

MWK-MPR-27

RESEARCH AND DEVELOPMENT DEPARTMENT



DEVELOPMENT OF KELLOGG COAL GASIFICATION PROCESS

Contract No. 14-01-0001-380

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THE M. W. KELLOGG COMPANY  
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### 1. SUMMARY

This progress report is the twenty-seventh 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.

Twelve new combustion runs have been made with bituminous coke in an effort to determine the effects of air pressure, superficial velocity, and ash level on rate. Contrary to expectations, neither air pressure in the range of 1 to 8 atmospheres nor superficial velocity in the range of 0.5 to 1.5 ft./sec. had any appreciable effect on the rate of combustion.

However, ash level in the melt was found to have an appreciable effect on combustion rate. Measured rates with 12% bituminous ash were found to be about 3.8 times higher than those obtained in pure sodium carbonate, and within this range the rates varied almost linearly with ash content.

A study was made to determine the economic incentives of recovering various by-products from the process. By-products considered were alumina, magnesia, titania, hydrated lime and sulfur. In addition, consideration was given to the possibility of selling the ash-carbon- $\text{Na}_2\text{CO}_3$  residue as aggregate for use in construction. Depending upon the feed, a credit of from 0.3 to 8.5¢/MSCF could be realized for pipeline gas manufacture. Sulfur was found to be the most important single by-product with credits of from 0.2 to 2.8¢/MSCF (with sulfur selling at \$30 per ton) being possible.

The complete recovery of sodium carbonate also offers the possibility of further cost savings. Credits of from 2 to 12¢/MSCF could be realized if all the salt could be contained in the process.

Studies have been made to determine whether any experimental work can be done prior to the design and construction of a pilot plant to determine the efficiency with which coal can be burned in molten salt and with which the subsequent heat evolved can be transferred to the melt. Efforts to design a larger scale unit than the present laboratory apparatus have thus far not been successful. However, initial attempts to gain such information from the existing equipment have been encouraging and further attention is being given to this approach.

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Corrosion Test #10 has continued to 450 hours where furnace failure has caused a temporary halt to the test.

A series of tests to study the effect of air velocity on the bed expansion of water, ethylene glycol and glycerine-water mixtures have been completed in a 5-1/2" I.D. plastic tower. It is anticipated that by studying these systems a better understanding of the behavior of the molten salt system can be obtained when laboratory studies on this system are made.

Experiments have also been conducted to determine the magnitude of cross-contamination of synthesis gas by combustion gas which can be expected in a commercial gasifier-combustor design. These simulation tests have been conducted using water as the liquid and oxygen and nitrogen as the lift gases in the two vessels. The results thus far have indicated that cross-contaminations are at least of the same order of magnitude as the acceptable contamination levels based on the allowable inert content of the product pipeline gas. Further reductions in this contamination appear possible by improving the design of the cross-flow system.



## ii. PROCESS RESEARCH

### A. Accomplishments

Effects of air pressure, superficial velocity, and level of bituminous coal ash on the rate of combustion of bituminous coke in the 2" I. D. reactor have been determined. Contrary to expectations, air pressure in the range of 1 to 8 atmospheres and superficial velocity in the range of 0.5 to 1.5 ft./sec. had no effect on the rate of combustion. However, ash level in the melt was found to have a significant effect on combustion rate. The summary of the combustion runs is presented in Table 1 and discussed below.

#### 1. Effect of Air Pressure on Combustion of Bituminous Coke

Runs 91 to 95 were made at 1 to 8 atmospheres air pressure, 1740° and 1840°F, 1 ft./sec. superficial air velocity, 4-inch bed height with a nominal level of 2% bituminous coal ash present, and 4% carbon initially. The results shown in the following tabulation indicate air pressure had no effect on combustion rate.

<u>Run</u> <u>H-</u>	<u>Pressure</u> <u>psia</u>	<u>Avg. Temp.</u> <u>F</u>	<u>Combustion Rate</u> <u>lbs. C/hr./CF</u>
92	14.8	1743	11.7
93	30.2	1750	17.7
49	44.7	1743	11.1
91	59.4	1740	10.6
94	120.7	1736	11.0
50	45.3	1841	22.2
95	120.6	1842	23.8

Run 93 was made with molten salt which had been used in the two previous runs, consequently it contained a higher amount of ash. However, adjusting the rate to 2% ash level and to 1740°F only brings the 17.7 rate down to 15.9, which is still unexplainably high. However, the large amount of evidence from the other runs certainly appears to indicate that air pressure has little effect on combustion rate.



This effect, although not expected, especially since pressure showed a positive effect on the gasification reaction of carbon and steam, has been mentioned in the literature<sup>(1)</sup>. This zero order effect has been attributed to coverage of the active sites on the coke surface by relatively stable oxides or by thermal healing or annealing of the new sites created by reaction. It may be that molten salt plays a role in this behavior.

2. Effect of Superficial Air Velocity on Combustion of Bituminous Coke

Runs 96 and 97 were made at identical conditions as well as earlier run 49, where only the superficial air velocity was varied from 0.5 to 1.5 ft./sec. The following tabulation of these runs indicates no effect of changing superficial air velocity. Thus, one may conclude that diffusion does not control the kinetics of combustion in this system.

Run H-	Super. Air Vel. ft./sec.	Rate lbs C/hr/CF
96	0.51	10.3
49	0.87	11.1
97	1.53	9.9

3. Effect of Ash Level on Combustion of Bituminous Coke

The remaining runs in Table 1 were employed to study the effect of zero to 12 weight percent ash from bituminous coal in the molten salt on the kinetics of combustion of coke derived from the same coal. Although conditions were held as constant as possible, runs made at 8 and 12% ash were accompanied by an increase in melt temperature from the exothermic combustion reaction, and gave higher combustion rates as shown in the following tabulation.

Run H-	Ash in Melt Wt. %	Temp. °F	Rate lbs C/hr/CF <sup>(2)</sup>
129	0	1740	6.0
130	0.27	1740	8.5
49	2.0	1743	11.1
98	4.0	1750	13.5
99	8.0	1794	29.5 (18.8)
100	12.0	1800	37.3 (22.8)

(1) "Chemistry of Coal Utilization", H. Lowry Ed., p. 921, Wiley (1963).

(2) Values in parenthesis are for rates corrected to 1740°F.



The results of this study have been graphed in Figure 1 where the rate increase is practically linear with increasing ash level in the melt.

This positive effect of ash on rate is difficult to interpret especially in view of the lack of dependence upon superficial air velocity. Ash, of course, has a physical effect of increasing viscosity which may play a role in the size of the air bubbles and their residence time in contact with the coke. However, it can also exert a chemical or catalytic effect on the overall carbon-oxygen reaction.

#### B. Projections

Evaluation of the effect on combustion of particle size and concentration of carbon in the melt remains to be done. Further investigation of the large effect of lignite ash on combustion is also being considered.

