEED GAS, SCFH	0.
RECYCLE GAS, SCFH	0.
BED HEIGHT, FT	6.50

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/IO	DENSITY LB/FT3	R1	R2	R3
3.11	339.20	2488.02	0.136	103.8	0.461	0.986	0.454
3.62	377.50	2492.92	0.151	98.3	0.513	0.984	0.504
4.26	238.50	1354.37	0.176	90.5	0.324	1.810	0.586
4.51	370.10	2503.98	0.148	99.6	0.503	0.979	0.492
5.06	485.50	2195.69	0.221	78.6	0.659	1.117	0.736
5.59	459.10	2360.58	0.194	85.3	0.623	1.039	0.647
6.09	487.70	2540.72	0.192	86.0	0.662	0.965	0.639
6.61	460.30	2069.50	0.222	78.3	0.625	1.185	0.740
7.12	780.40	2528.29	0.309	61.2	1.060	0.970	1.028
7.65	766.90	2539.18	0.302	62.4	1.041	0.966	1.006
8.16	767.90	2439.62	0.315	60.2	1.043	1.005	1.048
8.68	756.40	2407.89	0.314	60.3	1.027	1.018	1.046
8.96	729.70	2705.57	0.270	68.3	0.991	0.906	0.898
9.50	744.10	2400.55	0.310	61.0	1.010	1.021	1.032
10.01	736.50	2476.17	0.297	63.2	1.000	0.990	0.990
10.52	732.10	2432.94	0.301	62.6	0.994	1.008	1.002
11.02	717.90	2385.98	0.301	62.6	0.975	1.028	1.002
11.54	759.30	2485.39	0.306	61.8	1.031	0.987	1.017
12.06	748.00	2533.94	0.295	63.6	1.016	0.968	0.983
12.59	694.90	2456.65	0.283	65.8	0.944	0.998	0.942
13.08	744.60	2677.00	0.278	66.7	1.011	0.916	0.926
13.64	774.50	2585.26	0.300	62.8	1.052	0.948	0.997
14.13	748.50	2735.39	0.274	67.5	1.016	0.896	0.911
14.68	761.30	2964.35	0.257	70.8	1.034	0.827	0.855

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

TABLE XX

PDU FLUID DYNAMIC DATA, 9/24/80 PM

DATE	09-24-80PM
HRI PERIOD	47A
SLURRY FEED LB/HR	0.
RECYCLE , GPM/FT2	0.
H2 FEED GAS, SCFH	0.
RECYCLE GAS, SCFH	0.
BED HEIGHT, FT	6.50

ELEV, FT.	I-FLOW CPS	I-ZERO CPS	I/I0	DENSITY LB/FT3	R1	R2	R3
3.12	448.00	2496.84	0.179	89.5	0.653	0.982	0.641
3.62	445.60	2492.92	0.179	89.7	0.649	0.984	0.639
4.13	327.90	1206.05	0.272	67.8	0.478	2.033	0.971
4.52	408.80	2496.72	0.164	94.3	0.596	0.982	0.585
5.06	545.30	2195.69	0.248	72.6	0.795	1.117	0.887
5.59	522.50	2360.58	0.221	78.6	0.761	1.039	0.791
6.09	556.10	2540.72	0.219	79.1	0.810	0.965	0.782
6.61	505.60	2069.50	0.244	73.4	0.737	1.185	0.873
7.13	676.70	2527.69	0.268	68.7	0.986	0.970	0.956
7.66	682.40	2545.52	0.268	68.6	0.994	0.963	0.958
8.16	682.80	2439.62	0.280	66.3	0.995	1.005	1.000
8.68	663.50	2407.89	0.276	67.1	0.967	1.018	0.984
8.96	660.30	2705.57	0.244	73.5	0.962	0.906	0.872
9.49	661.00	2409.37	0.274	67.4	0.963	1.018	0.980
10.01	686.30	2476.17	0.277	66.8	1.000	0.990	0.990
10.53	674.80	2431.93	0.277	66.8	0.983	1.008	0.991
11.03	656.40	2384.88	0.275	67.2	0.956	1.028	0.983
11.55	664.00	2481.86	0.268	68.7	0.968	0.988	0.956
12.07	690.70	2533.73	0.273	67.7	1.006	0.968	0.974
12.59	660.80	2456.65	0.269	68.4	0.963	0.998	0.961
13.09	653.90	2677.18	0.244	73.4	0.953	0.916	0.873
13.73	677.50	2601.79	0.260	70.1	0.987	0.942	0.930
14.14	672.50	2738.73	0.246	73.2	0.980	0.895	0.877
14.70	664.50	2972.80	0.224	78.0	0.968	0.825	0.799

NOTES:

