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PROGRESS REPORT FOR OCTOBER

ON

DEVELOPMENT OF TEST UNIT FOR PRODUCTION OF OXYGEN BY A REGENERATIVE CHEMICAL

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Arthur D. Little, Inc.

CHEMISTS·ENGINEERS

CAMBRIDGE, MASS.

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BY AUTH. CG DAR-1 1.1

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National Defense Research Committee

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Progress Report for October on Development of Test Unit for Production of Oxygen by a Regenerative Chemical

For the past two months work at Arthur D. Little, Inc. has been concerned with the study of the performance of units having a loaded capacity of about 35 pounds Salcomine each and of the characteristics of Salcomine when used in such units.

Two types of cases have been studied to date, namely, a deep bed type employing Thermek heat transfer surfaces and a shallow bed type employing a finned tube type of transfer surface. Both cases show advantages and disadvantages over one another.

During the early cycles of automatic operation with fresh 20-35 mesh Salcomine the shallow bed case gives the higher yield of oxygen. Thus, the shallow bed gives 3.32 lbs. O_2/100 lbs. saturated powder/cycle whereas the deep bed gives only 2.87.

On the other hand, the drop off in productivity after the powder has produced 15 times its own weight of oxygen is greater in the shallow case. Thus, the drop from original productivity is 18.5% in the shallow bed and only 11.0% in the deep bed.

The deep bed shows a rather high initial pressure drop, namely 8 to 10 psi. compared to that of the shallow bed of less than one psi. The pressure drop builds up steadily with use in the case of the deep bed reaching 60 psi. after a total production of about 24 pounds of oxygen per pound of powder. The shallow bed on the other hand shows only slight if any build up in pressure drop.

The above figures are based on the use of 20-35 mesh powder. When the deep bed is loaded with 10-20 mesh powder the pressure drop is only 3 psi. when the unit is freshly loaded. Extended runs with powder of this mesh size are now in progress so that it is too early to know how the pressure drop increases with powder use.

Desorption is extremely rapid with both types of beds. Oxygen stripping is better with the deep bed.

Work in the immediate future is to be directed to a study of the effect of varying the temperature of the various heating and cooling media. On the basis of

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the data included in this report and that being currently obtained a design for a 60-80 cu. ft. O_2 per hour mobile unit is being worked out by E. B. Badger and Sons Co. with current plans calling for the use of shallow beds similar to the type described herein. The effect of larger granular size is being studied both as to productivity and the tendency to build up pressure when employed in a deep bed.

Four half inch tube units similar to those being used by the Gilliland group at M.I.T. have been set up to study the effect of air quality. The same air as that used in the 35 pound Salcomine cases is supplied to two of the 1/2" tubes while the same air passed through activated charcoal is fed to the other 1/2" tubes. To date operation of these tubes has not been consistent enough to give data of a satisfactory nature.

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Body of Report

Basic Services Set-Up

To expedite the testing work on the size cases used in this work and to insure adequate supply for several cases of hot and cold water and air of the same quality service lines were set up so that a series of cases could readily be attached. This permits operating several types of cases with the same services and makes possible the ready shift from one case to another.

This set-up consists of 2-inch supply and return lines for water and a 3/4-inch line for air.

Air is supplied by a Gardner-Denver two-stage air cooled compressor and is passed in succession through a Protectomotor pipe line filter, through silica gel driers and then, if desired, through a cooler. From the cooler the air is fed into the 3/4" main mentioned above.

In order to get reasonable steady air flow into the various cases being tested a pressure reducer placed ahead of the pipe line filter first reduces the compressor pressure of 150 psi to 130 to 140 psi. Ahead of each case another regulator is installed to reduce the 130-140 psi. to about 90 psi. ahead of the needle valves used to control the flow into each case.

Oxygen produced is piped by a manifold to a gas holder and collected over water and measured. In early tests an iron case meter was used to measure the oxygen produced. Such a meter was found not too accurate over the wide range of rates encountered in atmospheric desorption of the powder.

Temperature control on the heating and cooling water to date has been as follows. For the cold water used in absorption and the cooling of the cases after the desorption, city water has been used at the line temperature. During the course of the runs to date this has decreased from a temperature of 57°F. during the runs in October to the present level of 50 °F. for the tests during November. Hot water is supplied from a recycle system consisting of two 50-gallon drums, one mounted on the floor level slightly below the various cases being tested and the other mounted some 3 or 4 ft. above the top of the deep bed unit. Hot water when not being used is circulated between the two drums. Flow to the units is out of the top drum, through the cases and back to the bottom drum by gravity. Low pressure steam is bled directly into the top drum. A temperature of about 200°F. is maintained by a Fulton Sylphon temperature regulator valve on the steam line.

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A refrigerated water system is similar to the hot water system with a 2-ton Freon unit supplying the necessary refrigeration and control.

Photograph No. 1 shows a general overall view of the entire set-up including the cases described in the next section of this report.

In order to duplicate repeatedly any chosen cycle on continuous operation an automatic timer has been constructed. This consists of a series of cams mounted on a shaft driven by a synchronous motor through a gear reducer. These cams control the flow of compressed air required to actuate piston type regulator valves on the various services. Cams are provided for cold water in and out, refrigerated water in and out, hot water in and out, air into the case, a vent to release pressure at the end of the absorption phase, oxygen removal, and an air blast to blow water out of the cases before shifting from water at one temperature level to that at another. This timer mounted on a table is shown in photograph No. 2.

Description of Cases Tested

Thermek Case

Two types of cases have been tested to date. One consists of a ten-foot deep bed and is built around the Thermek type extended transfer surface. The unit consists of 6 duplicate powder holders. Each holder consists of a tubular steel shell of two in. I.D. and ten ft. long. A ten ft. length of Thermek tubing having a 3/4 in. copper core tube with an overall diameter of 2" on the spines, and sealed on the top end is mounted within the steel shell. Powder is packed in the annular space between the copper tube and the steel tube around the spines. Heating and cooling water passes up through the copper tube and returns via an outlet pipe mounted at the axis of the copper tube and extending nearly to the top. The top end of the Thermek copper tube is closed off. Suitable screens and glass wool packing are provided at top and bottom of the powder beds to prevent powder working out the tubes during operation.

Six of these tubes are mounted on a rack and connected to suitable headers to supply air, water in and out and a line to remove exhaust air and oxygen.

In the first extended run venting of the 80-pound air pressure at the end of the adsorption and the removal of O_2 was from the top end of the tubes only. In the second extended run these operations were carried out from both ends. Airflow into the tubes for adsorption is at the bottom. Water flow likewise is in at the bottom so that flow for both air and water is upwards

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during absorption.

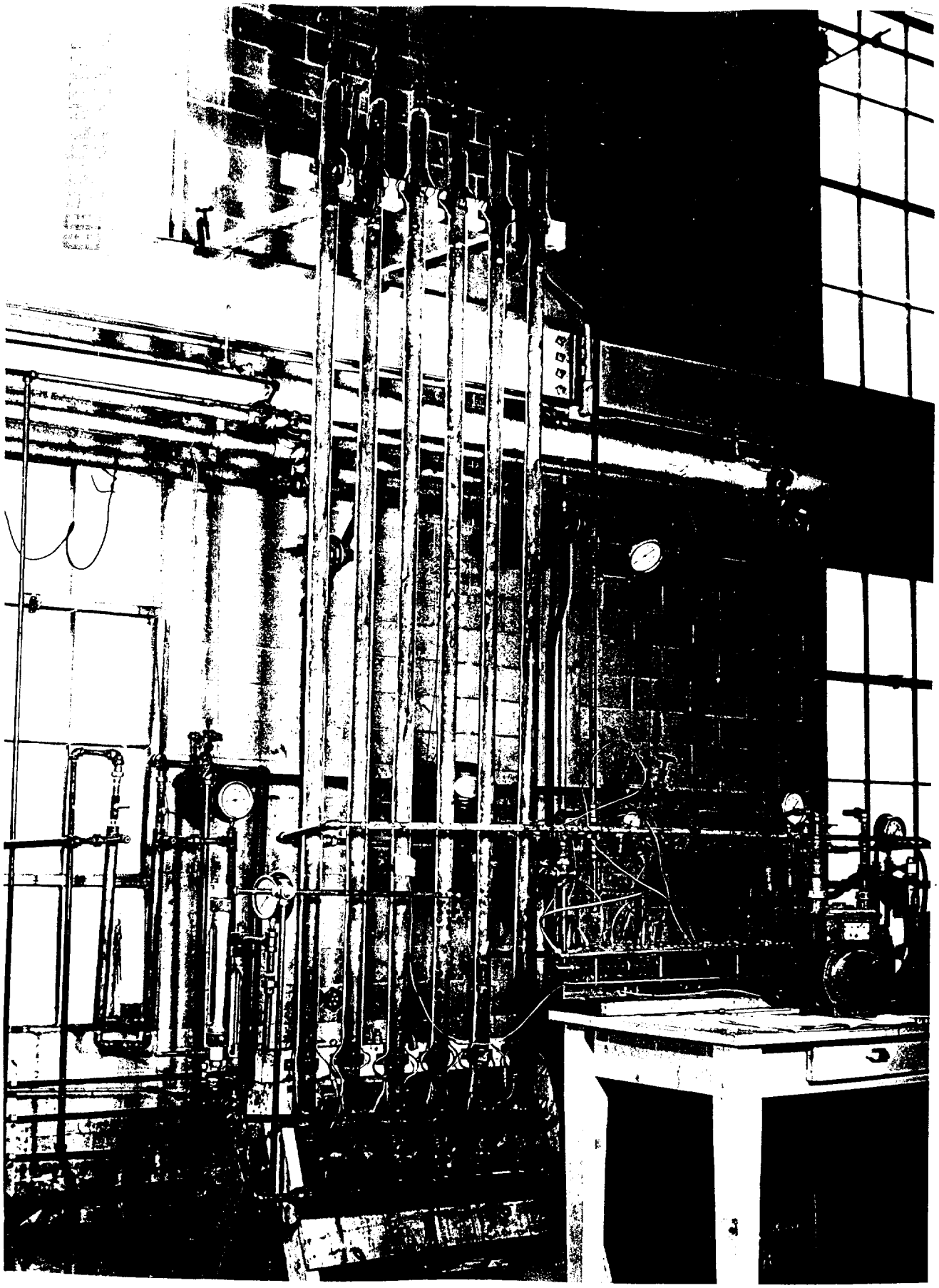
Control of air flow to the units is by means of a needle valve on the inlet side, a rotometer on the inlet side being used to show rate of flow at operating pressure, a pressure relief valve on the outlet side and finally a needle valve on the outlet side. When air is fed to the case, the pressure in the case builds up to approximately 65 psi. before the relief valve opens. Final control of pressure and flow is by means of the two needle valves. A general exterior view of this type case is shown in photograph No. 2.

