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The nature of the reactions occurring in the distillation of zinc from its ores and the effect on the speed of these reactions due to certain variables

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THE NATURE OF THE REACTIONS OCCURING IN THE DISTILLATION OF ZINC FROM ITS ORES AND THE EFFECT ON THE SPEED OF THESE REACTIONS DUE TO CERTAIN VARIABLES.

by

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A

Thesis

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Rolla Mo.

1913.

Approved by Durward Copeland.

Professor of Metallurgy.

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STATEMENT OF THE PROBLEM

The reactions that occur in the metallurgy of zinc are in general well known as to the end results obtained. The Zinc Smelter desireas a maximum recovery in a minumum time. There are certain factors that govern the fulfillment of this desire. The most important of these are TEMPERATURE , TIME , KIND OF REDUCTION MATERIAL , and THE NATURE OF THE ORE. There is much data available as to the temperatures at which these reactions go on and also there is obtainable some information as to the speed with which these reactions progress, particularly as to the length of time required for the commercial distillation. All of this information however is to a certain degree ~~more or less~~ disconnected and to some extent contradictory. The lack of information is particularly true as regards the time factor and the completeness of reaction at various temperatures under known conditions. The four points mentioned above, TIME, TEMPERATURE , KIND OF REDUCTION MATERIAL , and NATURE OF THE ORE are of vital importance to the zinc metallurgist for upon these factors hinge not only the capacity of his plant, because of the speed of distillation, but, also, the recovery of values.

There seems, then, to be room for experimental work even on a small scale, for the purpose of attempting to obtain and arrange in some compact form, data on the REACTIONS, SPEED OF REACTIONS, and the TEMPERATURES at which these reactions occur in the distillation of zinc from its ores, and this thesis was undertaken for work along this line.

)HISTORY

Although zinc was discovered by the ancients but little was known about it until 1721 when Henckle published his discovery that zinc could be obtained from calamine by distillation. The production on an industrial scale was first undertaken by John Champion who erected works in Bristol, England about 1740. Champion's scheme consisted in the distillation of the ore in large pots. This method was later known as the English Process and continued in use until 1860. Toward the end of the 18th century methods copied after the English were introduced into Upper Silesia, utilizing the pots of the wood-fired glass furnace. This was the beginning of the Silesian zinc industry. In 1805 Abbe Daniel Dony, a Belgian chemist, discovered, independently, a method of zinc smelting and from his experiments started the Belgian zinc industry. Zinc smelting was not attempted in the United States until 1850. Since that time the industry has grown steadily until to-day there are in use in this country 103,300 retorts with an output in 1912 of 347922 short tons of zinc. The increase in retorts in 1912 over 1911 was 15,5oo.In addition to the spelter output there was 533 tons of commercial zinc dust put on the market. All of our output,some 900,000 tons of it yearly, is thus produced from its ores by distillation.The zinc ore at proper temperature,in suitable vessels, is forced by carbon to give up its zinc and our problem has to do with this freeing of the zinc.

LITERATURE.

Metallurgy of Zinc and Cadmium	by	W.R.Ingalls.
Metallurgy of the Common Metals	by	L.S.Austin.
Metallurgy	by	Schnable.

The literature that concerns this thesis can be given as quotations from Ingalls:-

"Zinc oxide is reduced by carbon,carbon monoxide, and hydrogen; the reduction by carbon begins at 1100 degrees centigrade"

" Zinc silicate is reduced by carbon ......"

There is very little exact experimental data on the points we are trying to investigate.In making this statement we,of course, remember that the distillation of zinc ores has been carried on for a number of centuries and it is known that one reduction material is more satisfactory than another, that a certain temperature at least must be used, that a higher temperature means a greater temperature head and likewise a greater speed in distillation, also, that impurities such as lead and iron tend to retard the reduction and the lessen the per cent recovery.

METHOD OF ATTACKING THE PROBLEM.

In attempting the investigation of this problem, as usual difficulties were encountered, mostly however in the construction of a furnace suitable to this kind of work which should somewhat at any rate resemble the furnace used in commercial work.

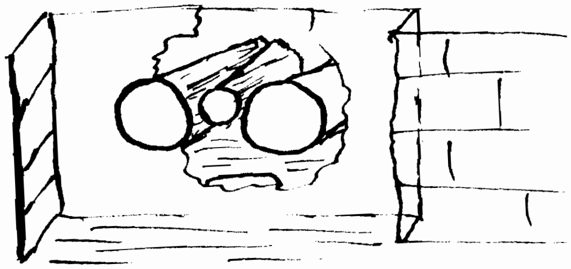
A graphite tube first suggested itself as being an ideal receptacle for acrrying on this experiment using an electrical resistant as the source of heat. This proved to be impractiale as no sufficient temperature could be attained and besides it would not be known what part the graphite played in the reduction. Next, the idea of using a Acheson graphite retort, since there would be little or no losses due to absorbtion, and using the gasoline furnace as a source of heat presented itself but this idea proved unsatisfactory due to the oxidizing effect of the hot gases of the furnace upon the outside of the retort.

Finally it was decided to use a number H Battersea-sand crucible as the retort and two telescoping 20-gram Battersea crucibles for the condenser. This scheme finally resulted in the construction of a furnace as shown on the accompanying sheet,using a 2 1/2" Case gasoline-burner as a source of heat.