TABLE I  
SUMMARY OF COMBUSTION RUNS IN MELTER SODIUM CARBONATE (1)

Run No. & Date - 1966	91 10/3	92 10/4	93 10/5	94 10/7	95 10/10	96 10/11	97 10/17	98 10/19	99 10/20	100 10/20	129 10/26	130 10/27
-----Bituminous Coke VI-----												
Feed												
% Fixed Carbon	93.7											
% Total Carbon	90.6											
% Vol. Matter	6.7											
% Ash	18.5											
gms. charge	12720											
Mesh Size	4											
% C in Melt - Initial												
Melt												
gms. Na <sub>2</sub> CO <sub>3</sub>	405.7	(3)	(3)	405.7	(3)	405.7	405.7	(3)	(3)	(3)	414	(3)
gms. Ash	8.3	-	-	8.3	-	2.4	8.3	7.7	15.4	15.4	0	-
% Ash in Melt	2.0	2.26	2.5	2.0	2.26	2.26	2.0	4.0	8.0	12	0	0.27
Height - Inches												
Conditions												
Temp. °F - Initial	1740	1736	1746	1740	1847	1745	1746	1750	1740	1735	1740	1739
- average (?)	1760	1743	1750	1736	1847	1744	1740	1750	1754	1800	1740	1740
- maximum	1750	1758	1771	1746	1860	1755	1756	1776	1818	1822	1753	1750
Pressure - psia	59.4	14.8	10.2	120.7	170.6	66.8	66.1	44.9	66.1	(45.75)	44.5	45.1
Sup. Gas Vel. - ft./sec.	1.01	1.07	1.08	0.98	1.00	0.61	1.53	0.96	1.14	3.91	1.07	0.95
Run Time - min.	55	65	40	45	25	50	50	55	25	25	80	65
Air Rate - liters/min.	35.8	2.34	18.8	68.1	68.2	13.5	40.4	25.1	30.4	24.0	22.5	25.1
Results - Product Gas												
% CO <sub>2</sub> - 5 min.	2.7	2.5	7.0	1.9	2.8	6.8	2.1	1.9	7.7	9.3	2.5	3.0
- 35 min.	1.3	5.6	--	1.1	--	4.0	1.8	1.5	--	--	1.4	1.5
- end	1.2	1.7	1.2	1.0	1.6	1.3	0.7	0.9	2.3	1.7	0.6	0.9
% O <sub>2</sub> - 5 min.	18.5	13.0	15.0	17.5	19.0	15.0	13.0	17.0	13.0	12.5	18.0	17.0
- 35 min.	19.0	17.0	--	20.0	--	17.0	19.0	19.0	--	--	19.0	18.5
- end	19.0	18.2	19.0	20.0	20.0	19.4	20.2	20.0	18.0	11.5	20.0	19.0
Combustion Rate Constant	0.90	0.99	1.49	0.93	2.02	0.87	0.86	1.14	2.50	3.16	0.51	0.72
Total % Fixed Carbon Consumed	97.3	100	101	93.7	107	101	98.8	100	104	100	89	80
Rate - lbs. C/hr./CF	10.6	11.7	17.6	11.0	23.8	10.3	9.9	13.5	29.5	37.3	6.0	6.5
% Total Carbon - Devolatilized	5.0	6.3	6.5	4.5	5.8	4.7	1.6	4.5	4.7	8.1	4.2	6.0
% Total Carbon - Burned	92.5	93.6	94.7	89.5	100.4	96.1	95.1	95.4	95.6	92.2	95.1	63.1
% Total Carbon - Tar + Loss	2.5	0.1	--	--	--	--	--	--	--	--	--	--

- (1) Used 2" I. O. Inconel reactor. Coke charged in H<sub>2</sub> at 0.1 ft./sec., 5 min. devolatilization period before air introduced.
- (2) Average temperature in 50% carbon consumption period.
- (3) Reused melt from previous run.

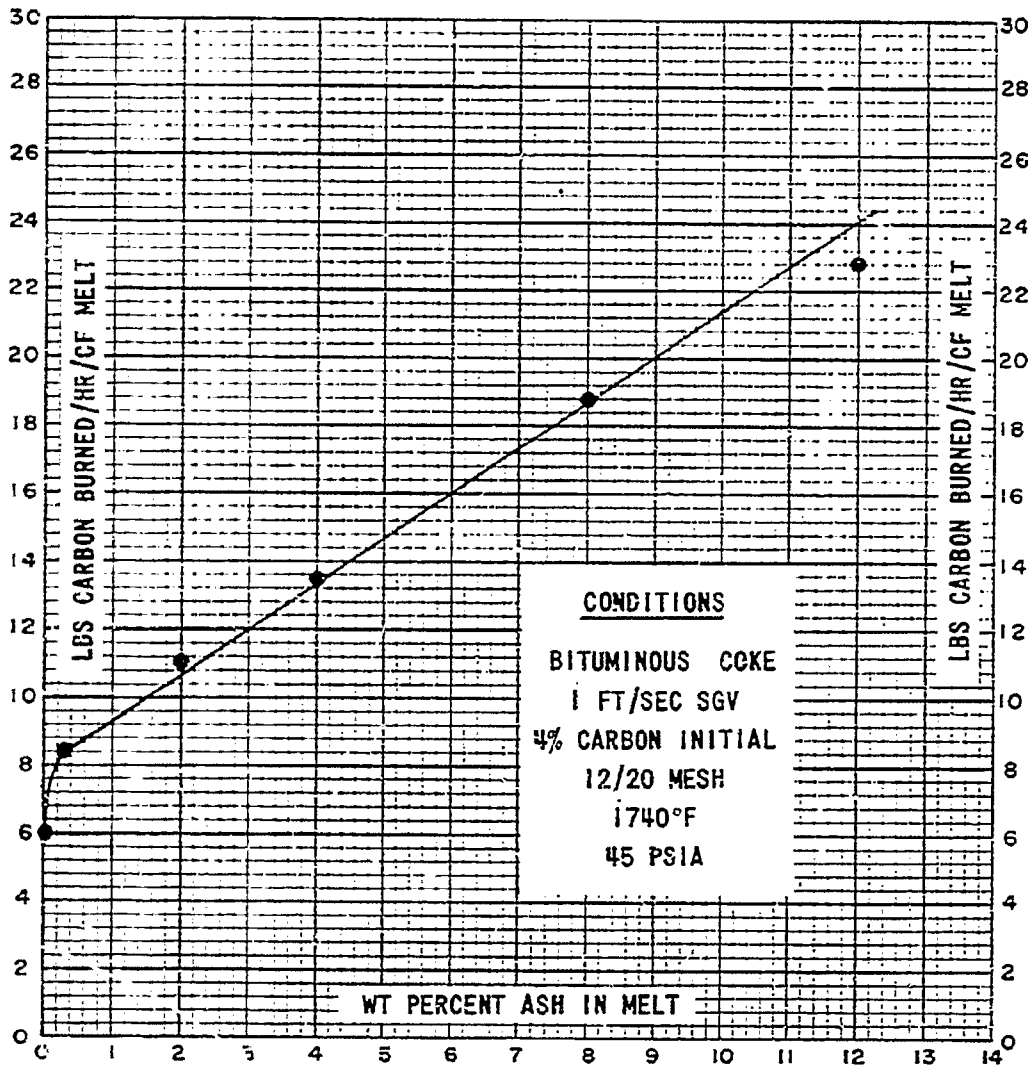






FIGURE 1

EFFECT OF ASH LEVEL IN MELT ON COMBUSTION RATE  
OF  
BITUMINOUS COKE





### III. CHEMICAL ENGINEERING STUDIES AND DEVELOPMENT

#### A. Accomplishments

##### 1. Secondary Product Recovery

A study has been made in an attempt to determine the economic incentives of recovering various by-products from the Molten Salt Gasification Process. By-products considered in this investigation included alumina, magnesia, titania, hydrated lime, and sulfur. In addition, consideration was given to the possibility of selling the ash-carbon- $\text{Na}_2\text{CO}_3$  residue as aggregate for use in construction. The results of this study are summarized in Table 2. The figures shown for each of the feeds indicates the range of credit which could be obtained by recovering sulfur from the synthesis gas and by either selling the solid residue as aggregate or by recovering the aforementioned minerals from the residue.