1. DENSITY ASSUMES MASS ABSORPTION COEFFICIENT = 0.0271 FT2/LBM

2. R1 = (FLOW CPS AT ELEV) / (FLOW CPS AT 10 FEET)
   R2 = (ZERO CPS AT 10 FEET) / (ZERO CPS AT ELEV)
   R3 = R1 * R2

Figure 1

HRI SHUTDOWN OIL DENSITY

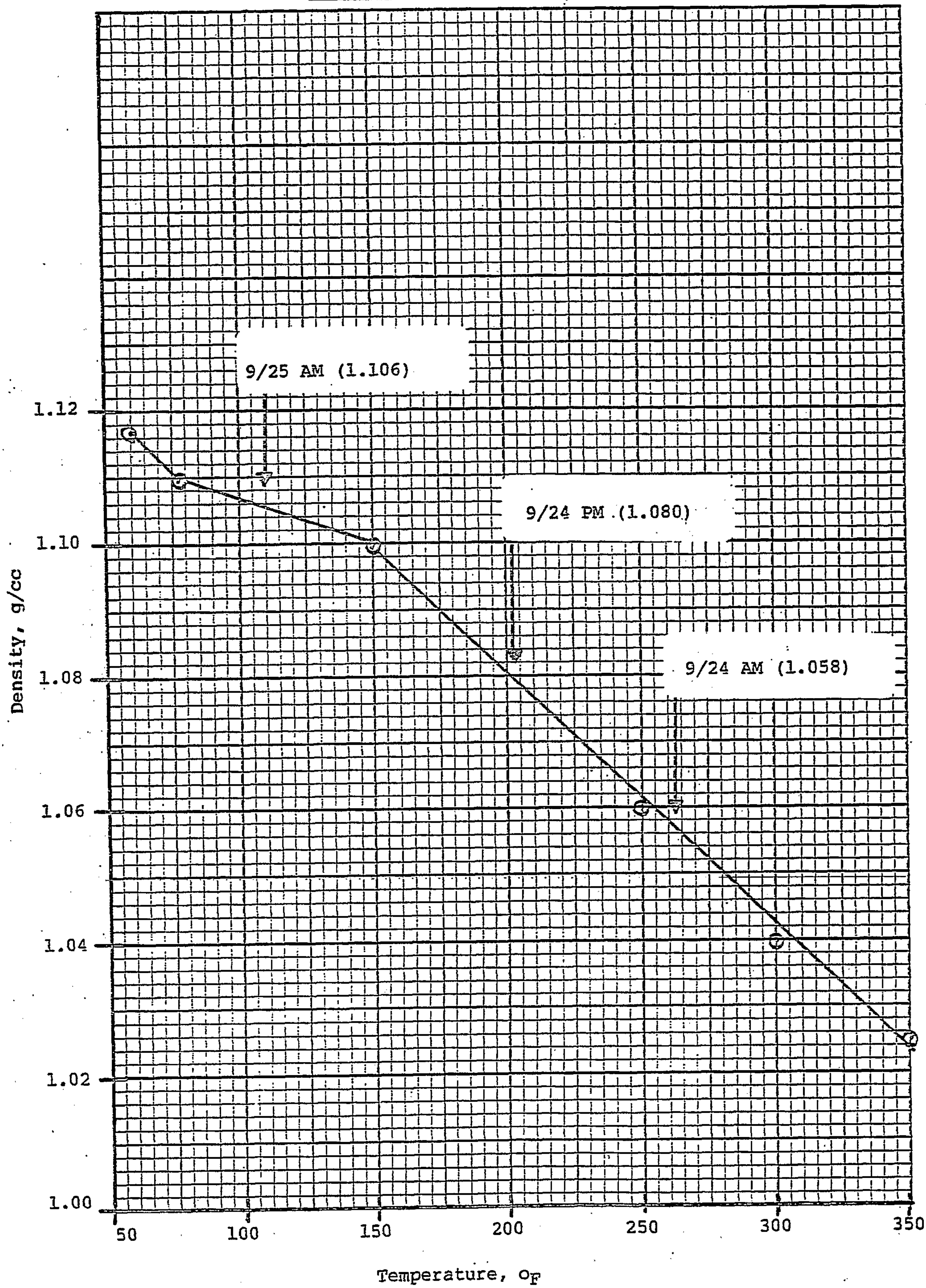


Figure 2

DENSITY PROFILE, 7/30 AND 8/5/80

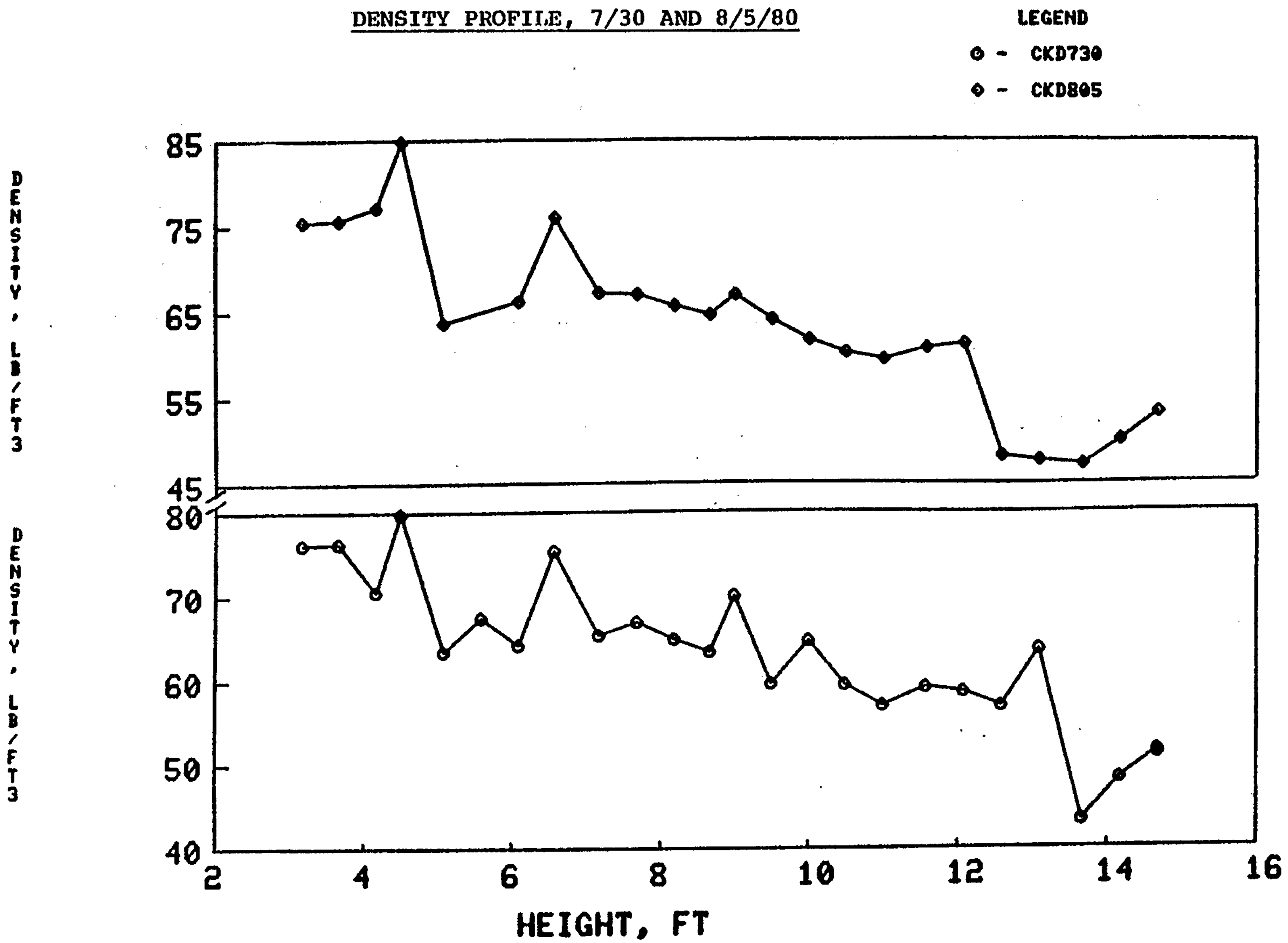


Figure 3

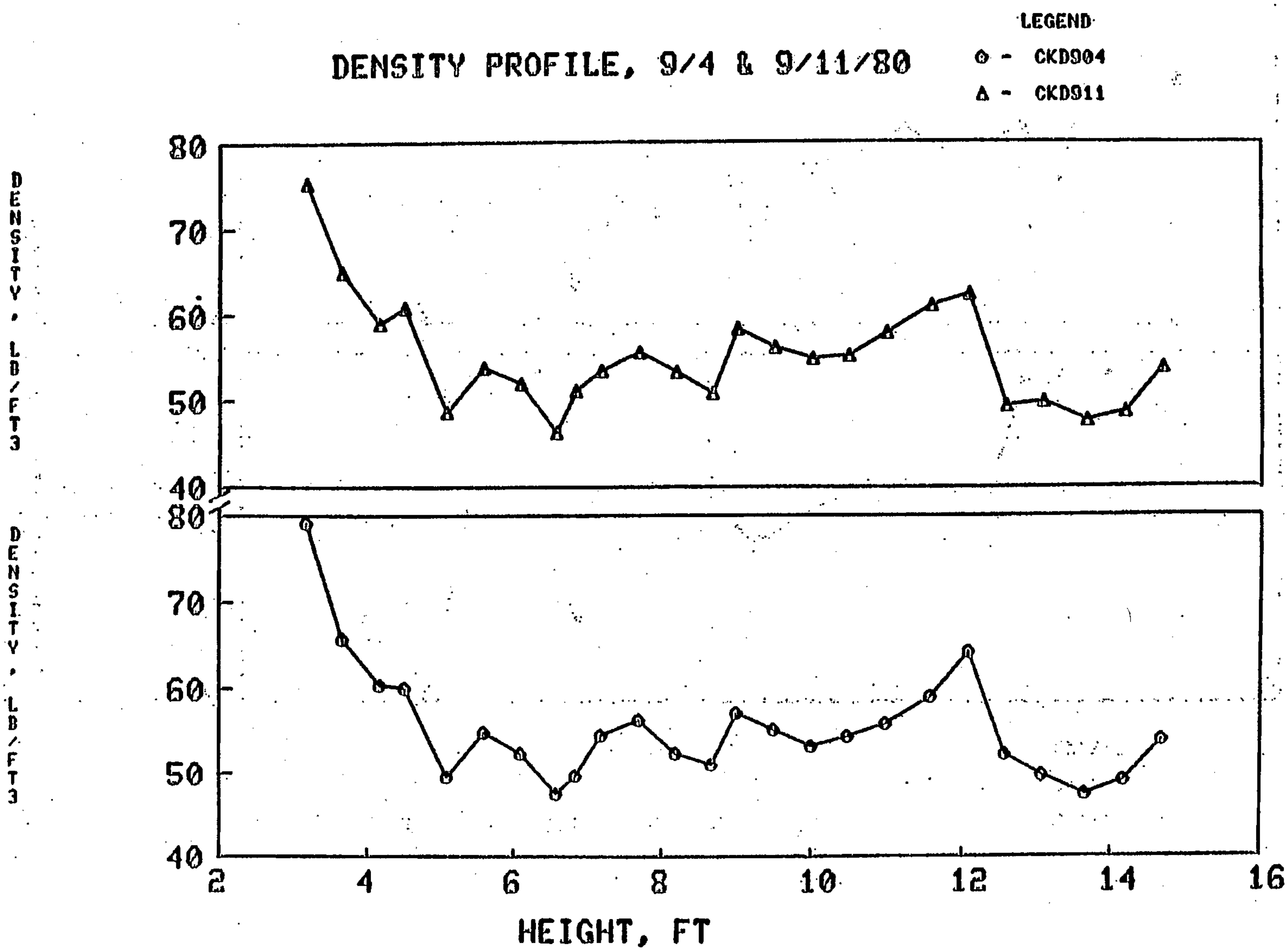

DENSITY PROFILE, 9/4 & 9/11/80
LEGEND
o - CKD904
Δ - CKD911
DENSITY, LB/FT3
DENSITY, LB/FT3
80
70
60
50
40
80
70
60
50
40
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 4

