MWL-MPR-30

RESEARCH AND DEVELOPMENT DEPARTMENT

KELLOGG

DEVELOPMENT OF KELLOGG COAL GASIFICATION PROCESS

Contract No. 14-01-0001-380

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Progress Report No. 30

APPROVED:

Project Manager

MANAGER

RESEARCH & DEVELOPMENT DEPARTMENT

CONTENTS

I. SUMMARY

This progress report is the thirtieth since the awarding of the contract. It is concerned with the first phase of the contract and summarizes the progress that has been made in the three principal areas now being studied: process research, chemical engineering studies and mechanical development.

Seven new combustion runs have been made in an effort to determine the effect of melt height on combustion rate of bituminous coke. This effect was found to be greater than was previously found for gasification. In increasing bed depth from two to six inches, combustion rate was found to just about halve. However, the rate appears to level off at bed heights beyond six inches.

The effect of initial carbon concentrations from two to eight percent on combustion rate was also studied. This effect was found to parallel the effect on gasification but at lower rates. There appears to be an approximately linear effect on rate over the range of carbon levels studied.

Process design of the hydrogen-from-coal plant has been completed and equipment specifications have been submitted for cost estimation. Design work on the synthesis gas plant has been continued.

Work has been begun on the preparation of a preliminary process design of the one-ton-per-hour pilot plant in order to provide the basis for a detailed mechanical design and to delineate the most important problem areas yet remaining.

Studies were made of the time required for a simulated melt to degasify after the bed was aerated with carbon dioxide at velocities up to three feet per second. Such data are required to determine the size of the stilling section required above melt withdrawal outlets in order to minimize cross flow contamination. Degasification times up to about 45 seconds were observed at high aeration rates, although additional experiments are required to confirm these results.

Tests on cross flow contamination for water and ethylene glycol with bed superficial velocities of 2.0 feet per second have been completed. The results of these tests continue to be encouraging.

II. PROCESS RESEARCH

A. Accomplishments

The effect of melt height on the rate of combustion of bituminous coke was studied in the 2" ID Inconel reactor. This effect was found to be greater for combustion than was previously found for gasification. The results indicated a leveling off with increasing height at about 12 to 13 lbs. carbon (as coke) combusted/hr/cu ft of melt. The effect of initial carbon concentration of 2 to 8% in the melt on combustion of bituminous coke was found to parallel the effect on gasification but at a lower rate. The summary of the eleven combustion runs is presented in Table I and discussed below.

1. Effect of Melt Height on Combustion of Bituminous Coke

A series of seven runs, numbers 149 to 155, completed a study of the effect of melt height in the 7" ID reactor on the combustion rate of bituminous coke, one of the least reactive feedstocks. The results had to be corrected to 1740°F average reaction temperature in order to allow a direct comparison. The actual and the corrected rates are presented in the following tabulation.

Melt Height inches	Avg. Run Temp. °F	Combustion Rate-lbs C/hr/cu.ft. For Run	at 1740°F
2	1758	32.7	28.8
3	1749	21.7	20.3
4	1752	17.4	16.1
5	1757	15.9	14.1
6	1765	15.6	13.1
6	1819	22.8	13.1
8	1801	18.6	12.7

The first five runs were made with the reactor in the usual position relative to the furnace. Bed expansions during combustion did not appear to be as high as during gasification. However, to make sure that the temperature profile was not interferring with the results, the furnace was moved 5 inches up so that the bottom of the reactor was even with the bottom winding of the furnace. This height adjustment influenced the average temperature and the rate, but the rate corrected to 1740°F was identical with the previous run.

The adjusted combustion rates are plotted in Figure I against melt height and compared to previous results for gasification at similar conditions. Although the results at 2 inches are about the same, increasing melt height has a much greater effect on combustion than gasification. Notably, the leveling off effect at 6 to 8 inches at about 12-13 lbs C combusted/hr/cu ft melt may be of interest when considering larger beds at commercial heights of 10-20 feet.

2. Effect of Carbon Concentration in Melt on Combustion Rate.

A series of four runs, numbers 156 to 159, studied the effect of initial carbon concentration in the melt on the combustion rate of bituminous coke. The results of these and a prior run (H-141) are shown in the following tabulation.