TABLE 2

#### POTENTIAL CREDITS IN PIPELINE GAS MANUFACTURE

##### FOR BY-PRODUCT RECOVERY

<u>Feed Material</u>	<u>Pipeline Gas Credit, c/MSCF</u>
Subbituminous	0.3 - 0.6
Bituminous	0.6 - 1.2
Anthracite	1.5 - 3.5
Lignite	2.7 - 3.5
Char	5.4 - 8.5

As can be seen, it is possible that pipeline gas costs could be reduced by recovery of by-products. However, the reduction is not sufficient to bring those cases with high costs below the fifty-cent level. A summary of the previously obtained gas costs for the aforementioned feeds is given in Table 3 and



the importance of secondary product recovery can be seen by comparing these two tables. The most important single by-product of the ones considered is sulfur. For the cases shown in Table 2, if only sulfur is recovered and sold for \$30 per ton, credits of from 0.2 to 2.8¢/MSCF could be realized, depending upon the feed.

There is another important material to be considered here, although it cannot strictly be classified as a by-product--namely,  $\text{Na}_2\text{CO}_3$ . Depending upon the feed material, anywhere from 2 to 12¢/MSCF are charged to gas cost for salt make-up (note Table 3). If more efficient and still economical means of recovering this additional salt from the residue could be developed, savings of this order could be realized in the gas selling prices.

## 2. Pre-Pilot Unit

Studies have been made to determine whether any experimental work could be done prior to a full-scale pilot plant operation to determine the efficiency with which coal can be burned in molten salt and with which the subsequent heat evolved can be transferred to the melt. Earlier calculations indicated that a high combustion efficiency is required for an economical operation. Various schemes to determine this efficiency have been considered and are summarized below:

### (a) Utilizing Present Reaction System

By calibrating the furnace power input for the existing 2" I. D. unit without combustion one could calculate the system heat losses at various conditions of melt temperature, gas flow rate, etc. If combustion experiments were then run at predetermined conditions, the percentage of the heat of combustion absorbed by the melt could be determined by utilizing the heat loss calibration curves thus obtained.

The main difficulties likely to be encountered using this method would be the thermal lag of the system and the reproducibility of similar runs. Also, the fact that the heat losses are most probably very large with respect to the total heat liberated would tend to obscure any small changes of melt temperature. This proposal is being investigated in more detail, and results so far are encouraging.

### (b) Utilizing Latent Heat of Fusion

The possibility of adding a suitable solid to the melt with a melting point in the range of 1600 to 1900 F and a high latent heat of fusion was then considered. The principle of operation would be that the solid would absorb the heat of combustion, melt, and the amount of solid left in the melt after a run would then be determined.

However, apart from the difficulties of measurements of the solid to liquid conversion, no solid was available which would absorb enough of the heat of combustion to permit its presence in the melt at reasonably low levels. This proposal was therefore abandoned.

TABLE 3  
COST SUMMARY  
250,000,000 SCFD OF PIPELINE GAS

Basis: 90% Stream Efficiency

<u>FEEDSTOCK</u>	<u>CHAR</u>	<u>ANTHRACITE</u>	<u>BITUMINOUS</u>	<u>SUBBITUMINOUS</u>	<u>LIGNITE 11*</u>
<u>TOTAL CAPITAL INVESTMENT</u>	<u>\$191,636,000</u>	<u>\$169,340,000</u>	<u>\$140,275,000</u>	<u>\$146,661,000</u>	<u>\$161,892,000</u>
	<u>Gas Cost, ¢/MSCF</u>				
Coal	20.5 (10¢/MM BTU)	53.3 (\$6/Ton)	21.1 (\$4/Ton)	14.8 (\$2/Ton)	21.3 (\$1.50/Ton)
Sodium Carbonate	12.1	4.4	2.8	1.8	6.8
Miscellaneous Chemicals	0.2	0.3	0.2	0.2	0.2
Sponge Iron	0.1	0.05	0.07	0.05	0.1
Methanation Catalyst	0.9	0.8	0.9	0.8	0.8
Direct Labor	2.0	2.2	1.7	2.0	2.0
Power Credit	-5.9	-9.1	-7.6	-8.9	-8.7
Maintenance	5.7	4.8	4.2	4.3	4.8
Supplies	0.8	0.7	0.6	0.7	0.7
Supervision	0.2	0.2	0.2	0.2	0.2
Payroll Overhead	0.2	0.2	0.2	0.2	0.2
General Overhead	<u>4.4</u>	<u>4.0</u>	<u>3.3</u>	<u>3.6</u>	<u>3.9</u>
Plant Operating Expenses	41.2	61.8	27.7	19.8	32.3
Depreciation	11.1	9.5	8.2	8.7	9.4
Local Taxes & Insurance	<u>6.7</u>	<u>5.7</u>	<u>4.2</u>	<u>5.2</u>	<u>5.6</u>
Subtotal	59.0	77.0	40.8	33.7	47.3
Contingencies	<u>1.2</u>	<u>1.5</u>	<u>0.8</u>	<u>0.7</u>	<u>0.9</u>
TOTAL OPERATING EXPENSES	60.2	78.5	41.6	34.4	48.2
GAS SELLING PRICE	72.1	89.9	50.3	43.5	58.3

\* Includes external sodium bicarbonate decomposition





(c) Utilizing Latent Heat of Vaporization

This method involves exactly the same principle as discussed in (b) except a liquid would be used to absorb the heat of combustion by being vaporized at its boiling point in the range 1600-1700°F.

However, the same limitations were apparent, namely that too much material would be needed in the melt for the purpose of the experiment.

This proposal was also abandoned.

(d) Utilizing the Endothermic Reaction of a Gas With Carbon Dioxide

According to the reaction  $X + CO_2 + \text{Heat} \rightleftharpoons CO + XO$ , the heat of combustion could be absorbed by a gas phase endothermic reaction with  $CO_2$  and the amount of CO in the reactor effluent measured analytically. A gas such as  $H_2$  could be used, whereby the reverse of the water gas shift reaction would occur, thus absorbing the heat of combustion. However, this could result in some of the coal being gasified by the steam formed (rather than being burned) and would make any valid conclusions difficult to make.

Preliminary results indicate that only about 6% of the heat of combustion could be absorbed in this way, so this scheme was eliminated.