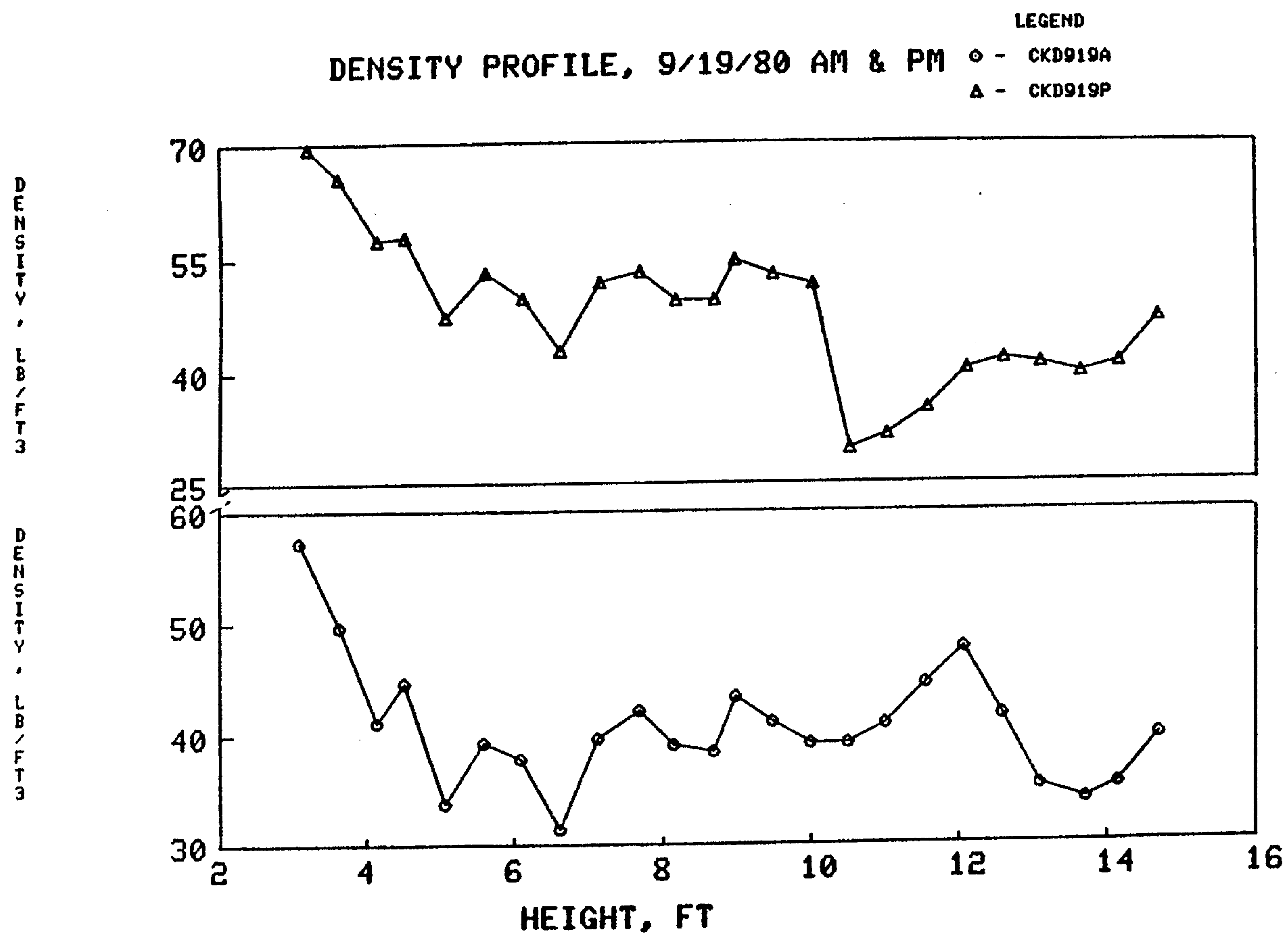

DENSITY PROFILE, 9/19/80 AM & PM
LEGEND
○ - CKD919A
△ - CKD919P
DENSITY, LB/FT3
70
55
40
25
60
50
40
30
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 5

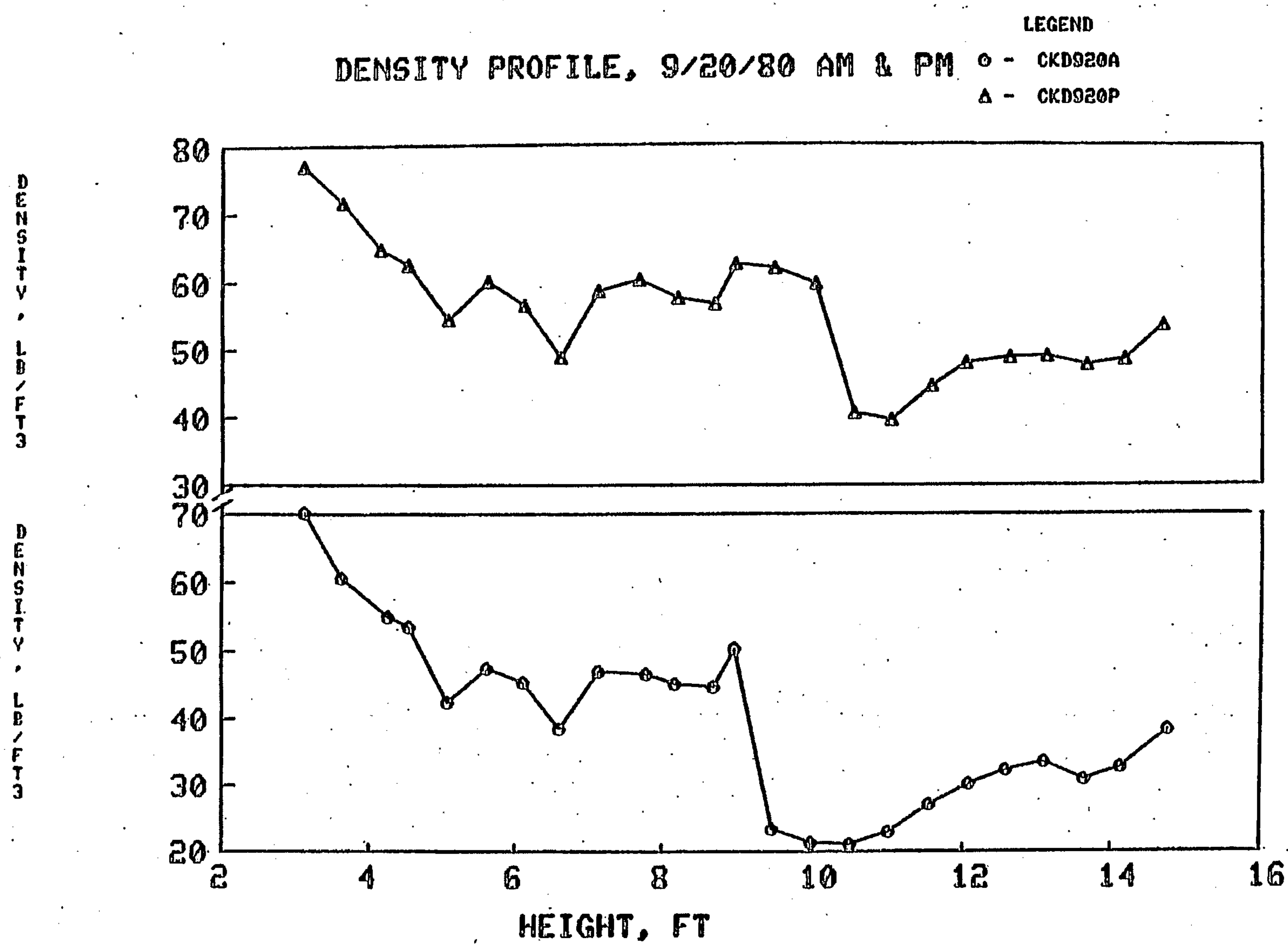

DENSITY PROFILE, 9/20/80 AM & PM
LEGEND
o - CKD920A
Δ - CKD920P
DENSITY, LB/FT3
DENSITY, LB/FT3
80
70
60
50
40
30
70
60
50
40
30
20
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 6