Flat Case

Another type of case being studied is a shallow-bed case termed the Flat Case. This consists of standard finned tube surface made by the V. Bush Mfg. Co., Hartford, Conn. The finned bank consists of copper tubes 5/8" O.D. by 24" long arranged in 4 layers of 8 tubes each. Tubes are spaced 1 5/8" on centers and have 1 5/8" square fins, 6 to the inch, made from .012 inch sheet aluminum. Overall dimensions of the finned banks are 24" x 13" x 6 1/2". This heat exchange surface of 100 sq. ft. is mounted inside of a reinforced cast iron case with the inlet and outlet water headers brought out of the iron case through packing glands. A 60-80 mesh screen is placed against the finned bank on top and bottom followed in both locations first by a perforated plate, then a layer of glass wool and finally a second perforated plate. These packings serve the dual purpose of keeping the powder within the finned bank and of obtaining uniform air distribution. Air is fed into the case below the bottom perforated plate into a space about half an inch deep and the full area of the bottom of the cast iron casing. Exhaust air is collected in a similar space at the top of the case for removal from the case. Control of air pressure, and air flow is obtained in the same manner as for the ten-foot Thermek unit.

During the first extended run with this case the spaces in the ends of the case between the headers of the finned bank and end walls of iron casing were blanked off with a mixture of plaster of Paris and sawdust. This seemed to blank off this end space satisfactorily for this run but during the second run definite evidence was found of air by-passing the powder bed.

In order to prevent this a system of baffling was installed within the case. This consisted of soldering to the main headers of the finned bank sheets of 16-gauge copper to form a continuous enclosed surface around the sides of the bank. Then these surfaces were extended up to the level of the flange to which the cover is bolted. A copper flange was then attached to these extended surfaces and bolted down under the cover with rubber gaskets above and below the copper flange. In this way all air



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passing through the case has to pass through the powder bed.

This flat case is shown in photograph No. 3, taken before the anti-by-passing baffles were installed.

General Operating Procedure

The general plan of operation for the cases just described is to use 80 psi. air during the absorption at a flow rate of about 0.2 CFM per pound of powder in the case. This should give a volumetric efficiency of 60-70% and a weight efficiency of 2.5-2.7%. Cooling water at 50-55°F. is employed. At the end of the adsorption a venting period of 0.5 to 1.0 minute is used to reduce the air pressure to atmospheric. Desorption is at atmospheric pressure using 200°F. hot water for heating. After desorption of at least 95% of the bound oxygen, a cooling period of about 4 to 5 minutes completes the cycle.

When three cases are in service at once, successive cases begin their cycles at the third points of the total cycle time. Thus only one case is desorbing at any one time while at three points in the cycle two cases are drawing air simultaneously.

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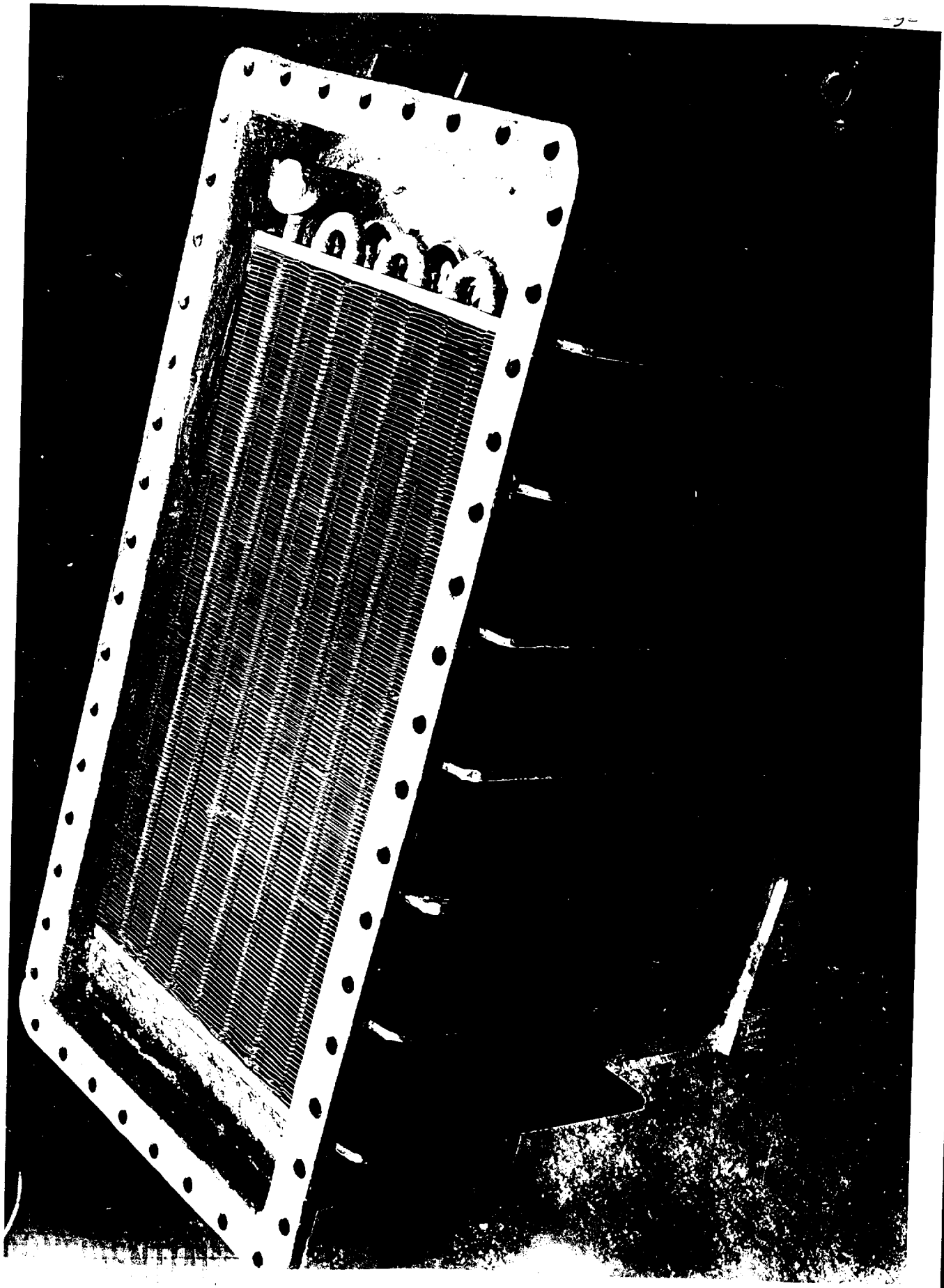