% C Init.	% Ash	Temp. °F	Combustion Rate lbs C/hr/cu.ft.(1) at Temp.	at 1740°F & 2% Ash
2	2.0	1740	4.8	4.8
4(H-141)	2.0	1740	8.3	8.3
4	2.1	1740	8.9	8.9
6	2.4	1745	19.0	17.7
8	2.8	1793	34.4	23.0

(1) Basis initial carbon concentration shown.

These adjusted rates for combustion are compared in Figure 2 with rates of gasification at equivalent conditions. Rates of gasification are two to three times the values for combustion. The two curves show essentially a linear relationship with perhaps an indication of slightly better carbon utilization at the low carbon level.

B. Projections

Evaluation of the effect of pressure and the effect of superficial gas velocity on the rate of combustion of anthracite will be determined. Both of these variables had little or no effect on the rate of combustion of bituminous coke. Further investigation of the combustion mechanism will be made.

TABLE I

SUMMARY OF COMBUSTION RUNS IN MOLTEN SODIUM CARBONATE[/1/]

Run No. H-	149	150	151	152	153	154	155	156	157	158	159
Date - 1967	1/4	1/5	1/6	1/9	1/10	1/11	1/12	1/17	1/18	1/19	1/20
Feed	← Bituminous Coke →										
% Fixed Carbon					93.2						
% Total Carbon					0.6						
% Vol. Matter					6.2						
% Ash					18.5						
Gas. Charge					12/20						
Mesh Size											
% C in Melt - Initial	← 4 →							2	4	6	8
Melt											
Gms. Na_2CO_3	202.9	/3/ + 102	/3/ + 112	/3/ + 106.4	/3/ + 106.4	/3/ + 5	/3/ + 207.66	405.7	/3/	/3/	/3/
Gms. Ash	4.2	+1.47	+1.17	-0.79	+0.57	-	+0.56	8.3	-	-	-
% Ash in Melt	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.14	2.41	2.81
Height - Inches	2	3	4	5	6	6 /5/	8 /5/	4	4	4	4
Conditions											
Temp °F - Initial	1740	1740	1740	1740	1737	1742	1738	1739	1740	1740	1742
- Average/2/	1758	1760	1752	1757	1765	1819	1801	1740	1740	1746	1793
- Maximum	1791	1780	1779	1790	1789	1837	1814	1749	1757	1765	1828
Pressure- psia	44.7	44.7	44.8	44.7	44.7	44.7	44.7	44.7	44.7	44.7	44.7
Sup. Gas Vel. - ft/sec	1.02	1.01	0.98	0.96	0.96	0.88	0.96	0.98	0.94	0.98	0.97
Run Time - mins.	20	25	30	45	40	15/4/	35	60	60	55	55
Air Rate - liters/min	27.1	26.9	25.9	25.5	25.5	23.3	25.3	26.0	25.0	26.0	25.8
Results - Product Gas											
% CO_2 - 5 min	3.6	4.5	5.5	6.9	7.9	11.9	13.2	1.6	3.0	6.6	11.75
- 35 min	-	-	-	1.4	2.0	-	-	0.8	1.3	2.5	1.9
- end	1.2	1.6	1.6	0.6	1.3	7.5	1.9	0.4	0.5	0.85	0.85
% O_2 - 5 min	17.5	17.0	16.0	14.0	12.5	8.5	8.0	19.0	17.5	15.0	9.75
- 35 min	-	-	-	19.0	18.0	-	-	19.5	18.5	18.5	18.0
- end	19.3	19.5	19.5	19.0	19.5	13.0	18.5	20.8	20.2	19.5	19.5
Combustion Rate Constant	2.77	1.84	1.48	1.35	1.32	1.94	1.58	0.84	0.753	1.06	1.41
% Fixed Carbon Consumed	105	97	97	100	102	79	101	100	88	100	97
Rate - Lbs C/Hr/ Cu Ft at 4% carbon init.	32.7	21.7	17.4	15.9	15.6	22.8	18.6	9.9	8.9	12.5	16.6
% Total Carbon - Devolatilized	7.4	8.1	7.9	7.5	6.8	6.9	5.8	9.4	5.9	5.2	4.9
- Combusted	97.9	88.9	89.1	92.1	95.0	72.1	95.4	90.3	82.3	94.9	91.9
- Left + Loss	-	3.0	3.0	0.4	-	21.0	-	0.3	11.8	-	3.2

/1/ Used 2-inch ID Inconel reactor. Coke charged in N_2 at 0.1 ft/sec S.O.V., 5-minute devolatilization period before air in.