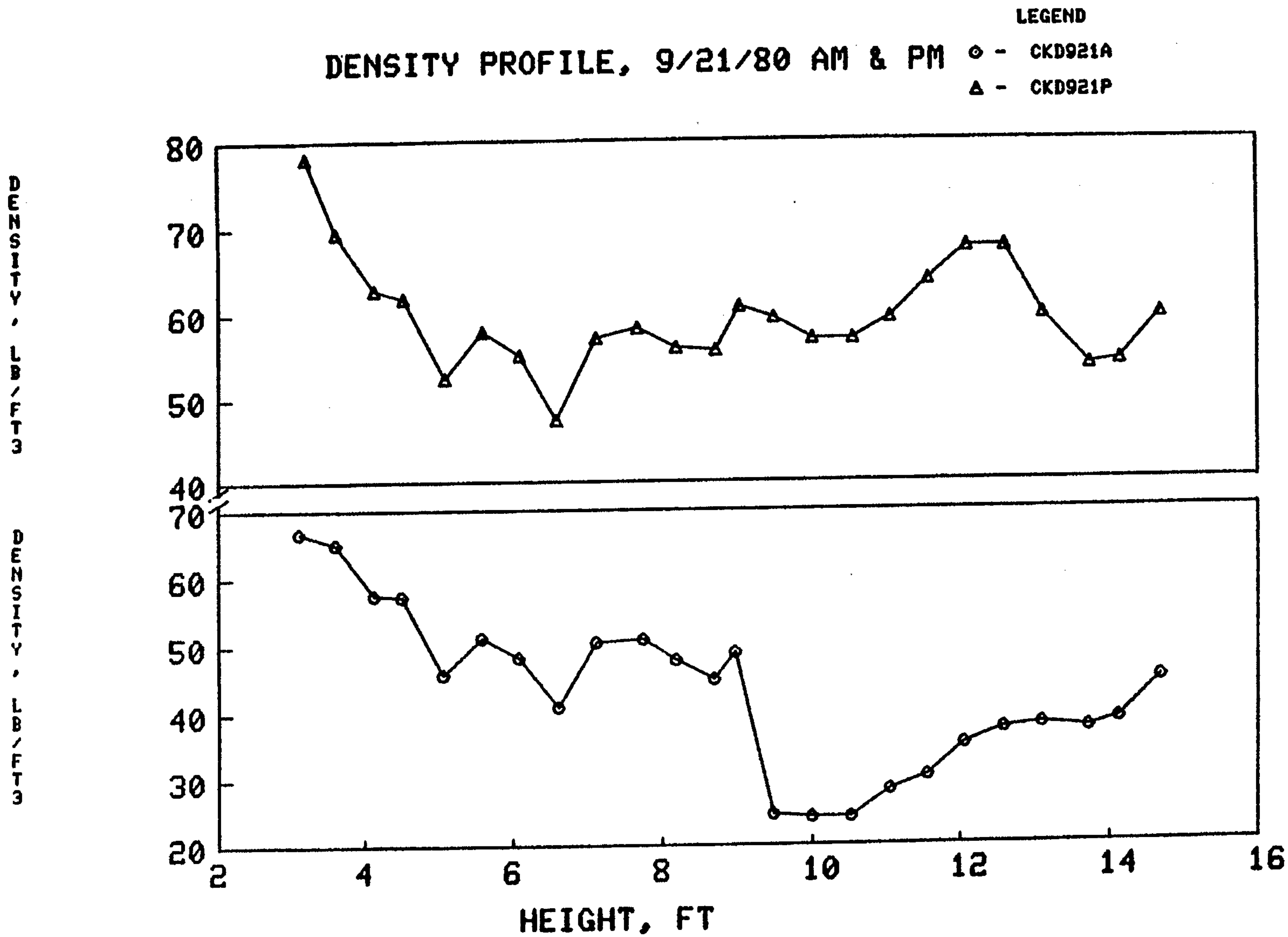

DENSITY PROFILE, 9/21/80 AM & PM
LEGEND
CKD921A
CKD921P
DENSITY, LB/FT3
DENSITY, LB/FT3
80
70
60
50
40
70
60
50
40
30
20
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 7

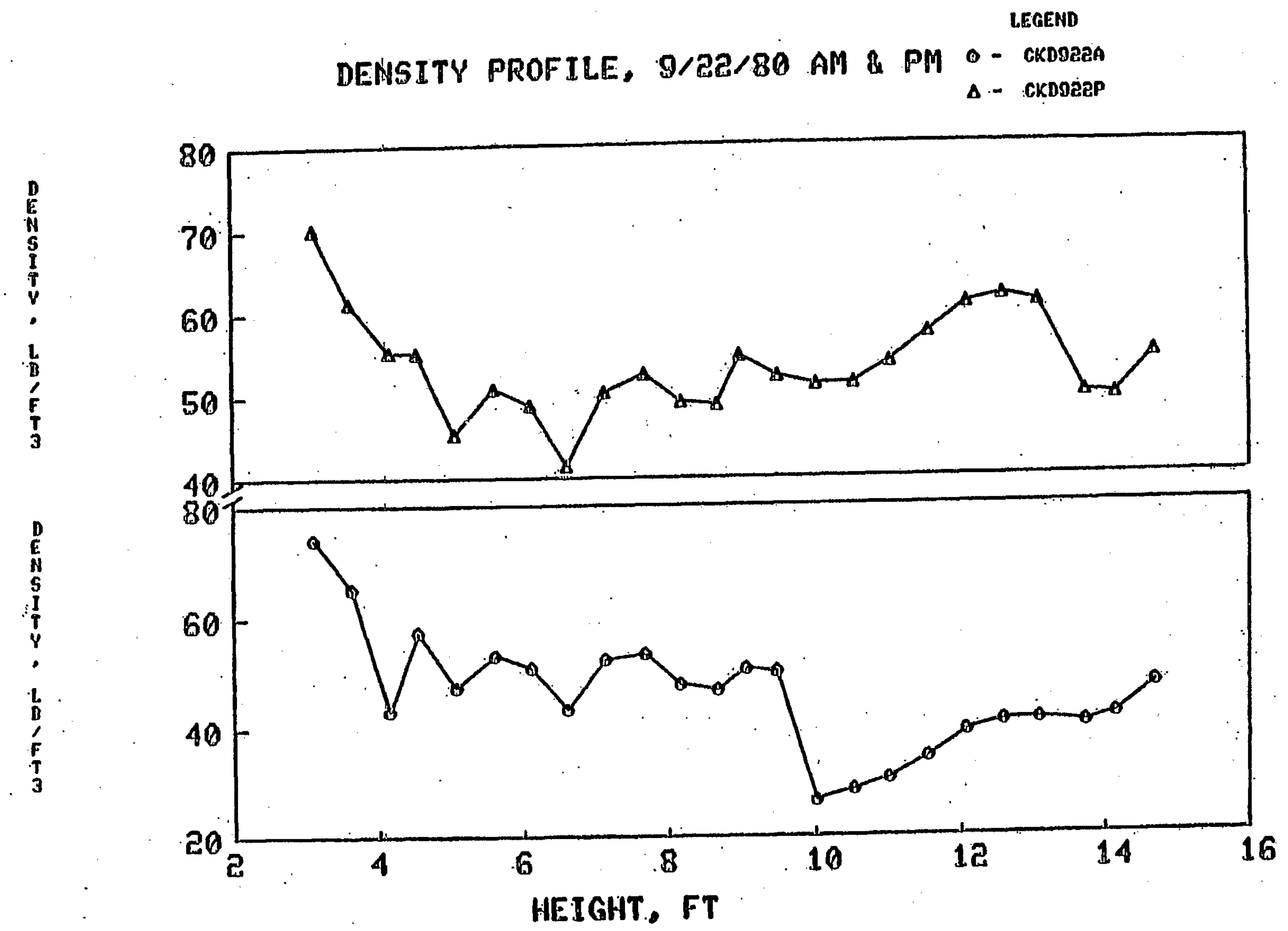

DENSITY PROFILE, 9/22/80 AM & PM
LEGEND
o - CKD922A
Δ - CKD922P
DENSITY, LB/FT3
DENSITY, LB/FT3
80
70
60
50
40
80
60
40
20
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 8