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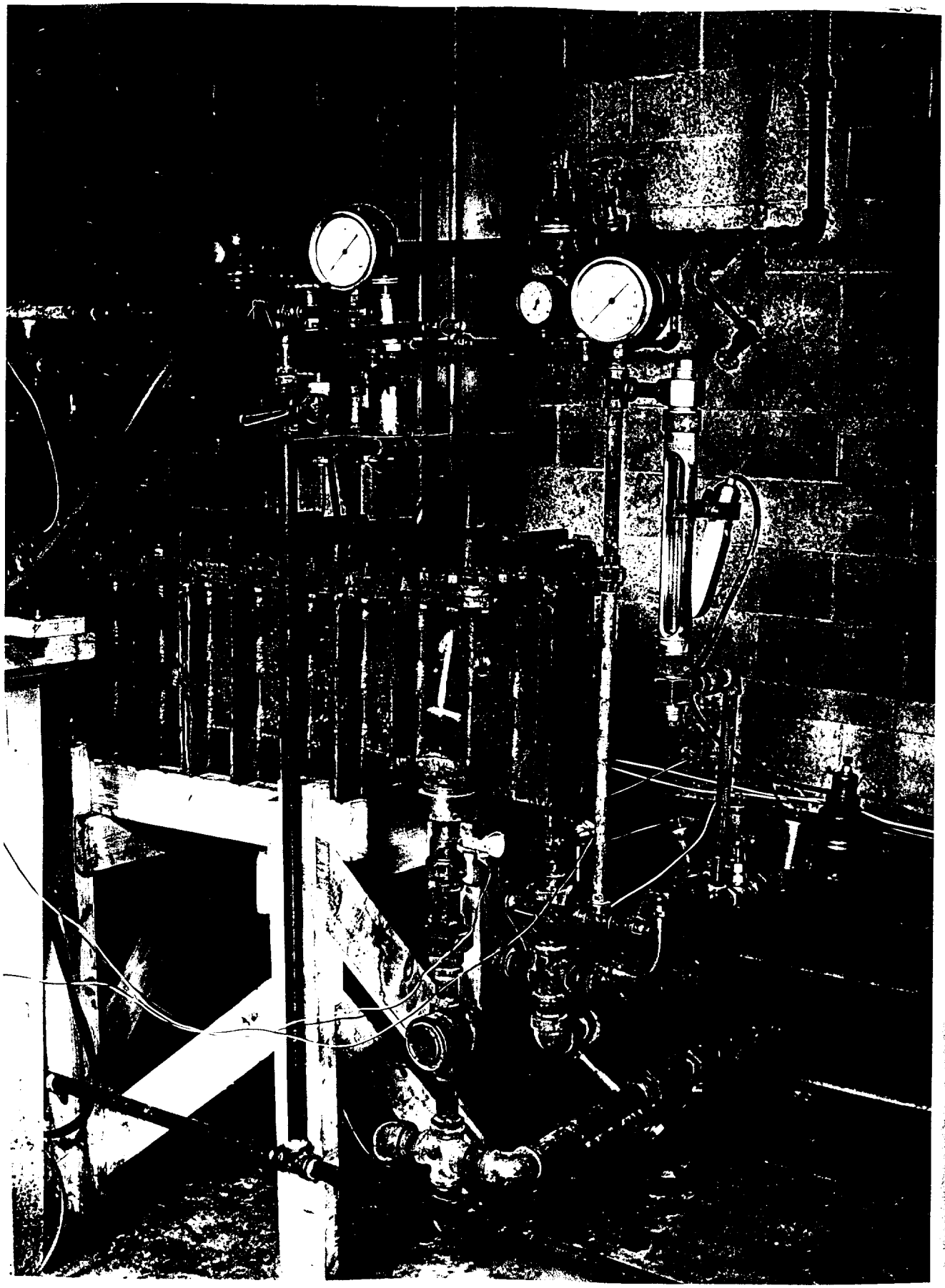

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Results

Preliminary Runs

The work during October and November on the deep and shallow bed type of cases has been divided into two main sections. It was first desired to determine the cycle for each case that would produce the greatest amount of oxygen per unit time. In order to do this a series of runs were made using desorption times of 5, 7.5, 10, and 12.5 minutes with 13.9°C. cooling water; venting for 1 minute; desorbing completely using 93°C. water and then allowing a 4-5 minute cooling period. The oxygen in the case was blown out with a blast of air at the end of the desorption before cooling. The results of this work are found in Table I and in plates I, II and III.

As an oxygen producer the shallow bed flat case is definitely superior. It appears that this is largely due to a higher thermal efficiency because of the smaller amount of powder in the flat case exposed to non-heating and cooling surfaces. In order to decrease the amount of this non-heating surface in the tubular deep bed a length of copper tubing was soldered up and down the outside of the 2" steel shells. Heating and cooling water was then passed through this tubing tempering the walls of the shells.

Since in much of the work being carried on elsewhere no sweeping out of the oxygen after desorption is used, such a non-purging cycle was investigated on the flat case. The effect is quite pronounced as will be seen by comparison of Table II with Table I. It would appear that this is due to a higher rate of adsorption after the powder has taken up an initial amount of oxygen. This increased rate can be seen in the Pauling oxygen meter curves presented in a later section of this report.

Life Tests Using Deep and Shallow Beds

Based on work described above the following cycle was chosen for use on life tests: adsorption time 12 min., vent to release 80 psi.air pressure 1 min., desorption time 4 min., cooling time 4.5 min. To date two life tests have been made on the two cases being studied. The first tests on each case were in the nature of a shake-down period to get smooth automatic operation. The cases were not reloaded after the preliminary manually operated cycles so that the powder used had already produced some oxygen. The data obtained is given in Table III and in plot IV.

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TABLE I

Preliminary Runs on Deep and Shallow Beds

Case	Adsorption Time (Min.)	Air Rate CFM per lb. of powder	Total Air Fed to System Cu. Ft.	Cu. Ft. of O_2 recovered	% of oxygen fed to case recovered	Wt. % Yield based on fully absorbed powder
Deep Bed	15	.27	130.8	12.96	50.0	3.31
Shallow Bed	15	.23	113.9	13.14	55.7	3.18
Deep Bed	12.5	.25	107.6	10.96	51.5	2.81
" "	12.5	.22	93.9	9.84	52.5	2.52
Shallow Bed	12.5	.22	103.2	11.12	53.5	2.69
Deep Bed	10.0	.25	86.8	10.26	60.5	2.68
" "	10.0	.21	73.8	8.22	57.2	2.11
Shallow Bed	10.0	.22	81.2	9.78	59.3	2.36
Deep Bed	7.5	.26	68.5	8.58	63.1	2.20
" "	7.5	.22	57.6	7.67	66.1	1.96
Shallow Bed	7.5	.22	61.3	7.82	64.3	1.92
Deep Bed	7.0	.26	63.4	8.40	66.0	2.14
Deep Bed	5.0	.26	45.9	6.44	70.0	1.65
" "	5.0	.22	38.2	5.41	71.0	1.38
Shallow Bed	5.0	.22	41.4	5.74	74.0	1.38

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TABLE II

Cycles with No Oxygen Purge at End of Desorption

Shallow Bed

Adsorption Time in Min.	Air Rate CFM per lb. of powder	Total Air Fed to System Cu. Ft.	Cu. Ft. of O_2 Recovered	% of O_2 Fed to Case recovered	Wt. % yield
5	.21	39.3	6.83	87	1.65
7 1/2	.22	60.0	8.90	74.5	2.17
10	.22	82.5	10.82	65.7	2.62
12 1/2	.225	104.3	12.48	60.0	3.01

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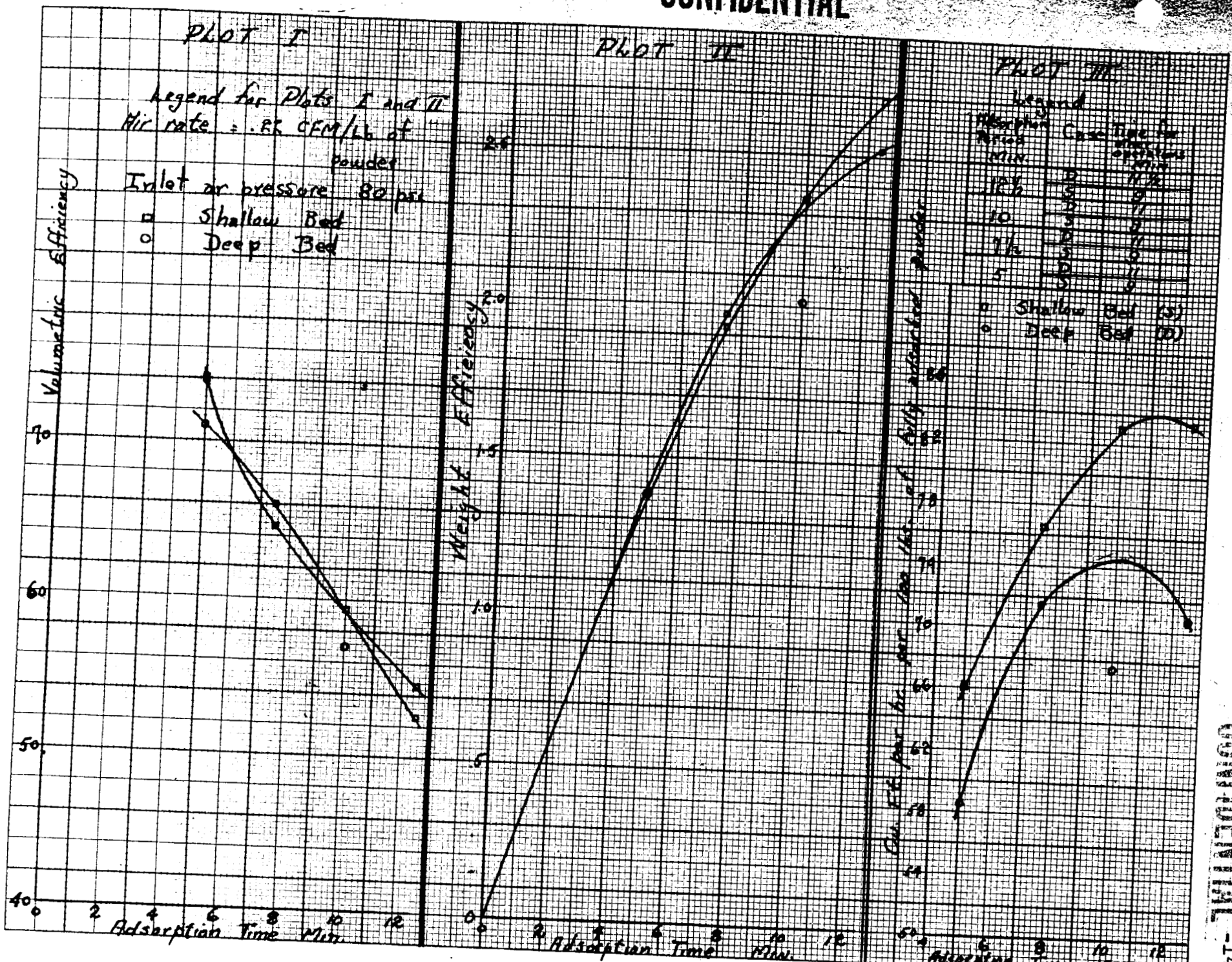