(e) Combination Gasification/Combustion Reactions

This proposal would involve the simultaneous reactions of gasification (endothermic) and combustion (exothermic) in one vessel with analysis of the product-gas, and would be subject to the same difficulties as discussed in proposal (d). In a commercial unit, the flue gas stream and the gasifier effluent stream would be separate, and capable of detailed analysis from which valid conclusions could be made. This proposal precludes separate gasification and combustion studies and was therefore abandoned.

(f) Coil in Reactor

This is the most obvious method to remove the heat of combustion and has been analyzed in some detail. For this study the reactor heat losses are assumed to be small (i.e., the reactor is well insulated) and that the space in the melt occupied by the coil is small compared to the melt volume. Owing to the nature of the system under discussion other important limitations also apply, and are tabulated below, with discussion where relevant.



(1) Heat Transfer medium (inside coil) must enter the coil at not less than 1550°F to prevent freezing of the melt (MP 1564°F) on the outside of the coil. This stipulation limits the  $\Delta T$  on the coil side at 200 F to 400°F depending on the melt temperature and means large flows and large areas of coil.

(2) Heat transfer medium must be stable and transportable at 1550-2000°F. This eliminates all liquids; possible gases would be superheated steam or a gas with a high specific heat such as helium. Helium has been considered for this discussion.

From preliminary studies, it became apparent that a suitable design could only be realized if the rate of heat emission was low due to the limitation of heat removal from the reactor. This could be attained either by utilizing a relatively unreactive feed or by using a more reactive feed with a very low initial carbon level, (<1%). This level of initial carbon in the melt was considerably lower than that anticipated for a commercial plant (4%), and thus any results might not represent what would happen in the commercial unit.

However, comparisons of possible coil/reactor designs have been made and have resulted in the following conclusions:

(1) It is impractical to design a reactor/coil assembly which would give meaningful results at the conditions proposed for the full scale commercial plant (4% initial carbon).

(2) The maximum initial carbon level that could be tolerated in such a design would be of the order of 1% or less. The higher this value, the smaller the equipment and the more inaccurate the measurements.

(3) Heat losses from such a reactor assembly might invalidate any conclusions drawn as to efficiency of heat transfer.

Due to the problems associated with methods b through f, Scheme a is being investigated more fully using combustion data on char in the existing 2" I. D. reactor and the results so far appear encouraging.

### 3. Hydrogen

Work has continued on the preparation of a flowsheet of a plant capable of producing 250,000,000 SCFD of hydrogen from bituminous coal.



B. Projections

1. Pre-Pilot Unit

Efforts will be continued in an attempt to determine what type of experimental work can be done prior to the pilot plant to determine the efficiency of coal combustion and the subsequent transfer of heat to the melt. Particular attention will be given to the possibility that such data might be able to be obtained in the present 2" I. D. laboratory unit.

2. Hydrogen

Work will continue on the hydrogen-from-coal flowsheet.



#### IV. MECHANICAL DEVELOPMENT

##### A. Accomplishments

###### 1. Environmental Testing of High Temperature Materials

Corrosion Test #10 has progressed to 450 hours where furnace failure has again caused a temporary halt to the test. Repairs are being made to the furnace and a new Inconel corrosion test vessel is being fabricated. Testing will resume shortly.

###### 2. Mechanical Characteristics Testing

Preliminary tests on bed expansion of the melt indicated the need for three-zone control of the furnace and the required modifications to the furnace power and control circuits were made. A defect in the furnace construction caused a furnace failure which has been repaired by the manufacturer. A modification of the furnace is in progress to prevent recurrence and bed expansion tests will resume shortly.

A series of tests on the bed expansion of water, ethylene glycol and glycerine-water mixture (100 c.p. viscosity) have been completed in a 5-1/2" I.D. plastic tower. Figure 2 shows the test apparatus used to determine the bed expansion. An electrical dip stick method using the electrical conductivity of the fluids to complete the circuit was employed. Bed height and expansion were measured by bench mark on the dip stick in combination with recordings on a strip chart recorder of the voltage drop across a resistor in series with the dip stick circuit. In this way, the irregular height of the expanded bed could be measured by comparison of the bed contact pattern recorded on the strip chart. Figures 3 through 5 show the results of these tests. The bed heights shown on the curves are the quiescent (unaerated) bed height. The range of expansion shown for each bed height was obtained by lowering the dip stick into the expanded bed. The upper curve for each bed height represents the point at which substantial initial contact is made with the bed. The lower curve represents the point where nearly continuous contact is maintained between the dip stick and the bed.

Similar tests are planned for the sodium carbonate melt in the near future. A full comparison of the data will be presented at that time.





### 3. Melt Circulation

Previous work has shown the gas lift is the most suitable method of transferring the molten salt between the oxidation and gasification side of the process. A reasonable method of predicting the flow produced by the gas lift has been developed and previously reported.

Another area of importance in melt circulation is that of crossflow contamination. Preliminary evaluation of the process requirements indicate a level of contamination of about 0.01 cubic foot of contaminating gas per cubic foot of melt transferred is desirable. This level is based on the circulation required with a temperature difference of 70°F between process sides, and is set by inert limits in the product gas. Safety and dilution (efficiency) limits would allow much higher contamination.

In an effort to determine the order of magnitude of cross flow contamination that might be expected, tests are being carried out in a cross flow circulation model. In addition, preliminary design data and an appreciation of the factors involved in contamination control design are being developed in the model test. Figure 6 shows the test apparatus used.

To date, tests have been conducted with aeration superficial velocities in the vessel from 0 to 1.5 feet per second with liquid transfer line velocities from 0.77 feet per second to 2.23 feet per second, using water as the liquid. Oxygen was introduced as both the aeration gas and the gas lift on one side of the model and nitrogen was used on the other side.

Contamination was measured as a percent of nitrogen appearing in the outlet gas on the oxygen side. The cross flow contamination was then calculated in cubic feet of contaminant transferred per cubic foot of liquid transferred. The liquid transfer rate was obtained by previous calibration of flow at various gas lift superficial velocities. The contamination in the outlet gas was measured by means of gas chromatograph.

The results of these tests are shown on Figure 7. The lower three curves show the results (with the inlet sparger installed) for three rates of bed aeration. As can be seen from the data, the cross flow contamination carry-over ratio remained relatively constant over the range tested. Only a slight increase was noted above transfer velocities of 1.7 feet per second. As expected, an increase of bed aeration increased the carry-over ratio.



The upper curve shows the results of a similar test at the highest aeration rate with the inlet sparger extension removed. In this test, due to the proximity of the inlet to the cross flow outlet, large bubbles from the inlet were sucked through the outlet at transfer velocities above 1.7 feet per second. This resulted in the rapid increase in cross flow contamination shown and points up the need for careful consideration in the inlet and outlet design.

These preliminary results are quite encouraging. The cross flow contamination levels experienced in the model were within the order of magnitude of contamination levels currently envisioned for the actual process. Improvements in inlet and outlet design could reduce the level of cross flow contamination further if required by the process.

It is recognized that cross flow contamination results from carry-over of both entrained gas and dissolved gas which is stripped from the circulating liquid. The rate of dissolved gas carried over is a function of solubility and contact time. As a limit the Handbook of Chemistry and Physics indicates approximately 0.015 cubic foot of nitrogen will dissolve in one cubic foot of water at 70 F and one atmosphere pressure. This is approximately the total carry-over shown for the 0 aeration test. However, additional work is required to determine the actual split because we know by observation that even in the 0 aeration case we have entrained gas carried over and for the cases with aeration, the maximum dissolved carry-over cannot account for the total contamination. The actual split is, of course, important in the work of extrapolating this and other data to the actual process circulation.