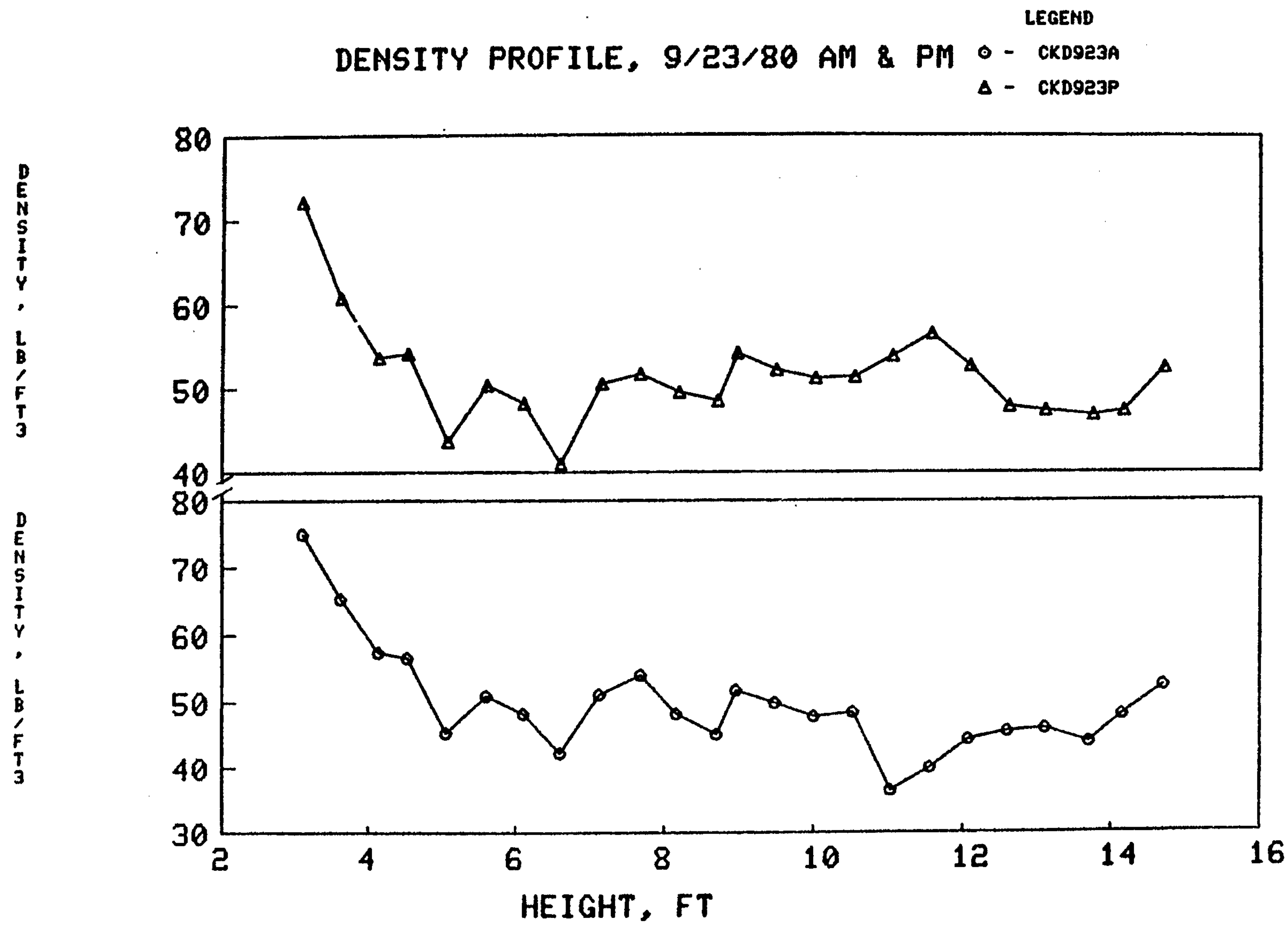
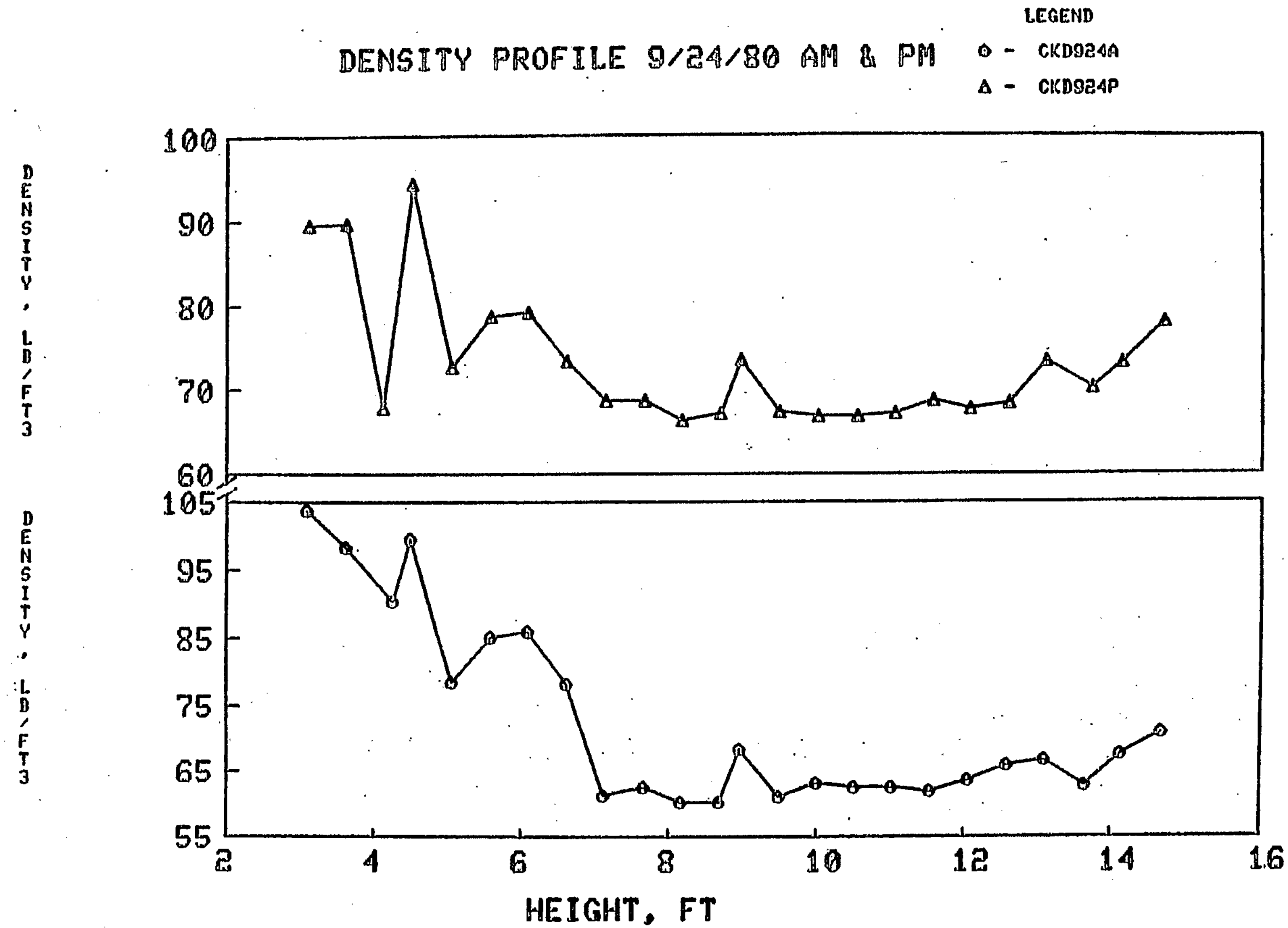

DENSITY PROFILE, 9/23/80 AM & PM
LEGEND
o - CKD923A
Δ - CKD923P
DENSITY, LB/FT3
DENSITY, LB/FT3
80
70
60
50
40
80
70
60
50
40
30
2
4
6
8
10
12
14
16
HEIGHT, FT

Figure 9



DENSITY PROFILE 9/24/80 AM & PM
LEGEND
o - CKD924A
Δ - CKD924P
DENSITY, LB/FT3
100
90
80
70
60
DENSITY, LB/FT3
105
95
85
75
65
55
2
4
6
8
10
12
14
16
HEIGHT, FT

APPENDIX A

BATTELLE PROGRESS REPORT

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

December 5, 1980

Dr. Douglas Rundell
AMOCO Research Center
Post Office Box 400
Naperville, Illinois 60540

Dear Dr. Rundell:

This is the second monthly report on your program on the viscosity of H-COAL samples. It covers the period through the end of November. The purpose of the program is to determine the rheological properties of H-COAL samples over the temperature range 350 to 450 C. The effect of pressure over the range 2000 to 3000 psi will be examined with only a few of the samples.

Samples

We have received 16 samples. Each is contained in a pressure vessel closed by valves at each end and each apparently consists of 300 to 500 grams of material drawn from the H-COAL pilot plant. Samples are designated AMOCO-1 through AMOCO-16. Further information about the conditions under which the samples were obtained is, no doubt, available to you.

Viscometer

The viscometer previously used for AMOCO samples, as described in our report dated December 11, 1979, has been modified in several respects. The instrument will be fully described in our final report. Here we give only a brief indication of the changes.