/2/ Average temperature in 50% carbon consumed period.

/3/ Reused melt from previous run.

/4/ Plug developed at regulator which terminated run.

/5/ Furnace moved 5 inches, bottom reactor at bottom furnace.

FIGURE 1

EFFECT OF MELT HEIGHT ON GASIFICATION AND COMBUSTION RATES OF BITUMINOUS COKE

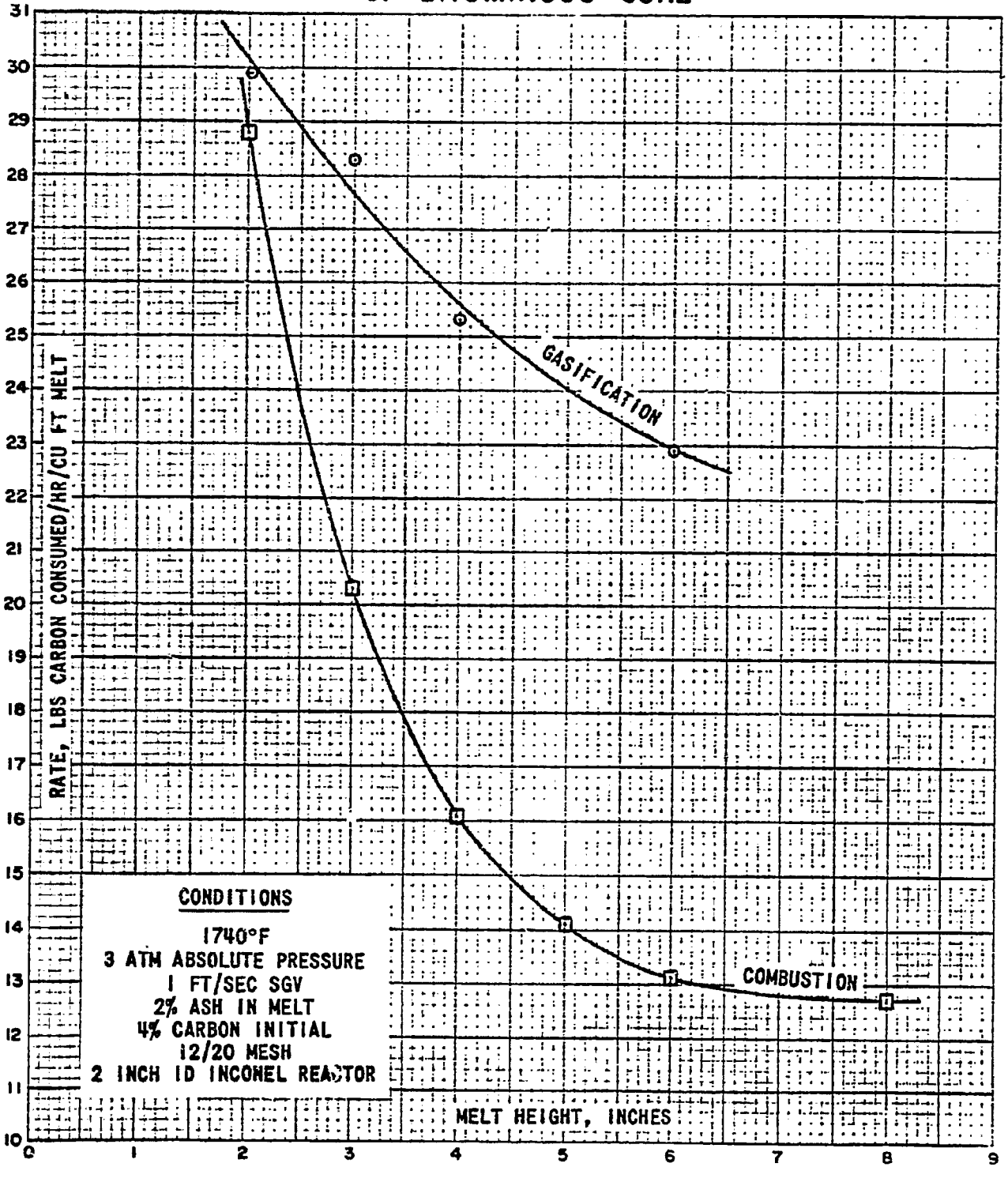
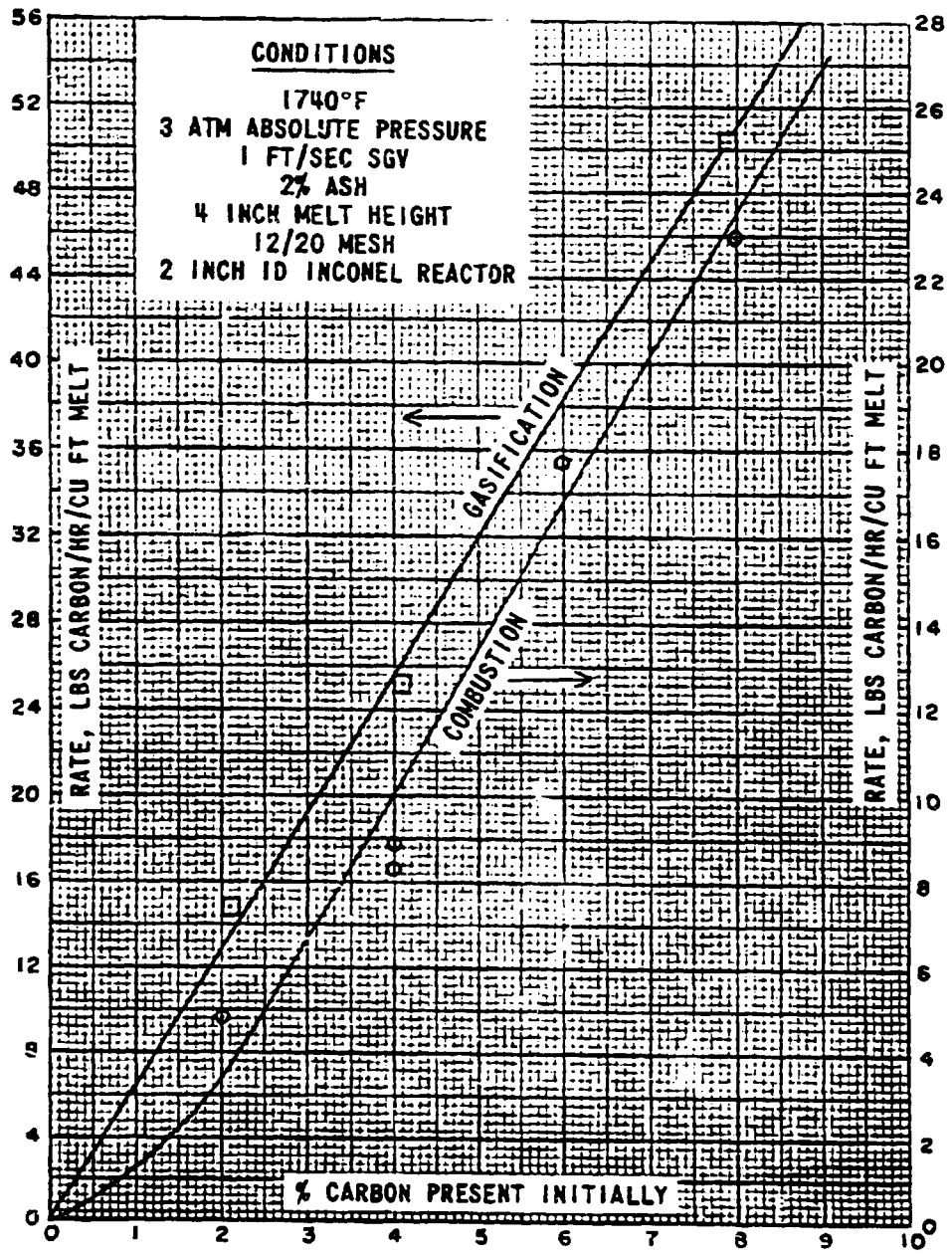