## B. Projections

### 1. Environmental Testing of High Temperature Materials

Corrosion Test #10 will continue to completion.

### 2. Mechanical Characteristics Testing

Bed expansion tests will be carried out in the sodium carbonate melt with bed heights up to three feet and superficial velocities up to two feet per second or higher, if possible.

### 3. Melt Circulation

The effect of physical properties of the transfer liquid such as viscosity will be evaluated by model test in an effort to expand our predictions of cross flow carry-over and allow extrapolation of data to a molten sodium carbonate system. Ethylene glycol will be used as the transfer liquid in the next series of tests.

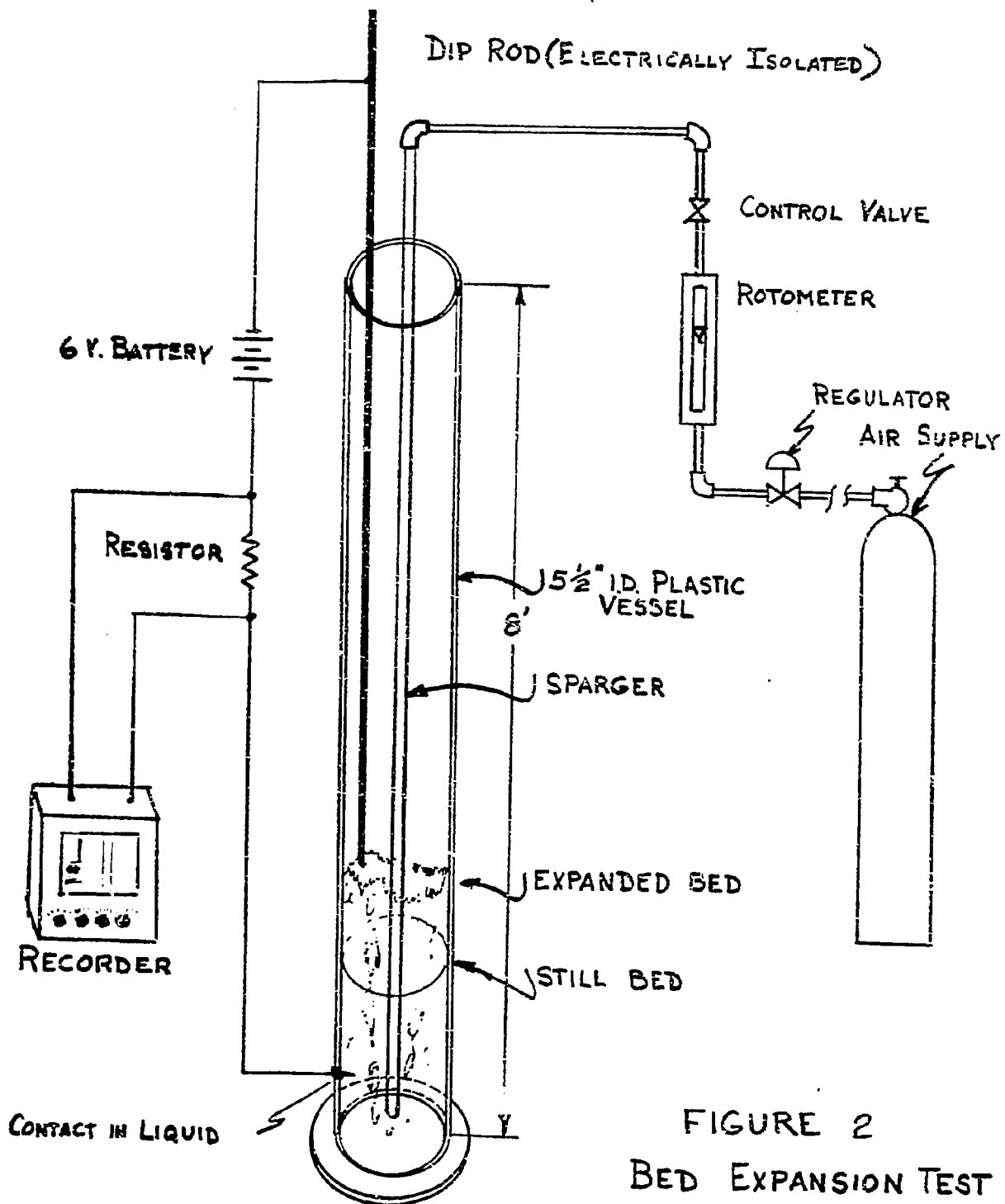
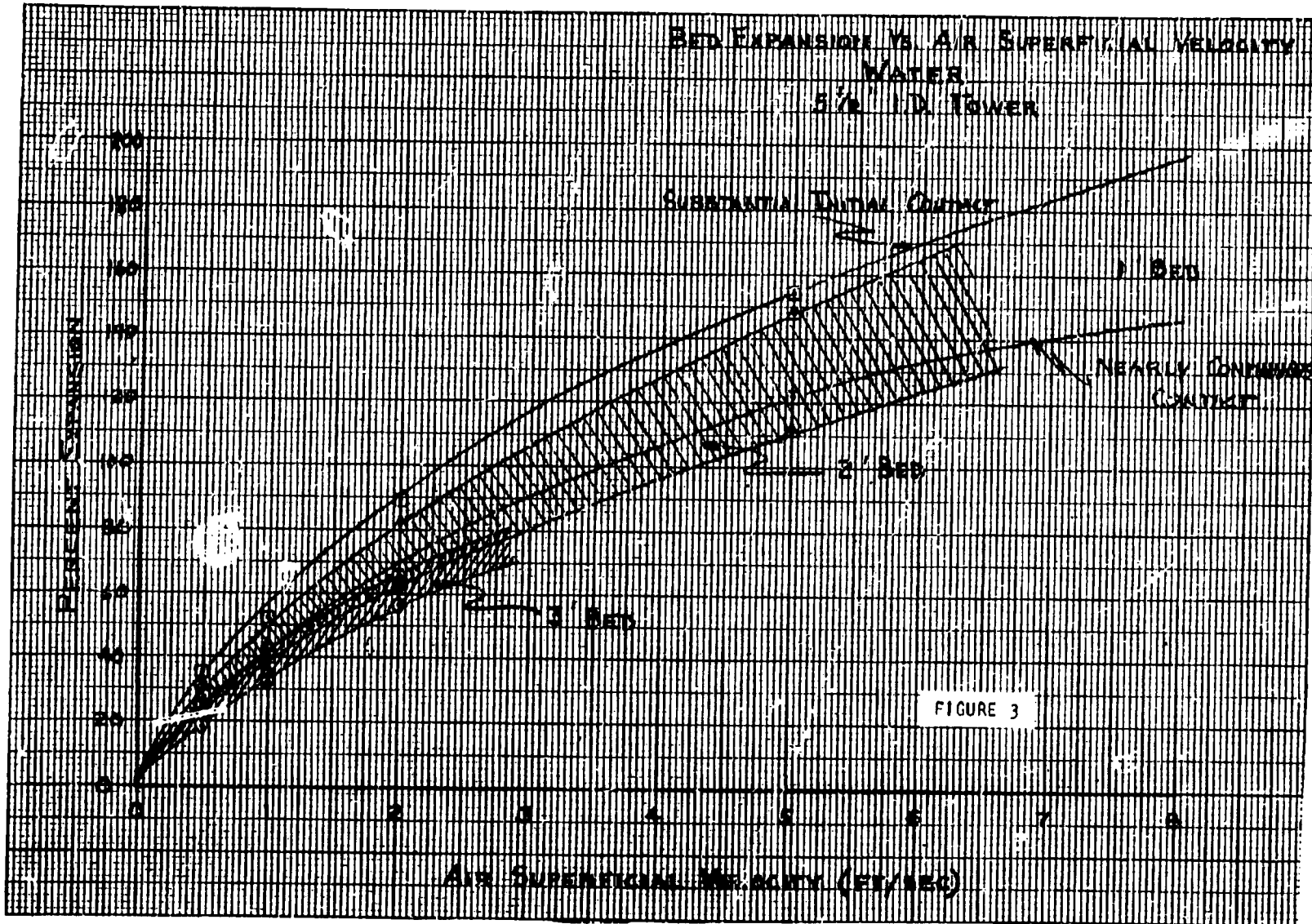