Both coils in the older version of the viscometer are now used to transmit lifting force to the permanent magnet which is attached to the bob. One coil surrounds each end of the magnet. The same current passes through the two coils in opposite sense. By controlling the current passed through the coils we control the vertical force causing the bob to move axially in the autoclave. A second permanent magnet, much smaller than the first, is supported above the first by a thin-walled tube. This magnet is also surrounded by a pair of oppositely wound coils. A signal is generated in this pair of coils which is proportional to the rate of movement of the bob. This signal is recorded. By calibration we are able to express the lifting force in terms of shear stress in the liquid and the rate of travel of the bob in terms of shear rate in the liquid. In the past we have found a straight-line relationship to exist, from which we determine the slope, called the "plastic viscosity" and the intercept, related to the yield stress.

Heaters and associated control devices have been added which enable us to achieve much better temperature control than we were formerly able to do.

A second autoclave has been mounted adjacent to the viscometer autoclave. It is equipped with similar temperature controls. The contents of this second autoclave can be stirred vigorously.

During the first month we have mounted a sample container in such a way that the contents can be transferred to the second autoclave and subsequently a portion into the first, so that a representative sample may be secured. Suitable pressure and temperature controls were provided.

Sample Transfer

After evacuating our system and replacing the air with hydrogen, the sample vessel was warmed to about 150 C and the excess gas was vented. An attempt to transfer the sample to the viscometer failed because of a plug in a valve. A second attempt the next day was successful but the transfer was accompanied by a lot of trouble and the possibility of some loss of sample by vaporization. Data at temperatures up to 450 C were generally unsatisfactory. Calculations have not been made but the appearance is of a high viscosity material. During attempts to unload the viscometer the bob was accidentally exposed to excessive pressure and distorted beyond repair.

In a second attempt, using a new bob and Sample No. 1, the sample was first mixed by passing hydrogen up through the sample container. About 300 cc was then transferred to the mixing autoclave where it was stirred for about 10 minutes. A viscosity sample (about 65 cc) was then transferred to the viscometer. Measurements were made at three pressures up to 450 C. All procedures worked smoothly, but the data were characterized by excessive scatter. The new bob has not yet been properly calibrated, but the viscosities seen to be of the order of about 1 cP.

Excessive scatter in the data seems to be related to the low viscosities, since we are required to work at very low force levels where small irregularities are exaggerated, and to the presence of solids, since we have less trouble with oils of similar viscosity. We plan to make some measurements with a larger bob in an attempt to improve the reproducibility of the results.

During the coming month, in addition to further measurements on the samples provided, we plan to make some calibration experiments.

In analyzing the data for a determination of yield stress, density data will be very useful, if not indispensable. We plan to use ORNL results and our own estimates. If you have any further data on densities, we would appreciate your sending them to us.

If you wish to discuss the program, I would urge you to call me at (614) 424-4933.

Very truly yours,

John W. Droege

John W. Droege
Fuels and Combustion Section

JWD:drr

APPENDIX B

NORTHWESTERN UNIVERSITY

OCTOBER AND NOVEMBER, 1980, PROGRESS REPORTS

MONTHLY (OCTOBER 1980) PROGRESS REPORT ON AMOCO DOE CONTRACT "ON H-COAL FLUID DYNAMICS"

AMOCO Project Status

1) Experimental Apparatus

Initial flow testing of the apparatus has been carried out using the single fluid, Dowanol DPM. This testing revealed three problems which limited the maximum flow up the column. The first of these was insufficient return line capacity which was corrected by replacing the horizontal and vertical sections of the line by a single angled run of pipe. The next problem was suction of entrained air in the fluid out of the holding tank and through the pump. This appears to have been taken care of by increasing the quantity of fluid in the system from 40 gallons to 55 gallons, thereby increasing both the depth and residence time of liquid in the tank. An additional quantity of diphenyl ether (~ 9 gallons) has been ordered and received, which will allow us to make up 65 gallons of the DPM-diphenyl ether combination.

The last, and currently being corrected problem, was too great a pressure drop from the pump exit to the bottom of the column (~ 12 psi at 3.5 inches/sec flow velocity in the column). To achieve the desired amount of bed expansion (about 30% volume fraction for the glass catalyst simulator), approximately 4.0 inches/sec will be required. To obtain this, the bulk of the one inch inlet piping is being converted to 1.5" piping, and some of the bends being eliminated.

In addition to the flow problems, our fluid became darker and darker the more the system was run. The pump also started to make abnormal sounds, and upon taking it apart we discovered both the impeller bushing (carbon) and shaft (stainless steel) were badly worn. Loose bushing material matched debris that had been filtered out of the fluid. A trip to March Pump Company in Glenview revealed that carbon and stainless steel are incompatible. Two ceramic shafts along with a new carbon bushing were provided. Besides converting to 1.5" input piping, a large flow capacity filter vessel is being added to maintain a clear liquid.

2) LDV Optics

The LDV optics are being assembled to work in the backscatter mode, but due to the need to keep the probe as small as possible, and the resulting small separation (~ 2 mm) between the two incoming beams, the receiving optics must be entirely separate from the input optics. This means an ability to align the two sets of optics so that they have the same focal point must be built into the probe. The method which has been decided upon to achieve this is as follows.

The receiving optics focus whatever reflected light they receive from the region about the focal point of the input optics to a corresponding region within the receiving tube. The signal is picked up by a narrow optical fiber, the end of which can be moved about inside of the tube. By positioning it at the point corresponding to the input optics focal point, the two sets of optics are aligned. The positioning is accomplished by putting a length of very thin hypodermic tubing inside of the receiving tube, positioned so that one end is in the focal plane of the optics, and the other end accessible at the rear end of the receiving tube. It is pivoted in the middle like a teeter-totter, and the optical fiber threaded through it. Two micrometers are then attached to the accessible end of the hypodermic tubing. The machining and assembling of the necessary parts is under way.

3) Holography

The traversing tables, which support the optical components, have been built and installed. Minor adjustments were made to align the System. For the holography experiments, two optical set-ups will be used and these are shown schematically in Figures 1 and 2. It is expected that the optical set-up shown in Figure 1 will be used predominantly. The main advantages in this set-up are that it is easier to examine the holographic plate -- no obstruction by the spool pieces; and one less folding mirror is required. However, we want to use the optical set-up shown in Figure 2 to check the θ dependence in the data.

4) Impedance probe

The idea of a radio-frequency was abandoned due to the small difference in dielectric constants of oil and nitrogen gas. Instead it was decided that an intermediate frequency (~ 10 kHz) impedance probe is to be used. The electronic circuit has been designed and all the necessary parts have just arrived. A schematic of the probe (Fig. 3) which has been built is enclosed.