FIGURE 2

EFFECT OF CARBON CONCENTRATION IN MELT ON GASIFICATION AND COMBUSTION RATES OF BITUMINOUS COKE



III. CHEMICAL ENGINEERING STUDIES AND DEVELOPMENT

A. Accomplishments

1. Flowsheet Studies

Work has been completed on the process design for the hydrogen-from-coal plant. Equipment specifications have been drawn up and have been submitted for estimating the capital cost. Efforts have also been continued on the preparation of the flowsheet for a plant capable of producing synthesis gas from bituminous coal.

2. Pilot Plant Design

Preliminary work has been begun on the preparation of the process design of the one-ton-per-hour gasification pilot plant. Emphasis is currently being given to delineating the most important problem areas encountered in this design so that the existing experimental programs of Process Research and Mechanical Development can study them and thereby provide the necessary information required for the final process and mechanical designs.

B. Projections

Efforts will continue to prepare the process design of the synthesis gas-from-coal plant. In addition, cost estimation of the hydrogen plant will begin.

The preliminary process design of the gasification pilot plant will be completed and recommendations for possible further experimental work will be made.

IV. MECHANICAL DEVELOPMENT

A. Accomplishments

1. Mechanical Characteristics Testing

The time required for molten sodium carbonate with eight percent ash to degasify was measured using the experimental test setup for determining bed expansion as previously described. The electrical dip stick was placed 1/4 inch above the 3-foot still bed height. Carbon dioxide was used to aerate the bed at superficial velocities up to three feet per second.

The expanded bed made contact with the dip stick. After approximately two minutes the gas flow was stopped and the time required to break contact with the dip stick was recorded. The results of this test are shown on Figure 3. It should be noted that slight differences in dip stick height created a substantial difference in the recorded deaeration times. At about 1/2 inch above the bed, times as low as three seconds were recorded with bed superficial velocities of 2.0 feet per second. The longer times may have been the result of melt drip from the dip stick, or froth.

Additional work is required in this area to confirm the results and isolate the reasons for wide variations in time with small charges in dip stick settings. This data will be useful in determining the size of the stilling section required above melt withdrawal outlets in the coal gasification reactors to minimize cross flow contamination.

2. Melt Circulation

Tests on cross flow contamination for water and ethylene glycol with bed superficial velocities of 2.0 feet per second have been completed. The results of these tests are shown on Figure 4 and Figure 5. The results of these tests continue to be encouraging.

B. Projections

1. Mechanical Characteristics Testing

Bed degasification tests similar to those previously conducted will be made with the dip stick at three different heights above the bed. This should provide a better indication of bed deaeration time and can be conducted in such a way as to

eliminate or identify drip or froth problems if they exist.

Similar tests will be conducted for water and ethylene glycol with the view of possibly using degasification data to predict cross flow contamination in the circulating melt system.

An experimental test setup to determine entrainment in the aeration gas exiting a sodium carbonate melt bed is being constructed. Entrainment data will be obtained for a three-foot bed in a 5-3/4" I. D. vessel. It is planned to determine both amount and deposit temperature. This data will be helpful in the design of reactor overhead equipment.

2. Melt Circulation

Previous work on prediction of melt circulation with an air lift pump will be extended to the case of essentially zero lift. Experimental work will be used to confirm the predicted flows with zero lift. The proposed pilot plant transfer lines will be sized and gas rates predicted for the required flow rates.