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TABLE III

Data from First Life Tests on Deep and Shallow Beds

	Deep Bed	Shallow Bed
Pounds of Fully Absorbed 20-35 mesh powder loaded	34.7	37.1
CFM. of Air to unit	7.58	8.10
Inlet Air Pressure	80	80
Initial Pressure Drop	8-10 psi.	less than 1 psi.
Pressure Drop after 200 cycles	28 psi.	less than 1 psi.
Initial yield of oxygen per cycle lbs. of oxygen per 100 lbs. fully absorbed powder	2.79	2.84

	% of Initial Yield per cycle	Total O_2 produced lbs. per lb. of fully absorbed powder	% of initial yield per cycle	Total O_2 produced lbs. per lb. of fully absorbed powder
After 50 automatic cycles	91	2.26	95.2	2.26
" 100 " "	89.3	3.38	91.9	3.41
" 150 " "	84.7	4.62	88.2	4.63
" 200 " "	79.5	5.65	84.6	5.82
" 250 " "			80.0	6.85
" 300 " "			77.5	7.91
" 350 " "			77.2	8.92
" 400 " "			72.7	9.95

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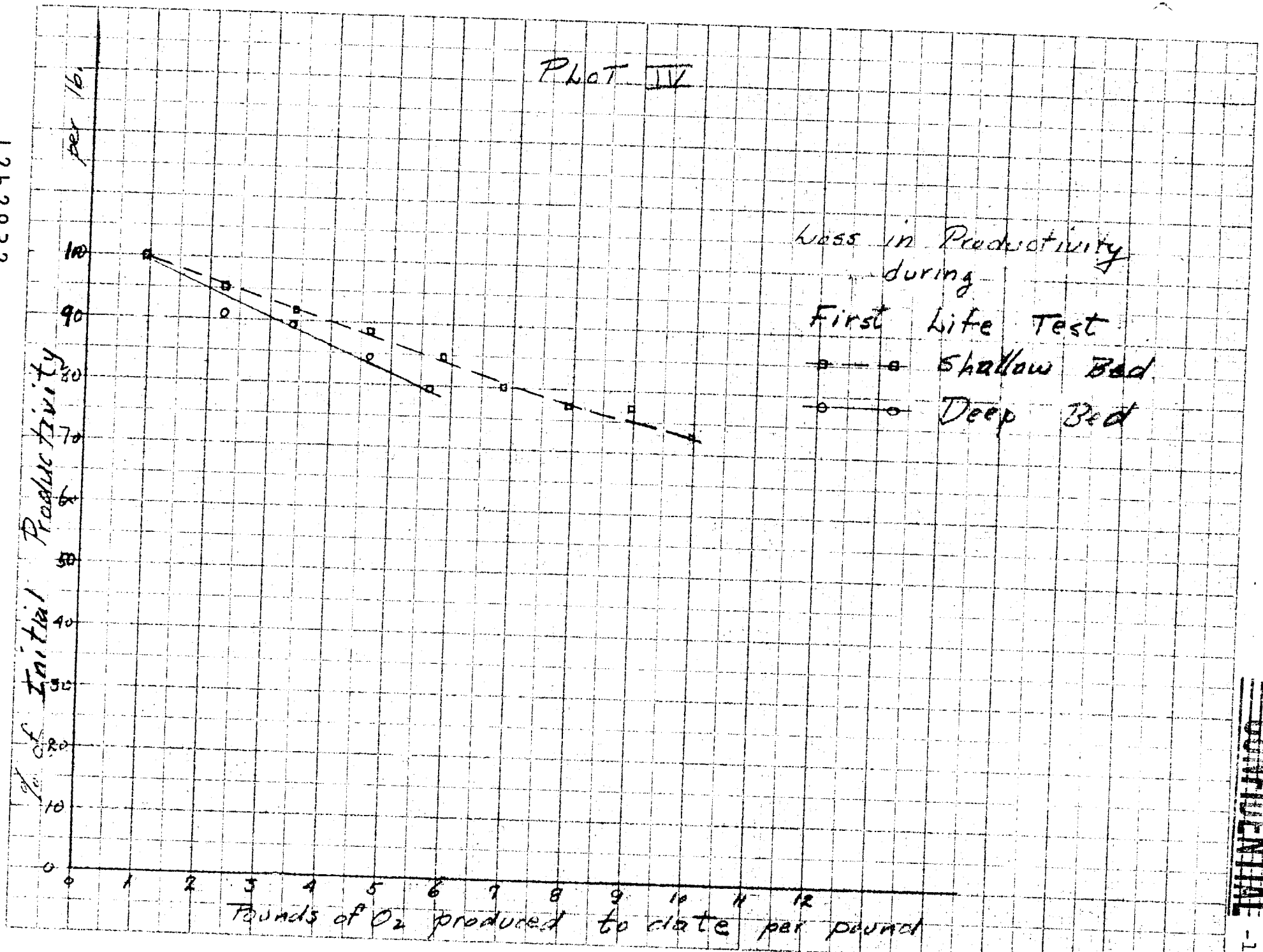

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From this data there seems to be little difference in the two cases. The flat case appears slightly superior on most counts.

The cases were opened and unloaded. Slight evidence of by-passing was noted in the flat case. A definite indication was found of dust collecting at the top and bottom of the deep bed case.

The cases were then loaded with fresh 20-35 mesh powder and started again. Immediately evidence was found of serious by-passing in the shallow bed case. Several different attempts were made to stop this by-passing before the system of baffling detailed in the description of this case given earlier in this report was worked out. This has proved most satisfactory.

The results for the second life test have been completed on the deep bed unit but not on the shallow bed. The data to date is given in Table IV and Plots V and VI. In this pair of tests the following types of data were taken regularly. At least every other cycle the oxygen yield was checked. Once a day each case was given a full adsorption of 30 minutes to determine the saturation level of the powder. On this test and on one regular cycle the compound was completely desorbed. Oxygen quality was checked once for each case. In the later part of the tests the desorption rates were checked every other day on the full adsorption cycle and on a regular cycle. Further on the full adsorption cycle and on a regular cycle the % O_2 in the stripped air coming off the case was determined every half minute with a Pauling oxygen meter. Pressure drops across the cases were followed and water temperatures noted periodically.

This additional data is presented in plots VIII, IX, X, XI.

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TABLE IV

Data from Second Life Tests on Deep and Shallow Beds

	Deep Bed	Shallow Bed
Pounds of Fully Absorbed 20-35 mesh powder loaded	35.1	36.1
CFM of air to unit	7.7	8.0
Inlet Air Pressure psi.	80	80
Initial Pressure Drop psi.	9	less than 1
Pressure Drop after 200 cycles psi.	18	" " 1
" " " 400 " "	22	" " 1
" " " 600 " "	38	" " 1
" " " 800 " "	60	" " 1
Initial Saturation: lbs. of O_2 per 100 lbs. of fully absorbed powder	4.01	4.00
Initial Productivity per regular Cycle: lbs. of O_2 per 100 lbs. of fully absorbed powder.	2.85	3.29

After cycle 358 on the Deep Bed the outlet pressure was raised to 80 psi. for the remainder of the life test.

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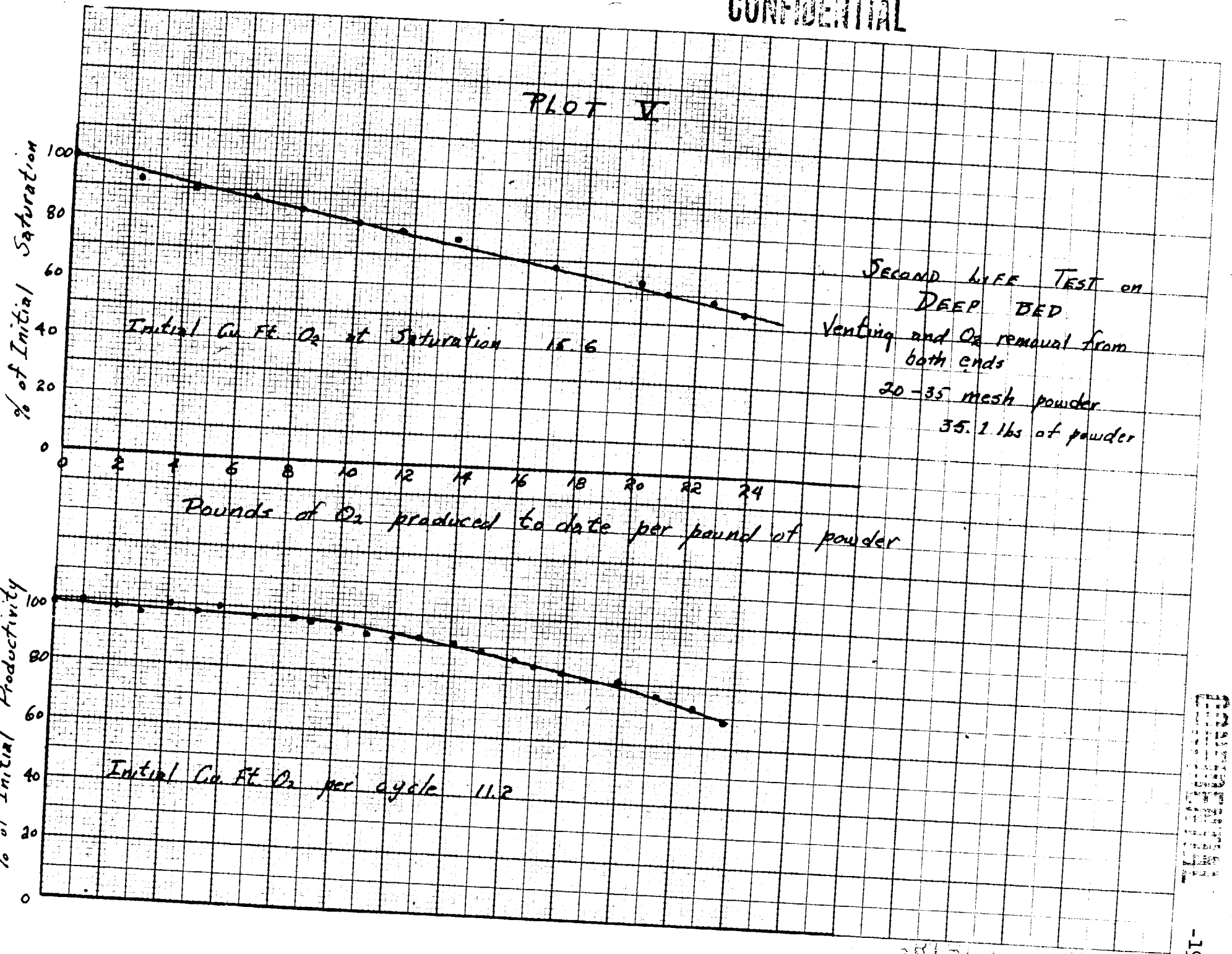