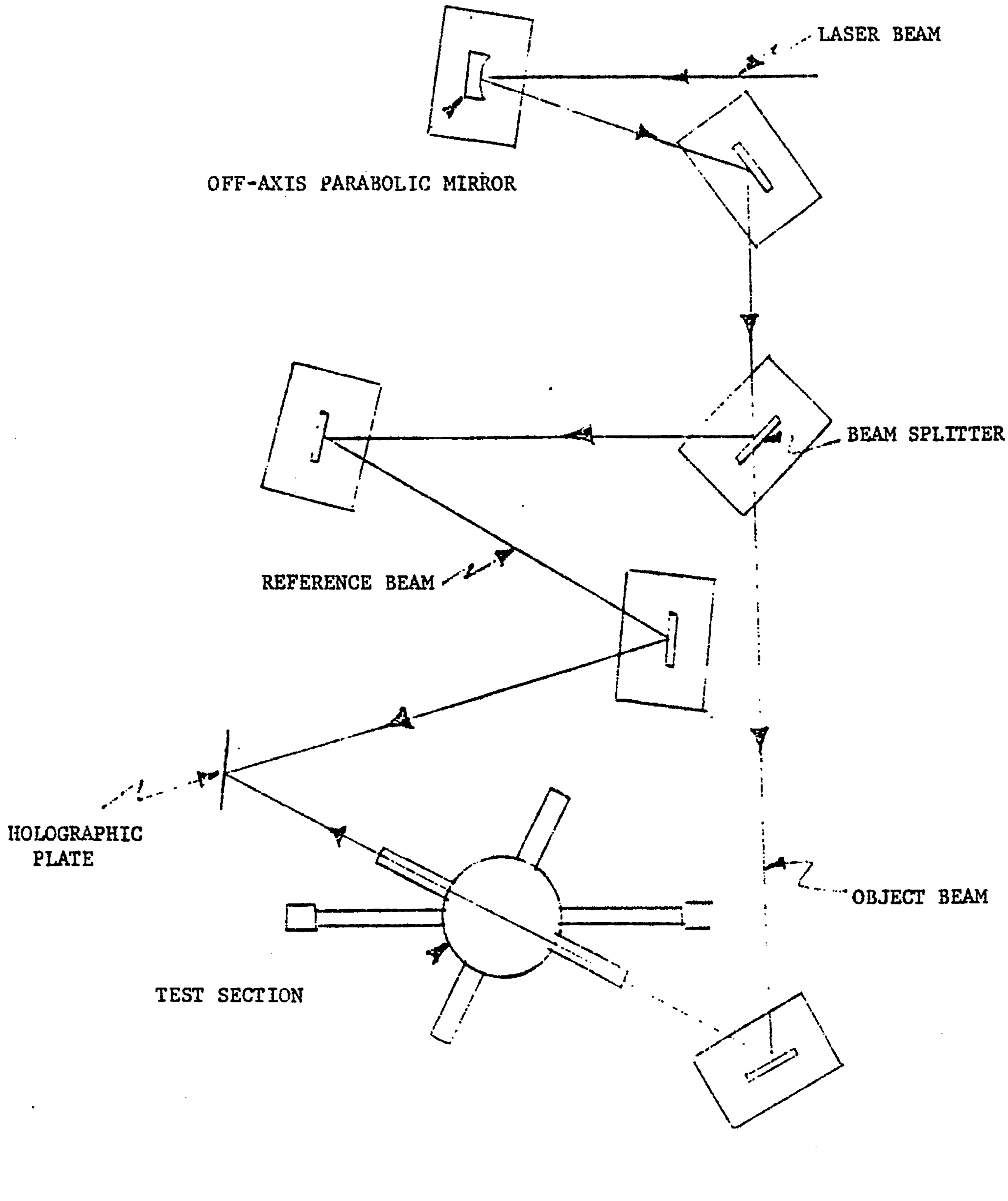


FIGURE 1. OPTICAL SET-UP (OFF-AXIS HOLOGRAPHY) TO DETERMINE BUBBLE SIZES AND DISTRIBUTIONS.

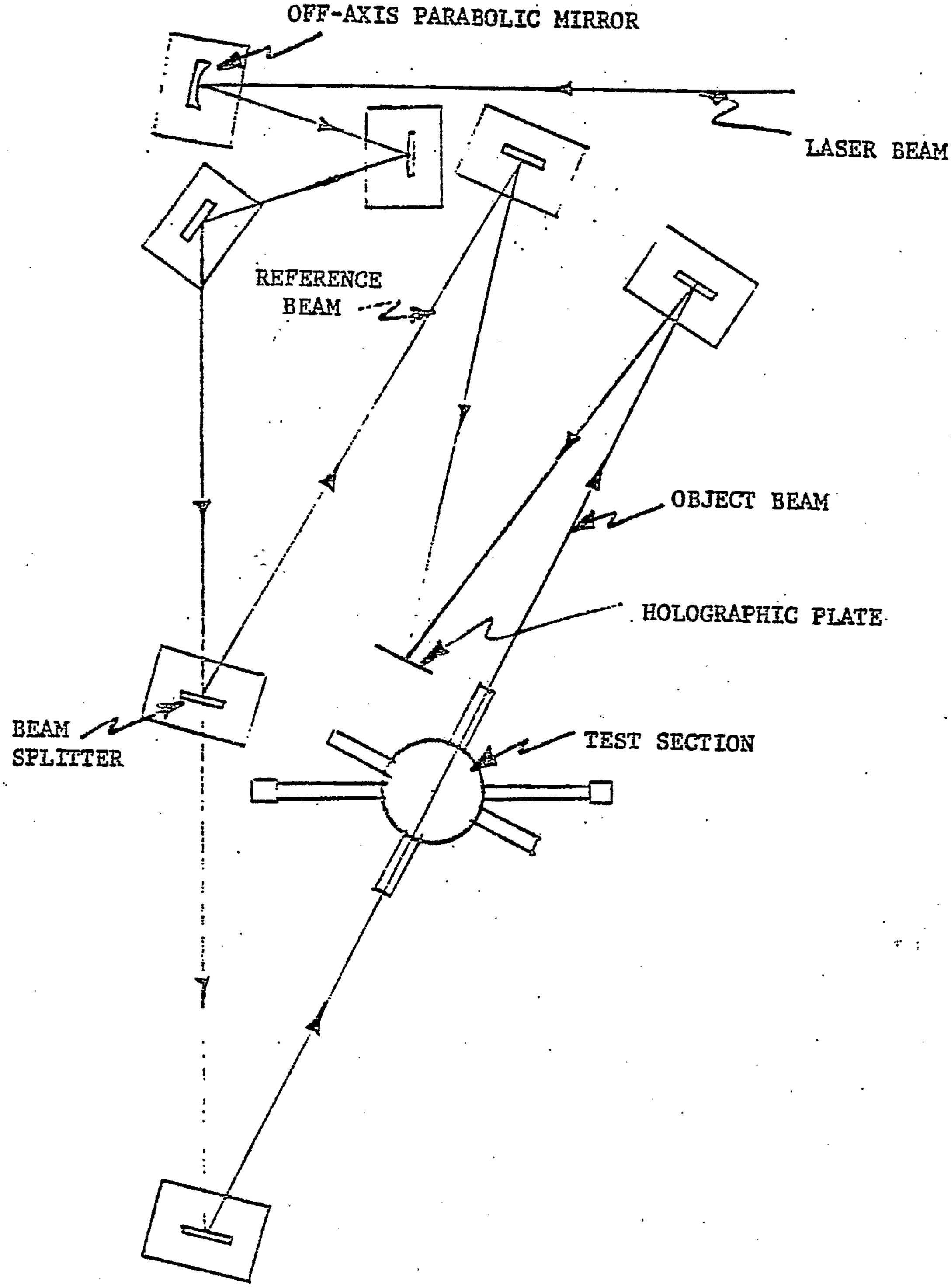


Figure 2. OPTICAL SET-UP (OFF-AXIS, HOLOGRAPHY) TO DETERMINE BUBBLE SIZES AND DISTRIBUTIONS.

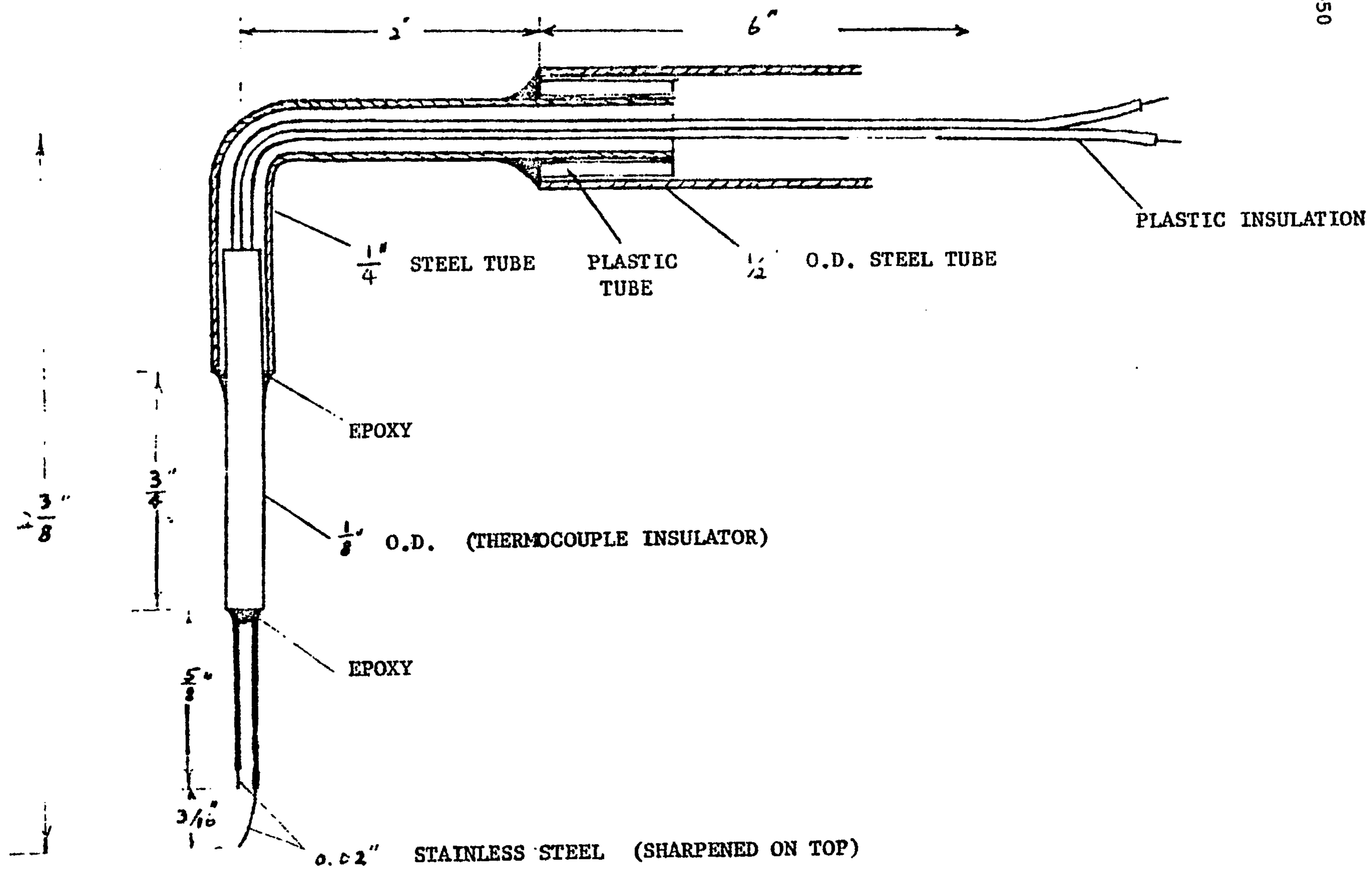


FIGURE 3. A SCHEMATIC OF THE IMPEDANCE PROBE.