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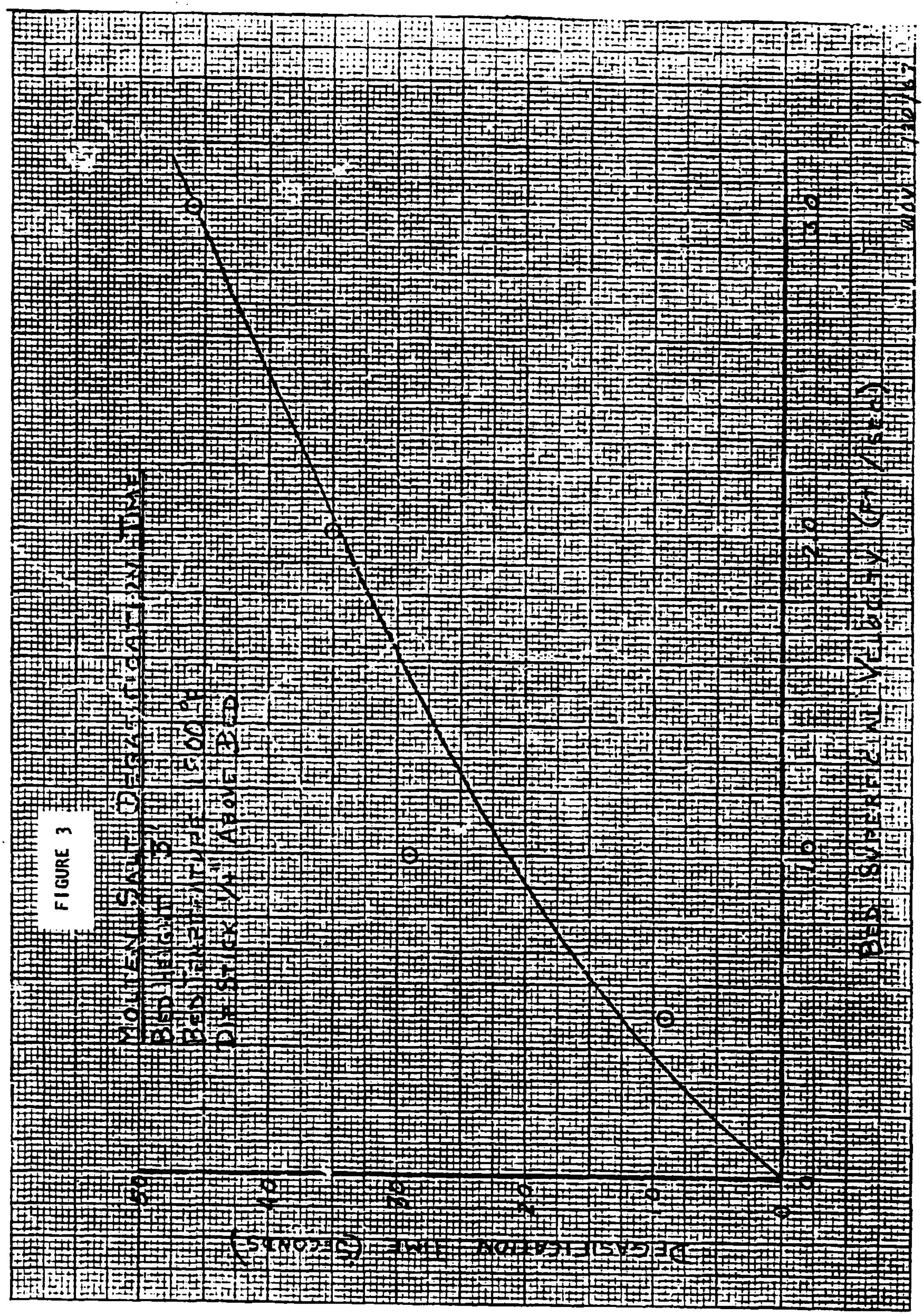