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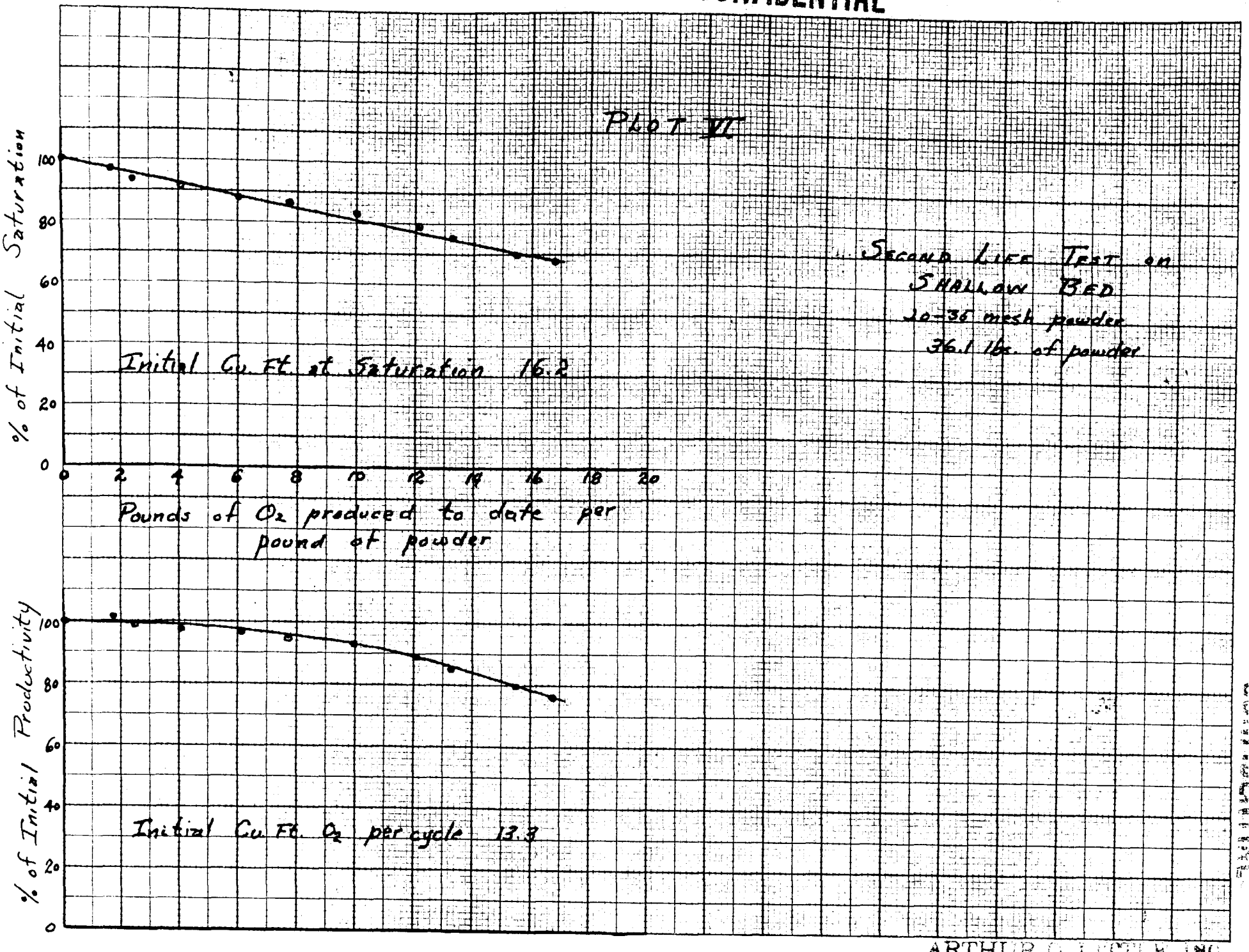

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Discussion of Data from Second Life Test

It is seen in Table IV that the initial saturation amounts of oxygen for the two cases check very well. On the other hand the shallow bed shows a much higher initial productivity per automatic cycle. This difference in initial productivity is the more startling when one notes on the Pauling meter curves that the oxygen removal from the air passed through the case during adsorption is greater for the deep bed than for the shallow.

The explanation for the high initial productivity of the shallow bed appears to lie in the larger amount of oxygen left in that case after desorption compared to the deep bed case. It will be recalled in the preliminary runs that the productivity per cycle is considerably more when the oxygen is not removed from the case after desorption. From the Pauling meter curves it is seen that a higher overall adsorption rate would be expected if adsorption were to start at a point where the catalyst already contained the amount of oxygen it picks up after say 1 minute of absorption. (See curve for initial cycle on the deep bed, page 30).

Another factor of probably less import in the case of the initial cycles is the difference in average pressure of the air in the case during adsorption. The shallow bed has the higher average air pressure so that other things being equal the adsorption rate should be higher.

From plot numbers V and VI it is seen that drop off in the amount of oxygen at saturation vs. total amount of oxygen produced per pound of powder is the same for both cases. On the other hand the drop off in productivity is quite a bit less for the deep bed case than for the shallow bed. The importance of this is shown in plot VII which indicates that while with fresh powder the shallow bed case produces the greater amount of oxygen per hour per pound of powder, after the powder in the two cases have produced 10 lbs. O_2 per lb. of powder the two cases are producing the same amount of O_2 per hour. With further use the deep bed produces more O_2 per hour than the shallow bed.

It is not just certain to what extent the increasing average pressure on the deep bed may cause the apparent improvement in action of the deep bed. With increasing air pressure during adsorption, increasing amounts of O_2 are known to be absorbed.

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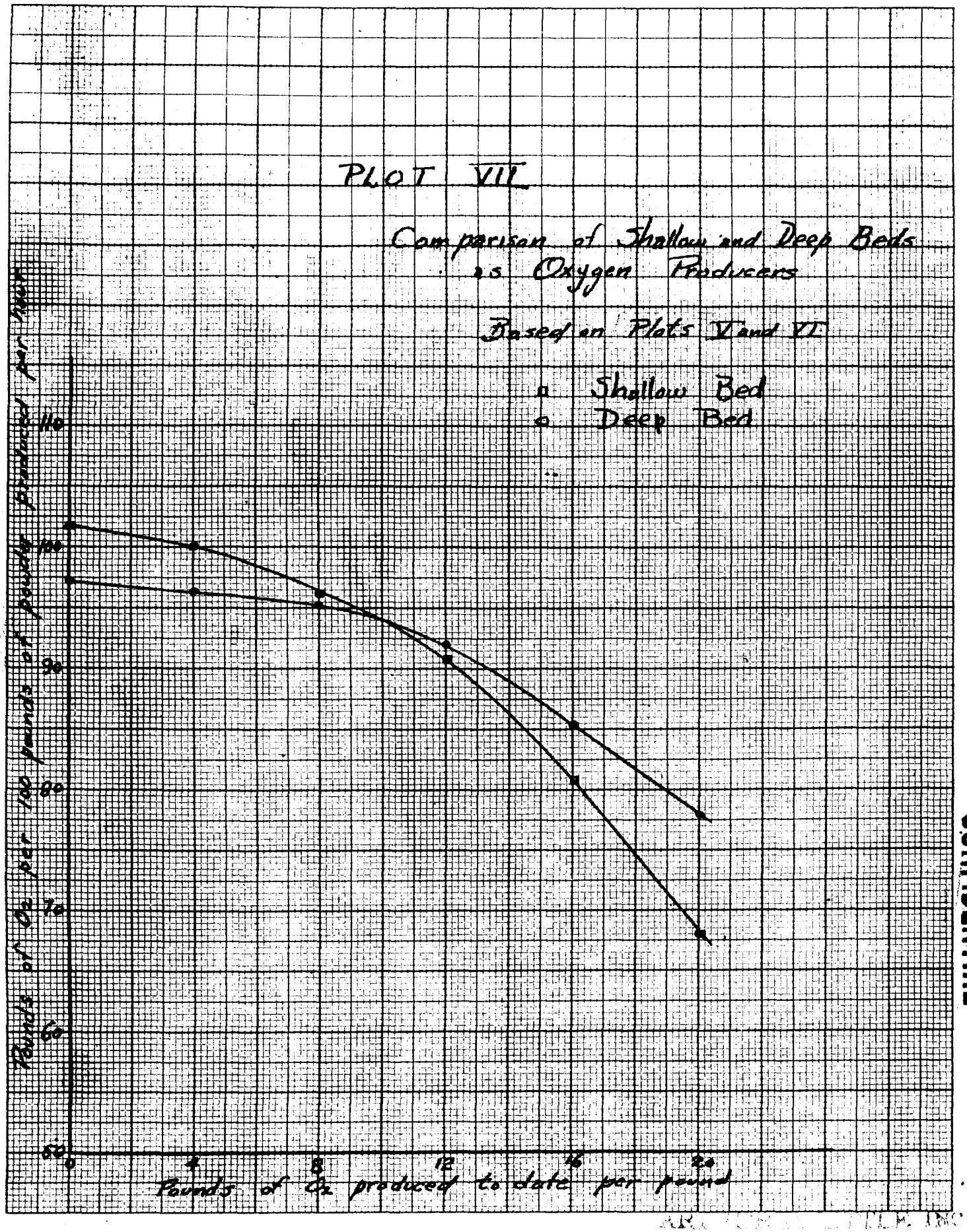