MONTHLY (NOVEMBER 1980) PROGRESS REPORT ON AMOCO DOE CONTRACT "ON H-COAL FLUID DYNAMICS"

AMOCO Project Status

1) Experimental Apparatus

The conversion from 1.0" to 1.5" piping (explained in last month's report) between the pump discharge and the bottom of the column has been completed and we are now able to obtain the necessary flow rate to achieve the desired bed expansion.

2) LDV Optics

A probe capable of functioning in air has been assembled and tested by measuring the velocity of a rotating plastic disk. The probe produces good doppler bursts and the method of aligning the transmitting and receiving optics described in last month's report works very well. The design of the somewhat more complicated optics for use in a fluid of 1.474 refractive index has now been completed and the necessary lenses ordered.

3) Impedance Probe

The circuit for the probe is almost built except for part #TL 560 cp which has not arrived. A diagram of the circuit is shown in Fig. 1.

An apparatus for testing the probe has been built (shown in Fig. 2). There are three positions for the probe. Bubble size and velocity are to be measured using the probe and from photographs. Results obtained by these two methods will be compared.

4) Holography

The optical flats and beam splitter have been received and the optical mounts have been constructed. We are now in the process of setting up the optical components on the traversing table and expect to take holograms in the near future.

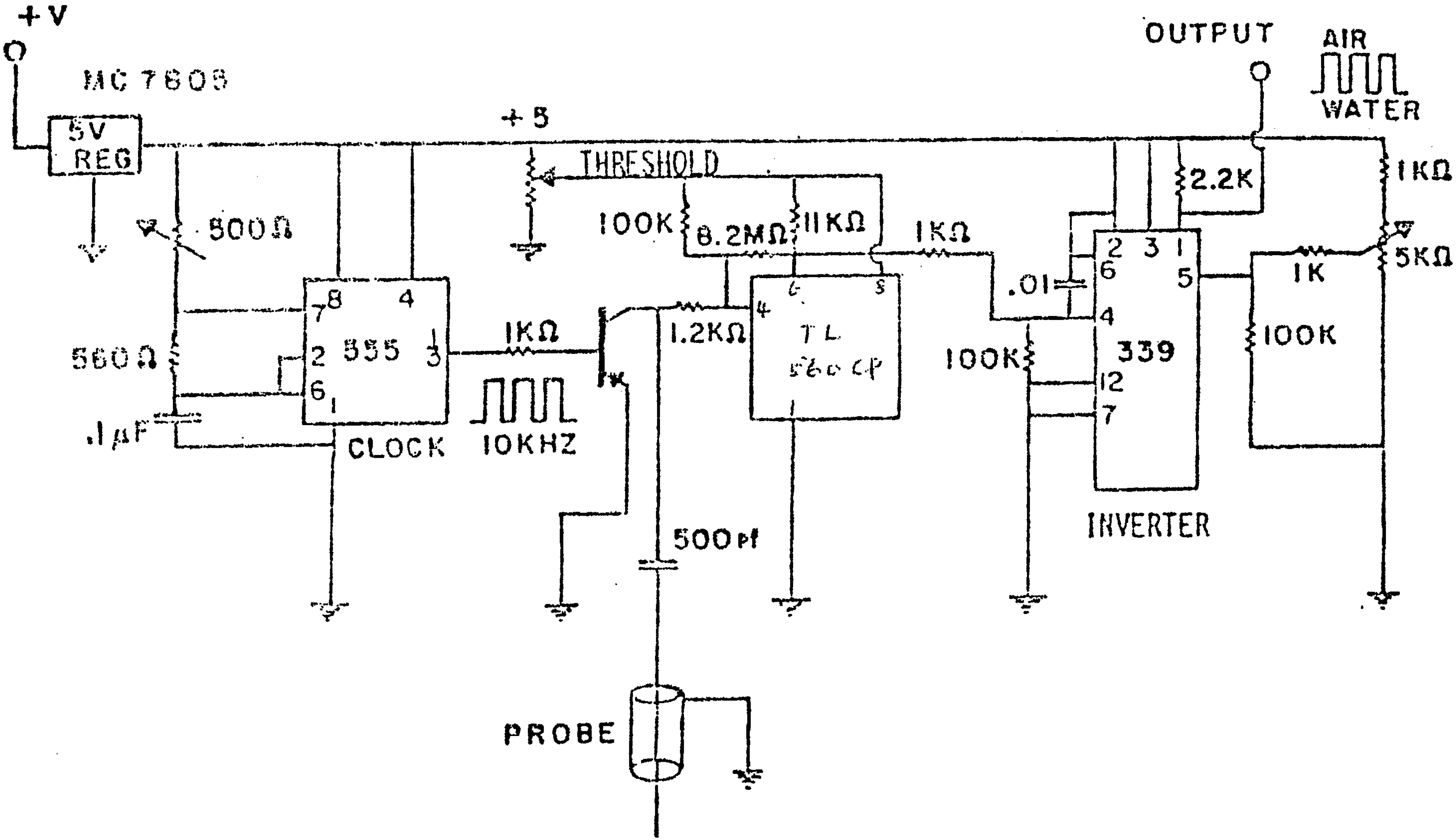


FIG 1 PROBE CIRCUIT

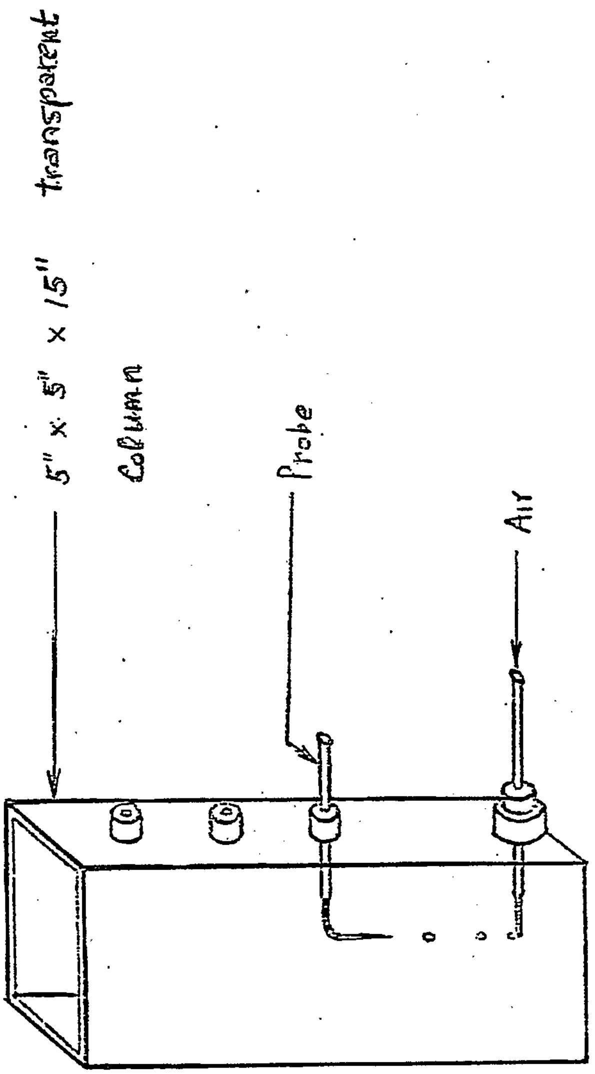


Fig. 2 Test Apparatus

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