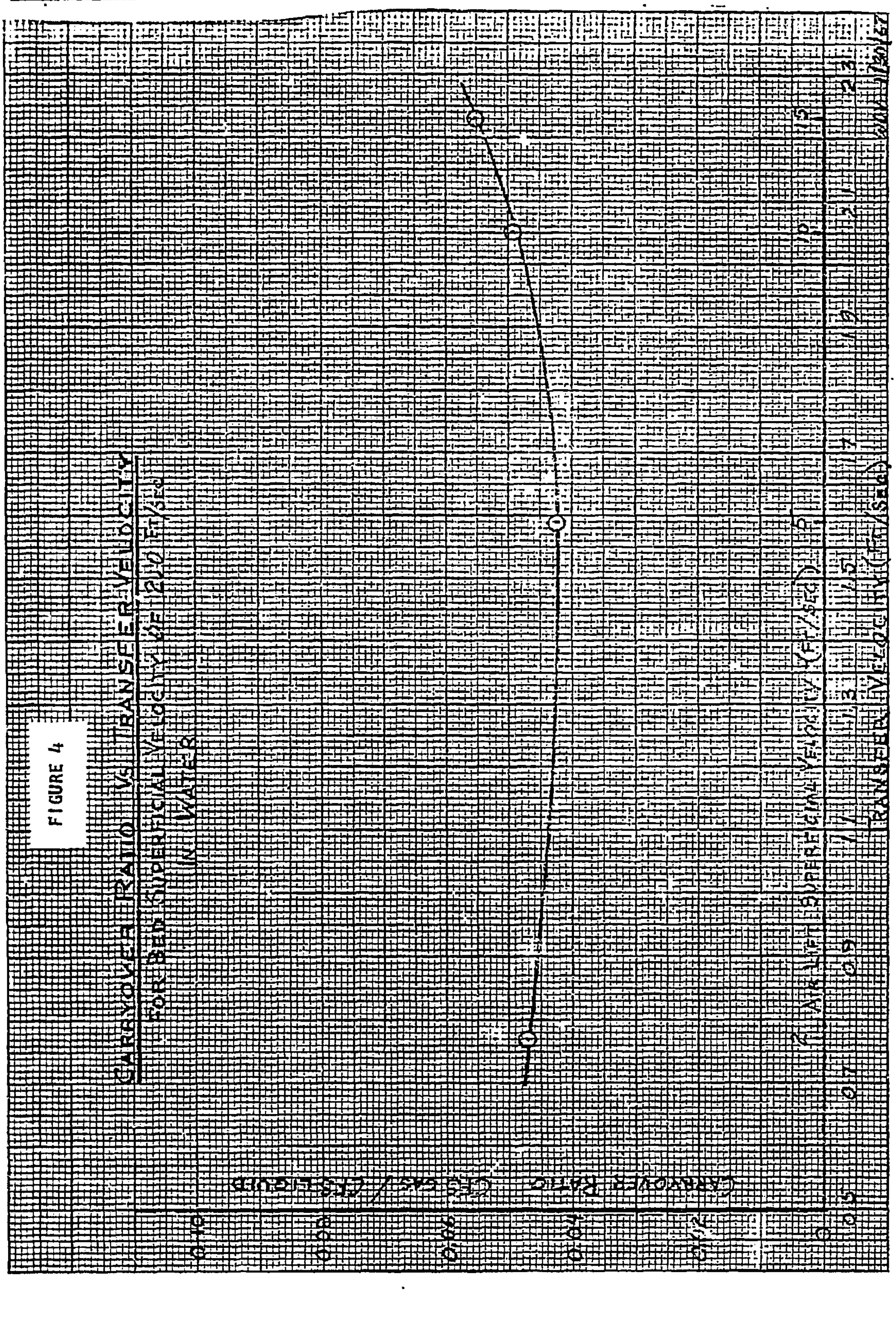
CARRYOVER RATIO Vs TRANSFER VELOCITY
FOR BED SUPERFICIAL VELOCITY OF 2.0 FT/SEC
IN WATER
AIR LIFT SUPERFICIAL VELOCITY (FT/SEC)
TRANSFER VELOCITY (FT/SEC)
CARRYOVER RATIO CFS GAS / CFS LIQUID
0.10
0.08
0.06
0.04
0.02