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A further cause for the lower loss in productivity of the deep bed may lie in the gradual erosion of the surfaces of the particles during continued use. This reduction in size of the granules would reduce the diffusion resistance offered the oxygen when it penetrates the granules to a location where it may become fixed. This should result in an increased absorption rate giving a higher yield of oxygen per cycle.

That fines are produced during use was evident during unloading of the powder holders. One tube was unloaded after cycle 244 and the material fractionated into 5 samples from "Top" to "Bottom" of the tube. These samples were submitted to The Rumford Chemical Works for their standard screening and activity tests. A sample of the material used to load the powder holders for the second life test was included for comparison. Their results on these samples are found in Table V.

A definite increase in the percentage of material below 35-mesh is noted as one passes from top to bottom of the tube. Also as would be expected a decrease in activity of the powder is shown when passing from top to bottom of the tube. One unforeseen thing developed out of these tests namely that the fines and the coarse granules both showed the same activity. The results of some of the activity tests carried out by Rumford are shown in the plot following Table V. This is a photostatic copy of the plot prepared by them of this data.

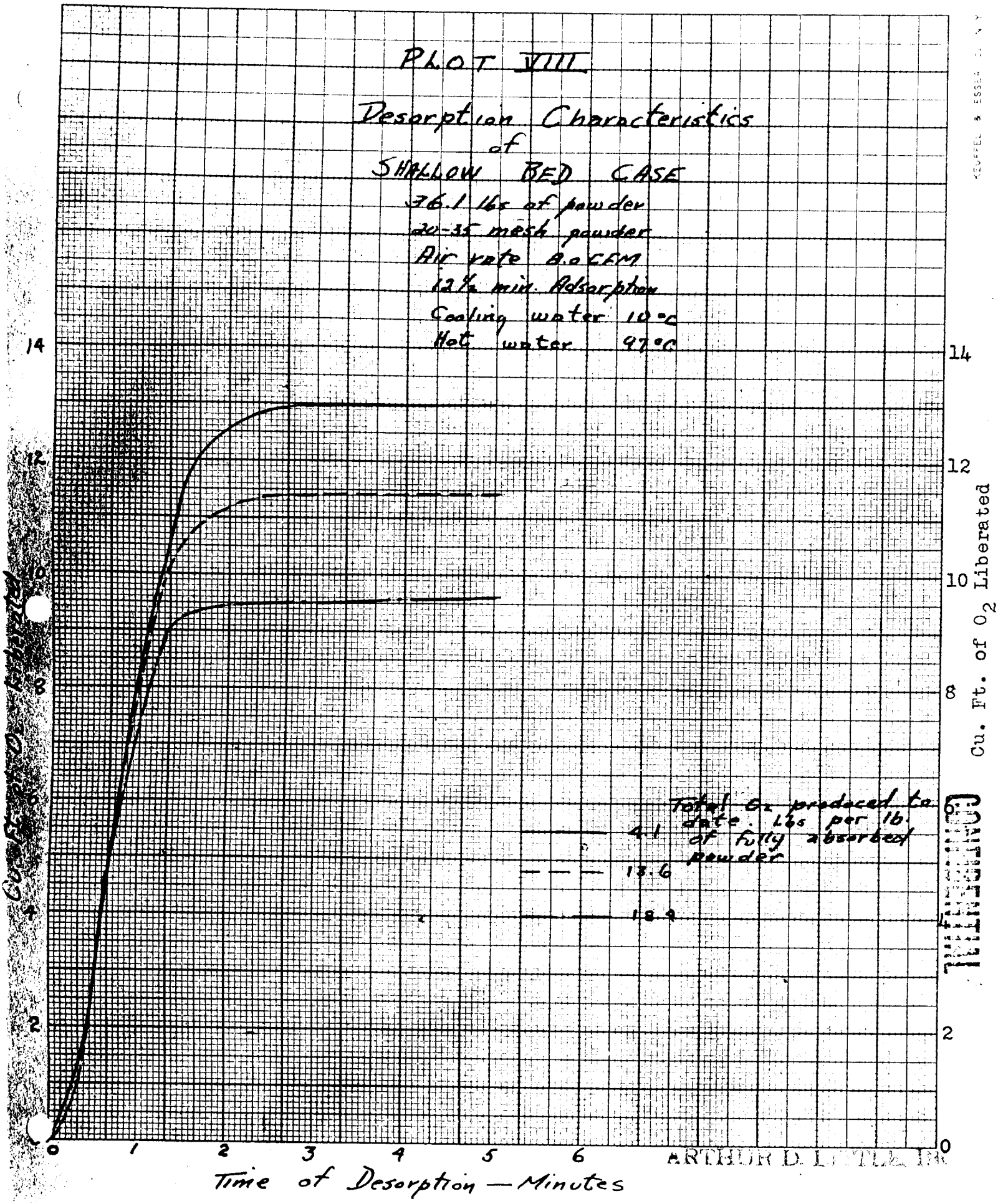
To gain a better knowledge of some of the other operational factors of interest from an engineering design point of view, several other types of data were taken.

Desorption Characteristics

The rates of desorption have been determined by timing the evolution of oxygen from the case into the gas holder. Typical curves for the two cases are given in plots VIII and IX.

It is unfortunate that this type of data was not taken during the initial cycles on the deep bed. However it can be reasoned that the comparison between cycles at various points in the life of the powder will be more or less similar for the two cases.

Two important facts should be noted. First, the rate of desorption of the shallow bed is higher than that of the deep bed. This is without a doubt a clear indication of the better thermal efficiency of this unit.



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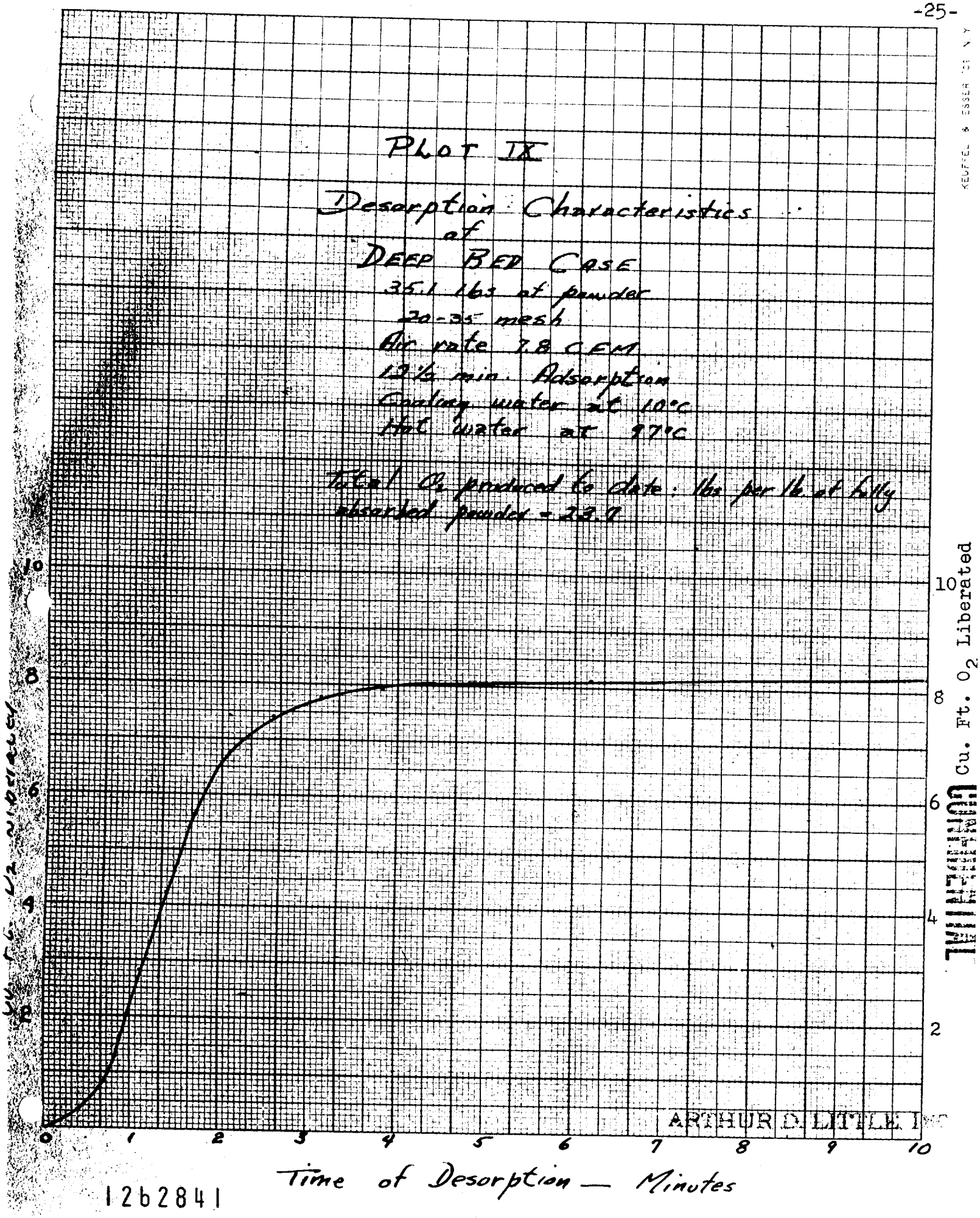
PLOT IX
Desorption Characteristics
of
DEEP BED CASE
35.1 lbs of powder
20-35 mesh
Air rate 7.8 CFM
13½ min. Adsorption
Cooling water at 10°C
Hot water at 97°C
Total O2 produced to date: lbs per lb of fully
absorbed powder = 23.7
Cu. Ft. O2 Liberated
Time of Desorption — Minutes
0
1
2
3
4
5
6
7
8
9
10
2
4
6
8
10
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TABLE V