FIGURE 2  
BED EXPANSION TEST  
APPARATUS



BED EXPANSION VS AIR SUPERFICIAL VELOCITY  
 ETHYLENE GLYCOL  
 5 1/2" ID TOWER

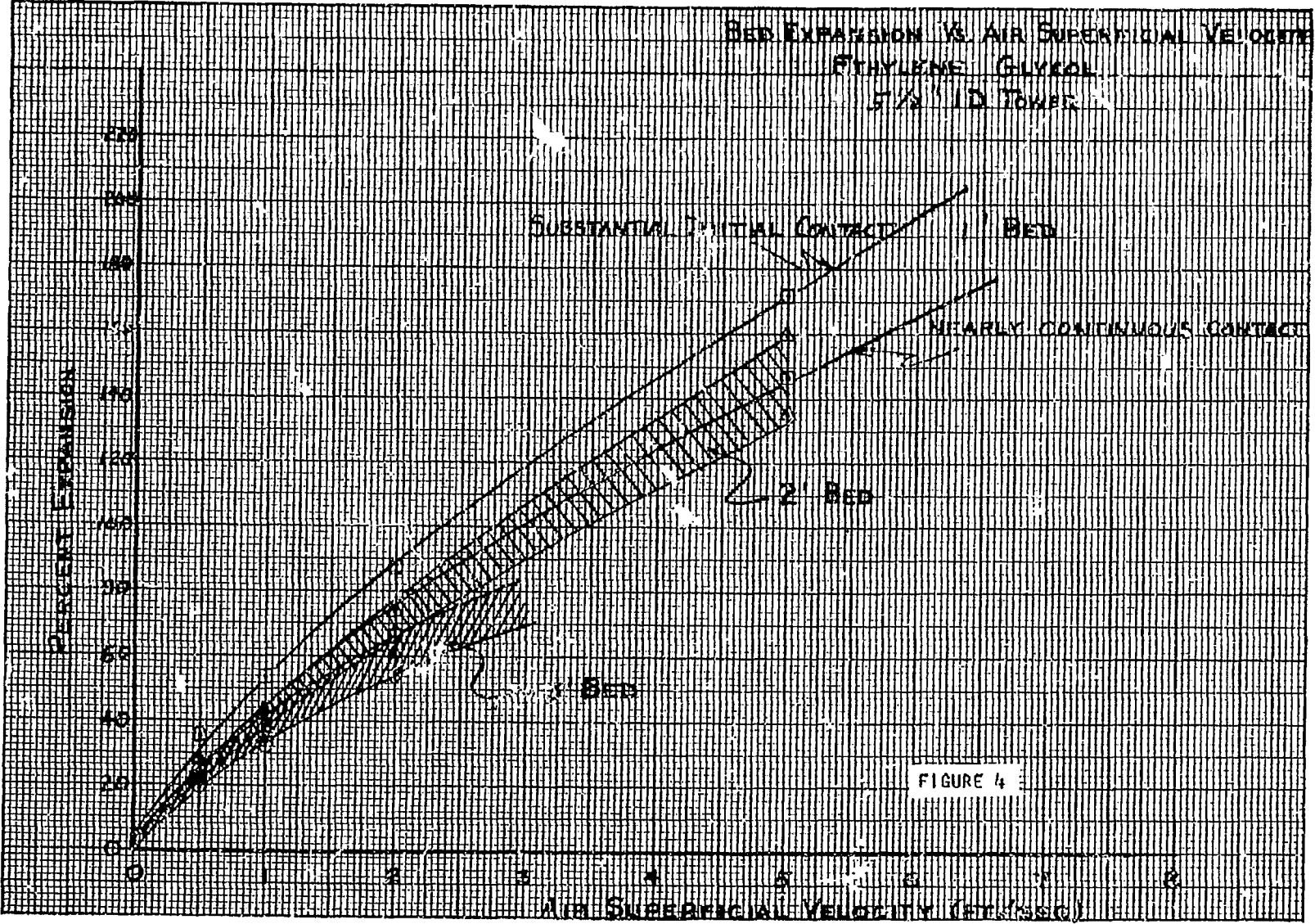
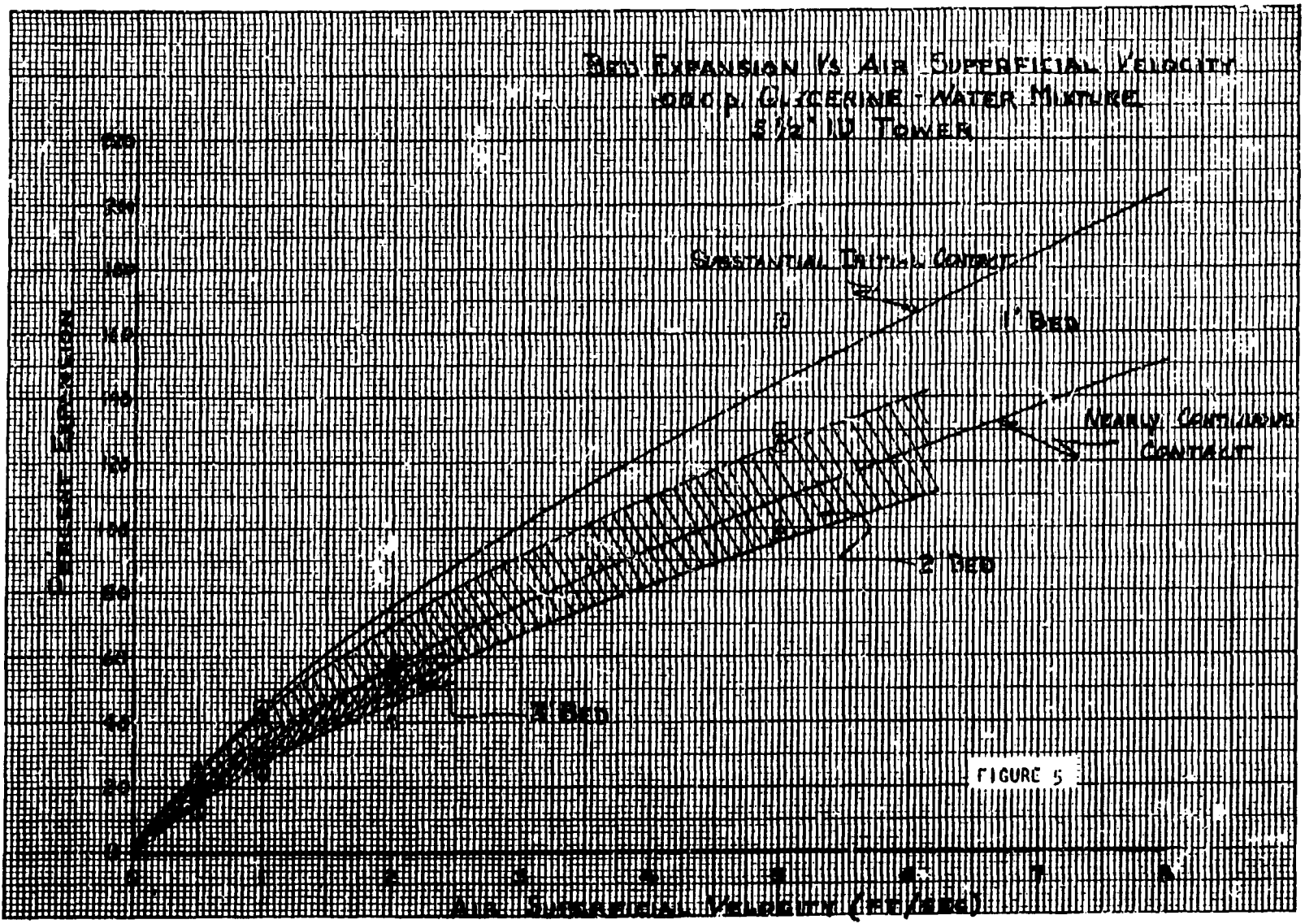