FIGURE 4

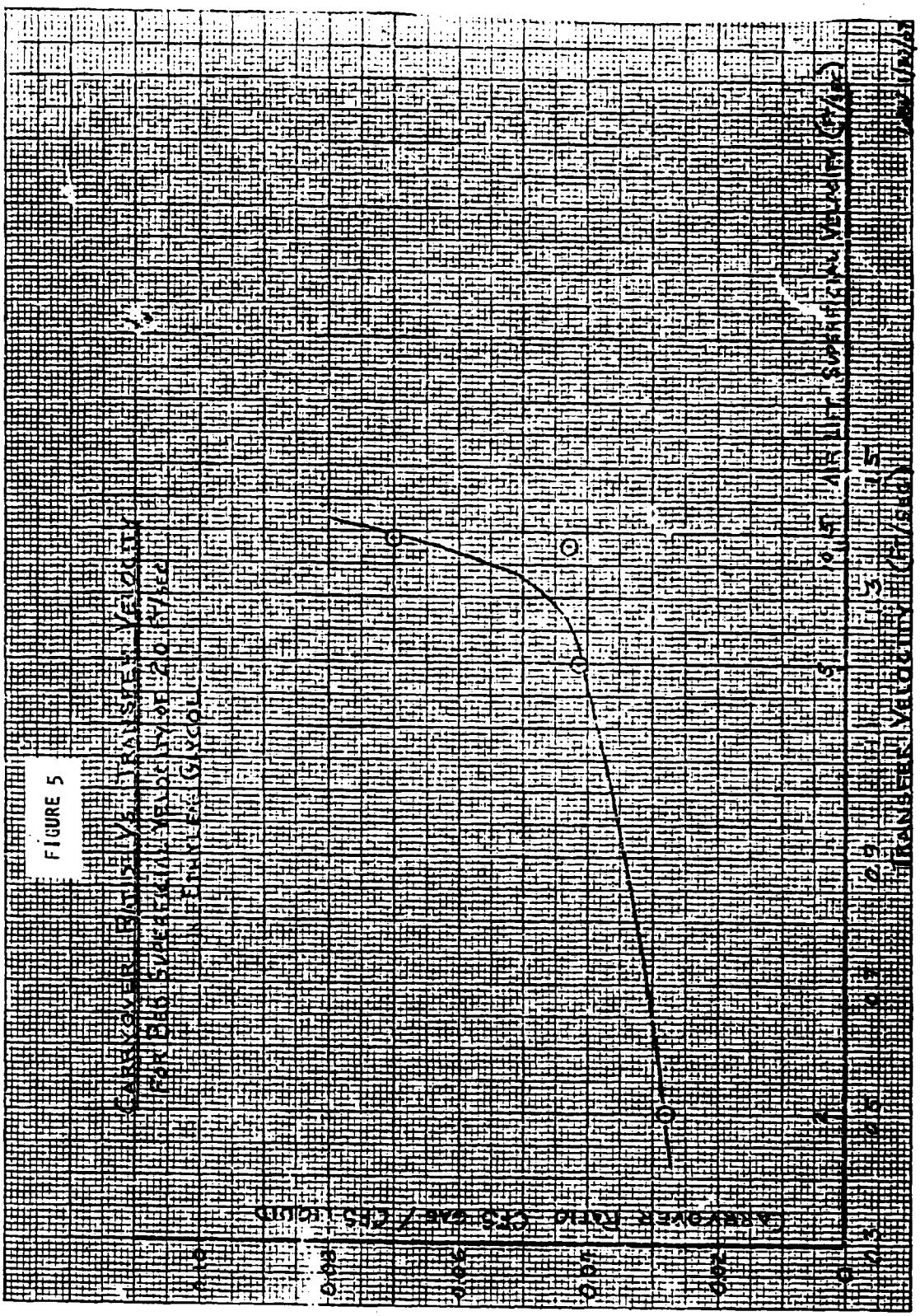
CARRYOVER RATIO VS. TRANSFER LINE VELOCITY
FOR BIG SUPERFINE ALUMINA AT 20 #/FT³
IN ETHYLENE GLYCOL
TRANSFER VELOCITY, (FT/SEC) 25 30 35 40 45
AIR LIFT SUPERFICIAL VELOCITY (FT/SEC)
CARRYOVER RATIO (LBS CAT / LBS LIQUID)
0.0 0.05 0.10 0.15 0.20

FIGURE 5