Report on Recycled Salcomine from Thermek *

Unit at Arthur D. Little, Inc.

Six samples were received and designated as follows:

Sample 1. "Top" 244 cycles
2. "Next to Top" 244 cycles
3. "Center" 244 cycles
4. "Next to Bottom" 244 cycles
5. "Bottom" 244 cycles
6. "Not Used" mixture 20-35 mesh Salcomine Granules

Samples of approximately 250 grams were screened on the Rotap for 25 minutes.

Screen Analysis

Per Cent

Mesh	Sample 1	2	3	4	5	6
+28	41.05	35.52	38.46	32.35	29.99	46.08
28-35	42.02	43.57	40.39	41.29	36.17	41.13
35-48	5.27	7.98	11.02	13.24	13.19	9.21
48-65	2.99	4.29	3.55	4.54	5.63	1.46
65-100	2.07	3.21	2.21	3.14	4.83	0.72
100-150	1.01	1.66	1.15	2.17	3.80	0.42
150-200	0.96	1.27	1.08	1.44	3.18	0.30
200-325	0.68	1.06	1.11	1.28	2.04	0.24
-325	0.20	0.06	0.03	0.06	0.08	0.21
Mechanical Loss	3.75	1.38	1.00	0.49	1.09	0.23

* Results of Tests made at the Rumford Chemical Works.

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Rates of Absorption

Determined in Differential Manometric Apparatus at Room Temperature Using Oxygen at 35 psi. ga.
Weight Per Cent Absorbed

Time Min.	Time Sec.	Sample 1	2	3	4	5	6
0	0						
	5						
	10	0.03	0.05	0.05	0.05	0.05	
	15	0.15	0.13	0.12	0.14	0.05	
	20	0.26	0.26	0.29	0.28	0.15	0.07
	25	0.38	0.43	0.43	0.42	0.25	0.22
	30	0.59	0.63	0.60	0.56	0.40	0.42
	35	0.77	0.78	0.82	0.75	0.57	0.65
	40	0.94	0.95	0.91	0.91	0.72	0.82
	45	1.12	1.10	1.01	1.05	0.85	0.99
	50	1.22	1.23	1.13	1.14	0.95	1.14
	55	1.33	1.32	1.23	1.26	1.07	1.22
1		1.40	1.42	1.32	1.33	1.20	1.44
	15	1.71	1.68	1.61	1.56	1.42	1.76
	30	1.96	1.91	1.80	1.82	1.70	2.11
	45	2.14	2.07	1.97	1.96	1.87	2.26
2		2.29	2.25	2.14	2.07	2.05	2.51
	15	2.47	2.40	2.28	2.21	2.20	2.71
	30	2.63	2.53	2.38	2.37	2.33	2.86
	45	2.71	2.66	2.50	2.45	2.42	3.03
3		2.81	2.74	2.57	2.51	2.55	3.16
	30	2.93	2.99	2.67	2.68	2.70	3.35
4		3.09	3.05	2.86	2.80	2.85	3.53
	30	3.19	3.12	2.93	2.89	2.95	3.65
5		3.26	3.23	3.00	2.96	3.02	3.73
6		3.39	3.31	3.12	3.08	3.15	3.87
7		3.44	3.36	3.22	3.17	3.25	3.97
8		3.52	3.44	3.29	3.22	3.32	4.02
10		3.62	3.46	3.36	3.33	3.37	4.12
12		3.70	3.54	3.46	3.43	3.45	4.17
15		3.80	3.64	3.58	3.52	3.55	4.22
Average Total Capacity		3.79	3.66	3.59	3.48	3.54	4.24

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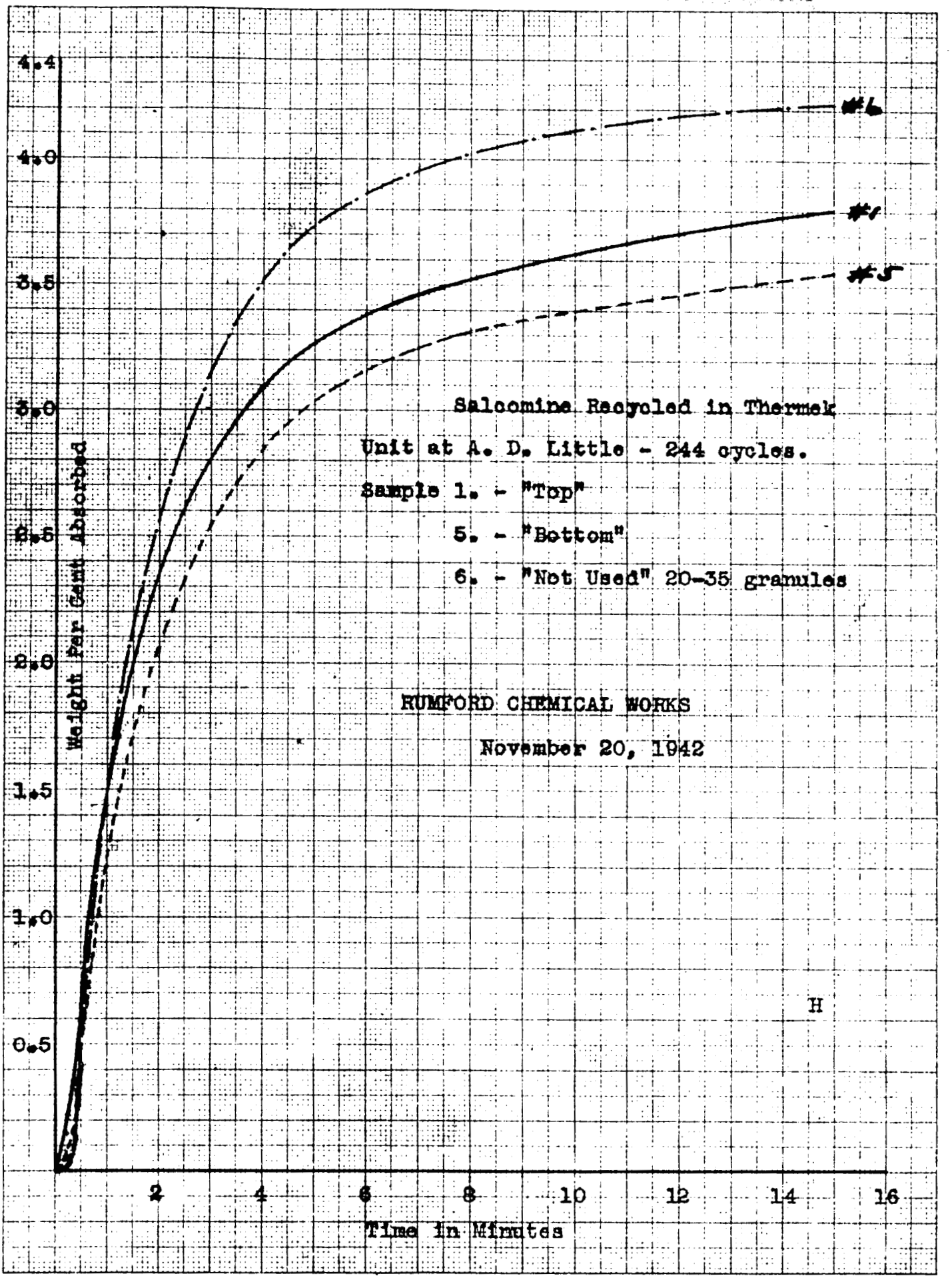

Millimeters, 10th lines heavy.
MADE IN U. S. A.