FIGURE 4



BED EXPANSION VS AIR SUPERFICIAL VELOCITY  
 1000 P. GLYCERINE - WATER MIXTURE  
 3 1/2" ID TOWER

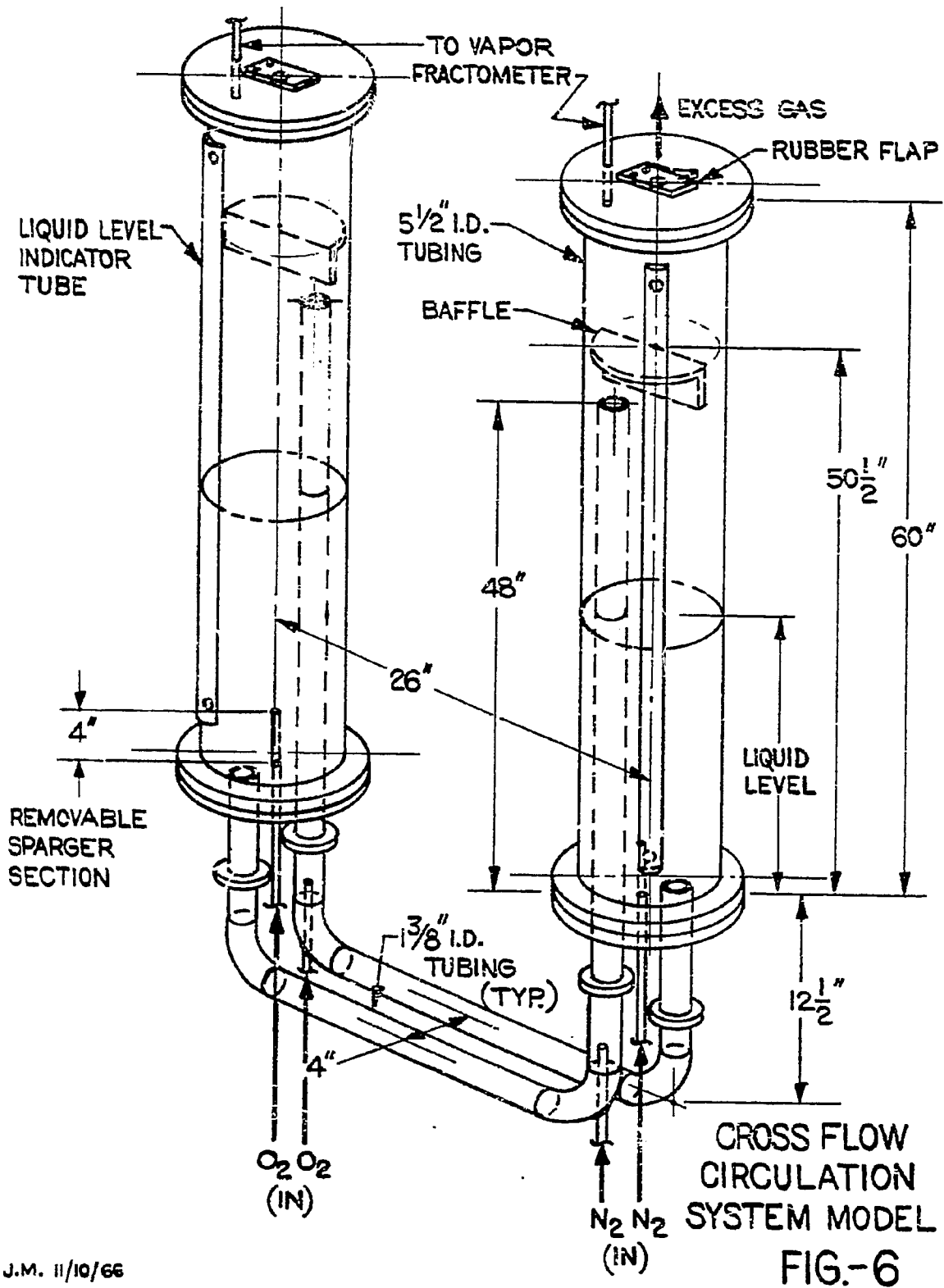


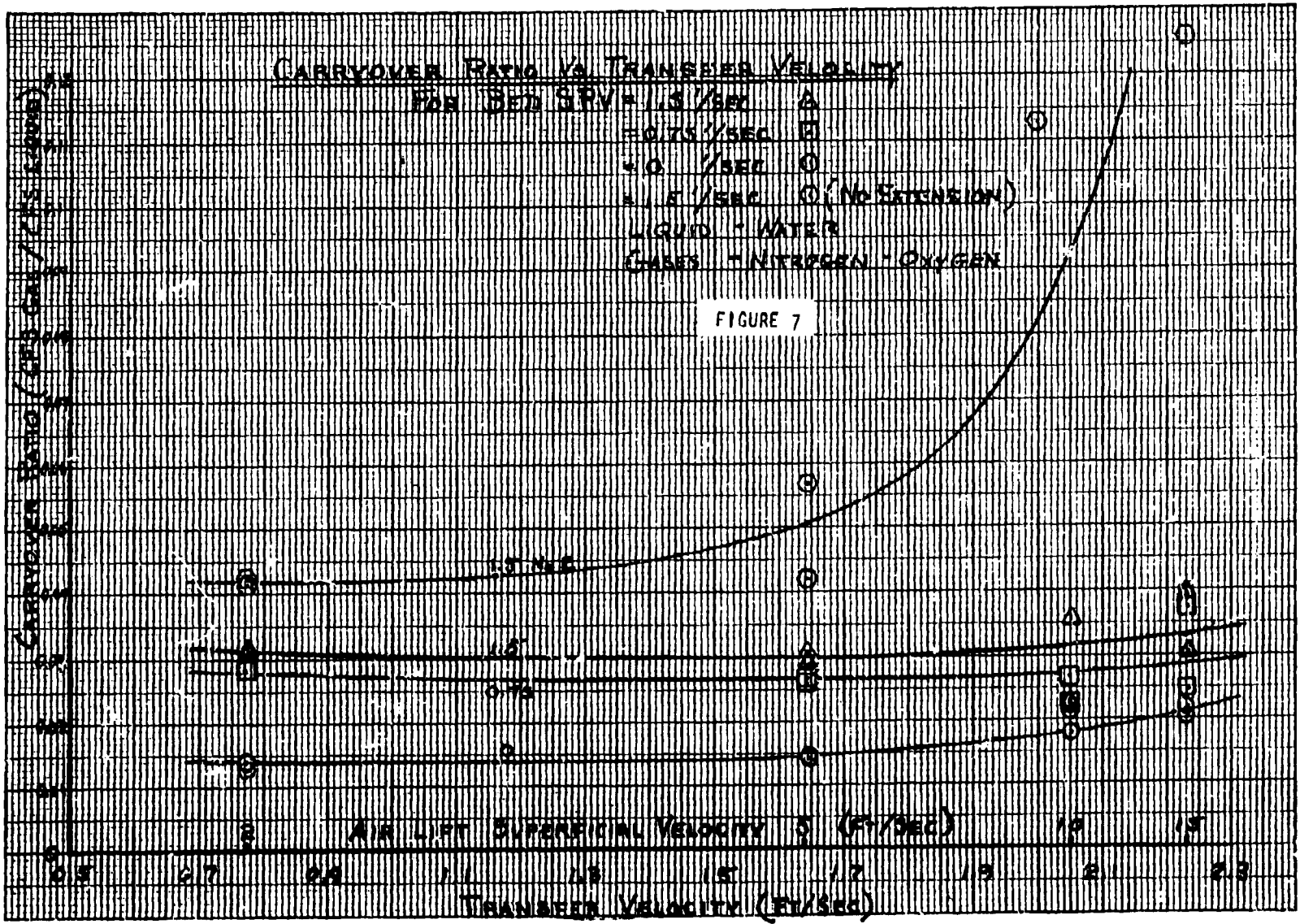
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FIGURE 5







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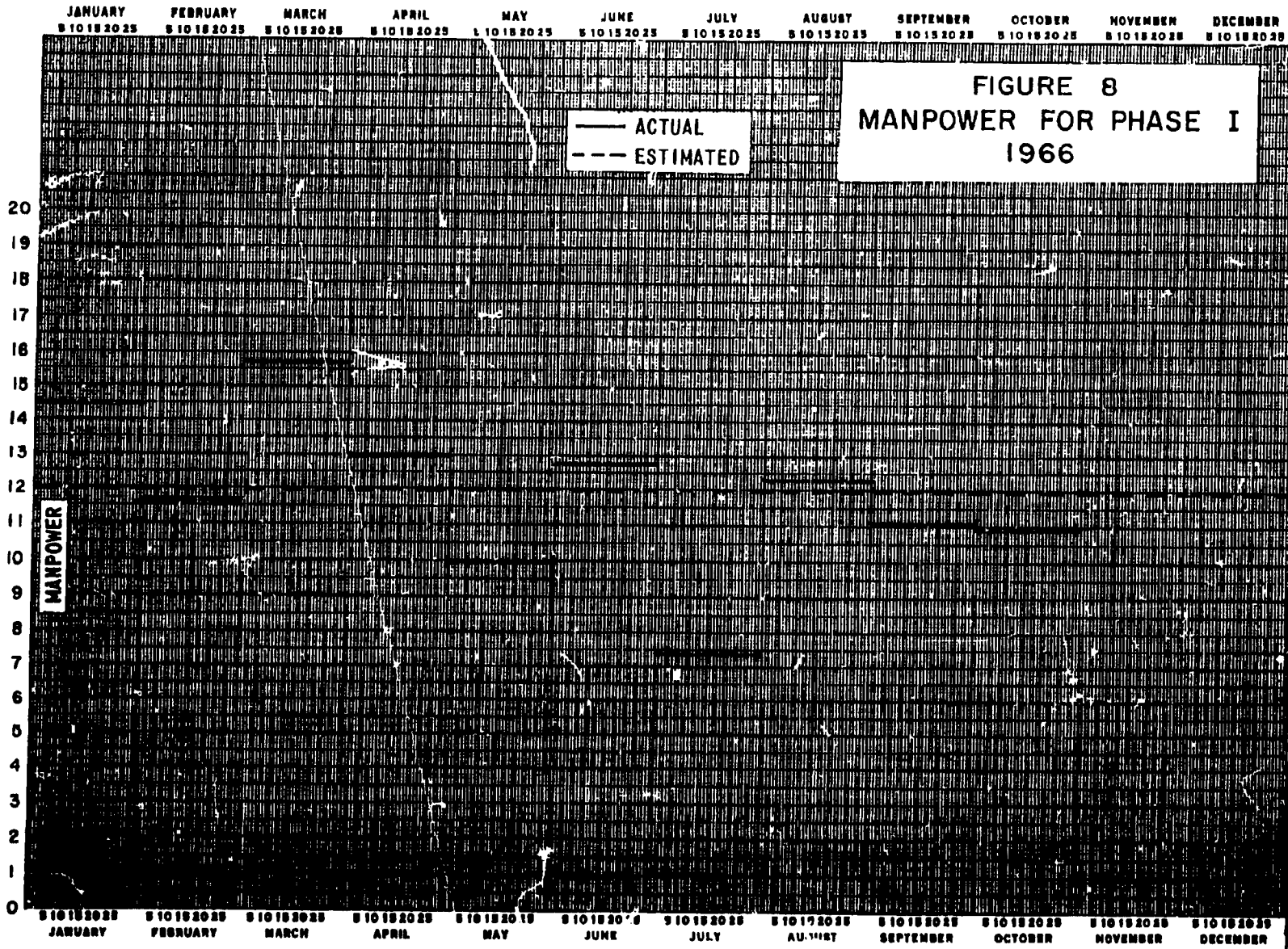
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#### V. MANPOWER AND COST ESTIMATES

Figure 8 shows the projected breakdown for Phase I for 1966 as well as the actual effort that was made. It can be seen that 10.9 man-effort was made during October.

Figure 9 shows the expenditures during October. For the month, \$19,720 was expended, not including fee and G & A. The total expenditures through October were \$526,993. Including fee and G & A the total expenditures were \$602,228. This is 55% of the encumbered funds.



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Department



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