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Second it should be noted that with a properly designed case from a thermal point of view, desorption is extremely rapid. Two minutes is quite sufficient to get over 90% of the oxygen bound during adsorption desorbed at the temperatures used in these tests.

Pauling Meter Studies

The oxygen content of the exhaust air during absorption has been followed on at least one regular cycle each day during the second life tests and also on the full absorption test run each day. The results of this data are shown in Plots X and XI.

Quite definite differences exist between the two cases. The Deep Bed Case shows better oxygen stripping as would be expected from a deep bed. The change in the adsorption characteristics as the powder is used are of interest. Particularly it should be noted that as the powder is used in both cases the adsorption rate during the first three to four minutes increases. This would seem to indicate some sort of orientation in the material with use which facilitates the take up and liberation of oxygen by the compound.

Oxygen Purity

Samples of oxygen were taken during the desorption period on each type of bed. The shallow bed gave a gas containing 97.5% oxygen while the deep bed showed 98.5%. The slightly higher purity of the oxygen from the deep bed is accounted for by the fact that there are less voids left filled with air after the venting of the 80 psi. air used during adsorption.

Terms Used

Saturation:	The amount of oxygen the compound will pick up upon 30 min. exposure to air at 80 psi. keeping the powder at 50-55°F.
Productivity:	The amount of oxygen the compound will pick up and deliver during some chosen cycle of operation.
Volumetric Efficiency:	The percentage of the oxygen entering the case that is fixed by the compound.
Weight Efficiency:	The weight of oxygen fixed by the compound divided by the weight of the saturated compound and multiplied by 100.
Cycle:	The series of operations carried out to remove oxygen from the air and release it again as substantially 100% oxygen.

Respectfully submitted,

Arthur D. Little, Inc.

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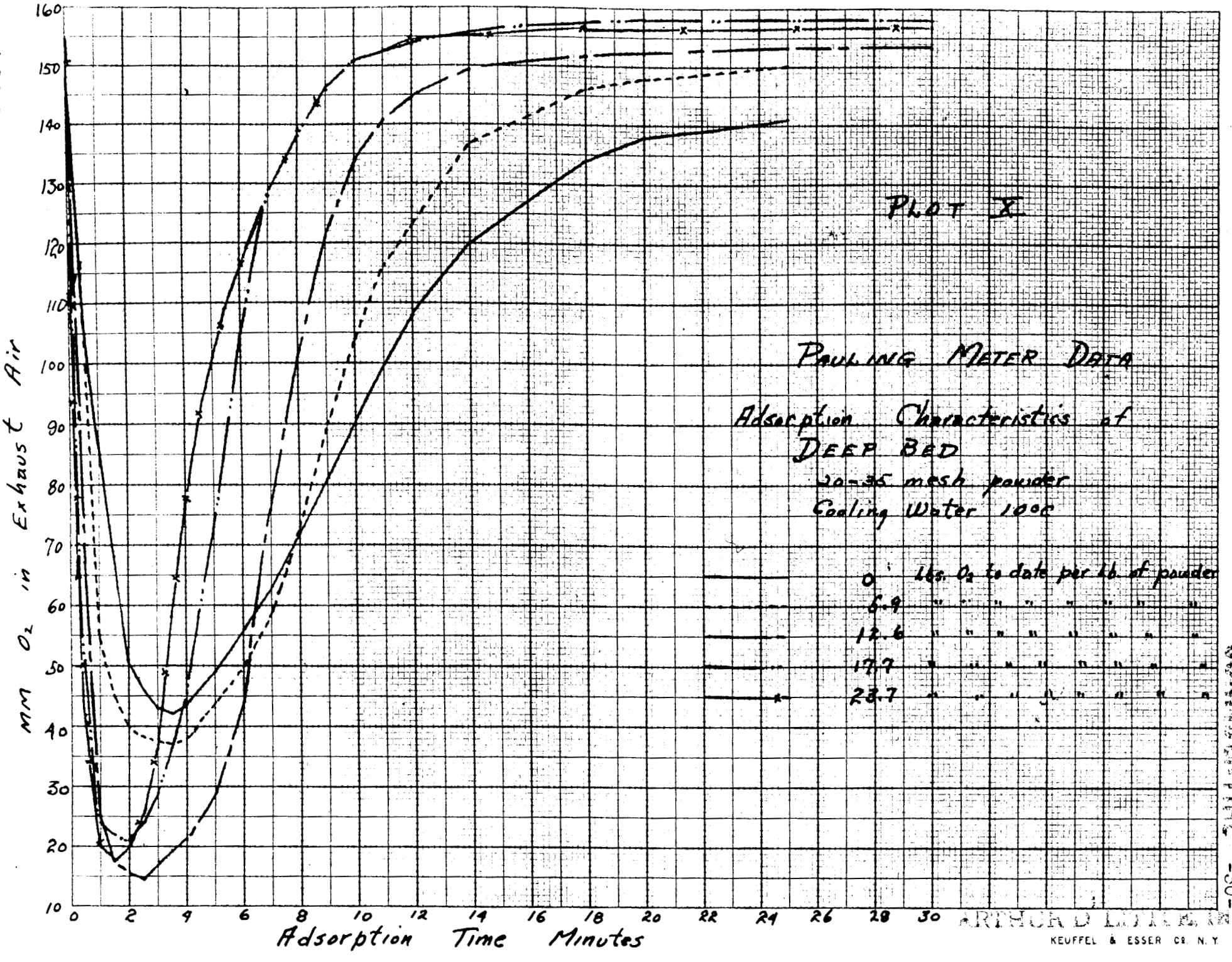

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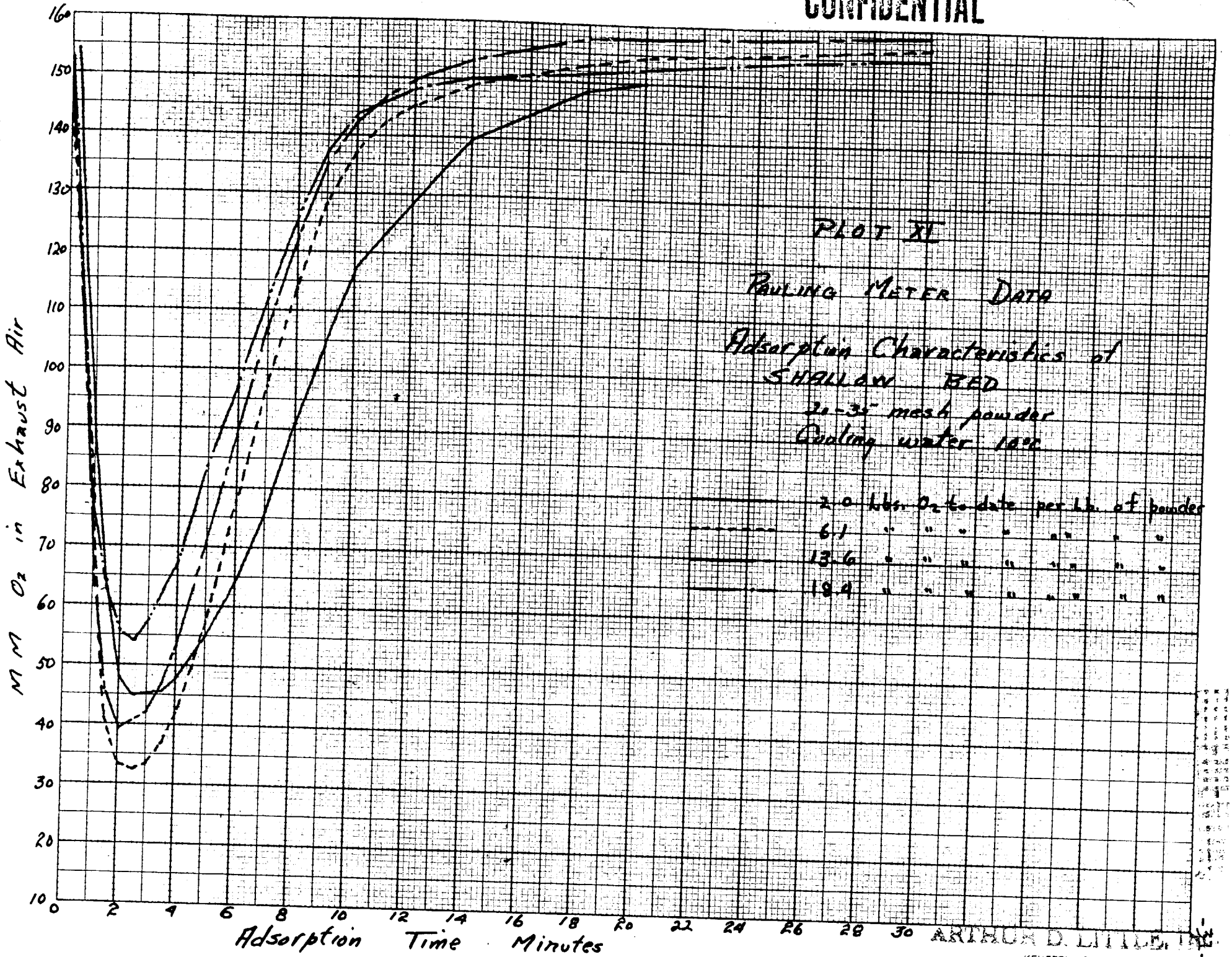

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