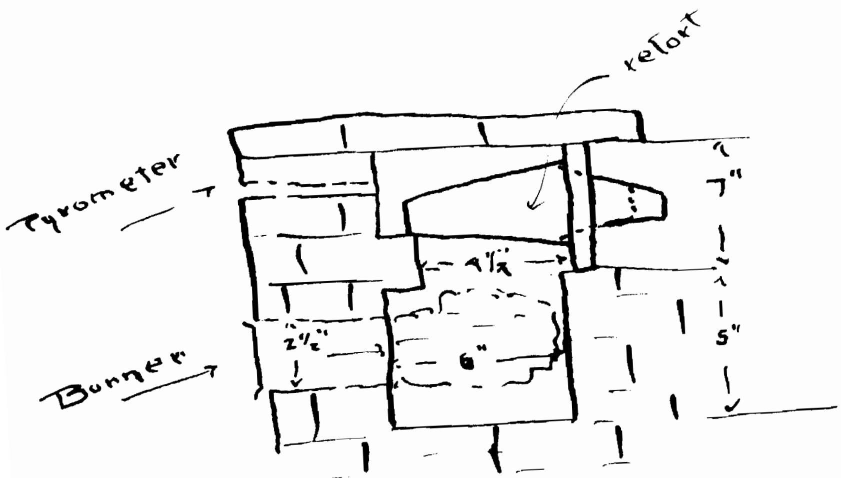
In charging amounts used were as follows 11.5 gms., 23 gms., 40gms., and 40.6 grams.This material was weighed mixed, wrapped up in paper and placed in the retorts by tongs,then, as rapidly as possible the condenser was put on and clayed up.In recovering the zinc which had been condensed it was necessary after each charge to remove the condenser and scrape out the metallics,zinc-dust, and oxide with a knife as the amount condensed each time was too small to permit of tapping as is the custon in practice.

Temperatures were obtained by placing a crucible (same kind as used for retorts) just between the two retorts and into this inserting a platinum -rhodium junction which had been calibrated in the usual manner using as fixed points: boiling water,boiling naptheline,boiling sulfur,freezing tin,freezing bismuth, freezing zinc, freezing antimony,freezing aluminum,freezing silver and freezing copper.It was noted that during the operation of of the furnace the temperature as shown by the pyromeeter when in the special place did not quite check up with the temperature as read in the retort.Correction was made for this.

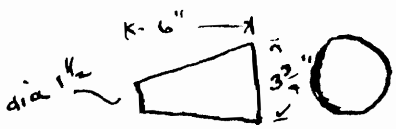
The FURNACE



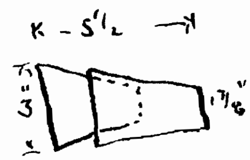
Front view.



Side view



Retort



Condenser.

MATERIALS USED IN THE CHARGE WITH ASSAY.

COAL

Analysis

volatile matter	46 %
fixed carbon	46%
ash	8 %

This coal was a bituminous coal used in the assay laboratory and showed a heat value of about 12,000B.T.U.

CINDER

Analysis

volitale matter	28.2%
fixed carbon	56.8%
ash	15.0%

This cinder,or,better called, lean coal was a partially burned coal that was picked up from under the fire-box of an assay furnace.

ZINC OXIDE

This was the C.P.Oxide put up by Merck.

ZINC SILICATE

This zinc silicate was obtained by hand picking the best pieces from an ore from the Joplin District.

Analysis

zinc	43. %
SiO_2	23.9%
Fe	0.87%

ROASTED ZINC ORE.

This ore was obtained from a Mississippi Valley Zinc-Smelter,the product a Brown Horseshoe Roaster made from a high grade blende.

ROASTED ZINC ORE (cont'd) Analysis

zinc	66.8%
sulfur	0.4%
mesh	thru #8.

SMELTER MIX. Analysis

Roasted Ore Zinc Dust Scrap	70.%
Material for Reduction	30.%

Rough Screen Analysis

Mesh	per cent	Nature of Material.
on 1/2"	5	coal
on 5 mesh	15	coal plus coked coal
on 6 "	3	" " " "
on 8 "	3	coke plus some ore
Thru 8 "	Balance	about 95 % ore 5 % coke

In using this mix for our work it was all put thru eight mesh, since with pieces as large as were in this material a good sample taking as small amount , as we did, would have been impossible .We, of course, realize that the size of particles in the charge may have a bearing on the various factors that we are trying to investigate, and therefore do not put forward the results obtained as those which would have been attained in the commercail distillation of this charge.

DIFFICULTIES ENCOUNTERED IN MANIPULATION.

Difficulty was encountered in attaining high temperatures, the maximum temperature attained inside the retort being 1200 degrees centigrade.

Some little difficulty was encountered in removing all the zinc from the condenser.

In some instances in the use of silicate of zinc as the ore part of the charge it was found that some of the charge decripitated over into the condenser.This could not be stopped, but , as very little went over ,it was neglected.

There was also trouble in accounting for the loss of some little amount of zinc in the operation.Although the amount of zinc obtained in the condenser whne a high temperature was used proved to be above that obtained at lower temperatures still it is thought that these results are low because of the fact that the amount of zinc condensed plus the amount in the residue did not quite check up to the amount put in the charge.The walls of the crucible,like the walls of the commercial retort, undoubtedly absorb more or les zinc.This would affect the results of the first charge put into the particular retort to the greatest extent.

With high temperatures at times the reaction progressed with such speed that all the material was reduced before the set time (15 minutes) was up. Even using two-thirds time on the high temperatures it was difficult to obtain satisfactory results because of the fact that the oxide adhered to the condenser so strongly that it could not all be removed . An attempt was made to reduce the time to 5 minutes but it was fonnd that the charge did not heat up in less than five minutes. Another reason the time could not be lessened was because the condenser would stick and require as much as five minutes for its removal.

NUMBER 1.

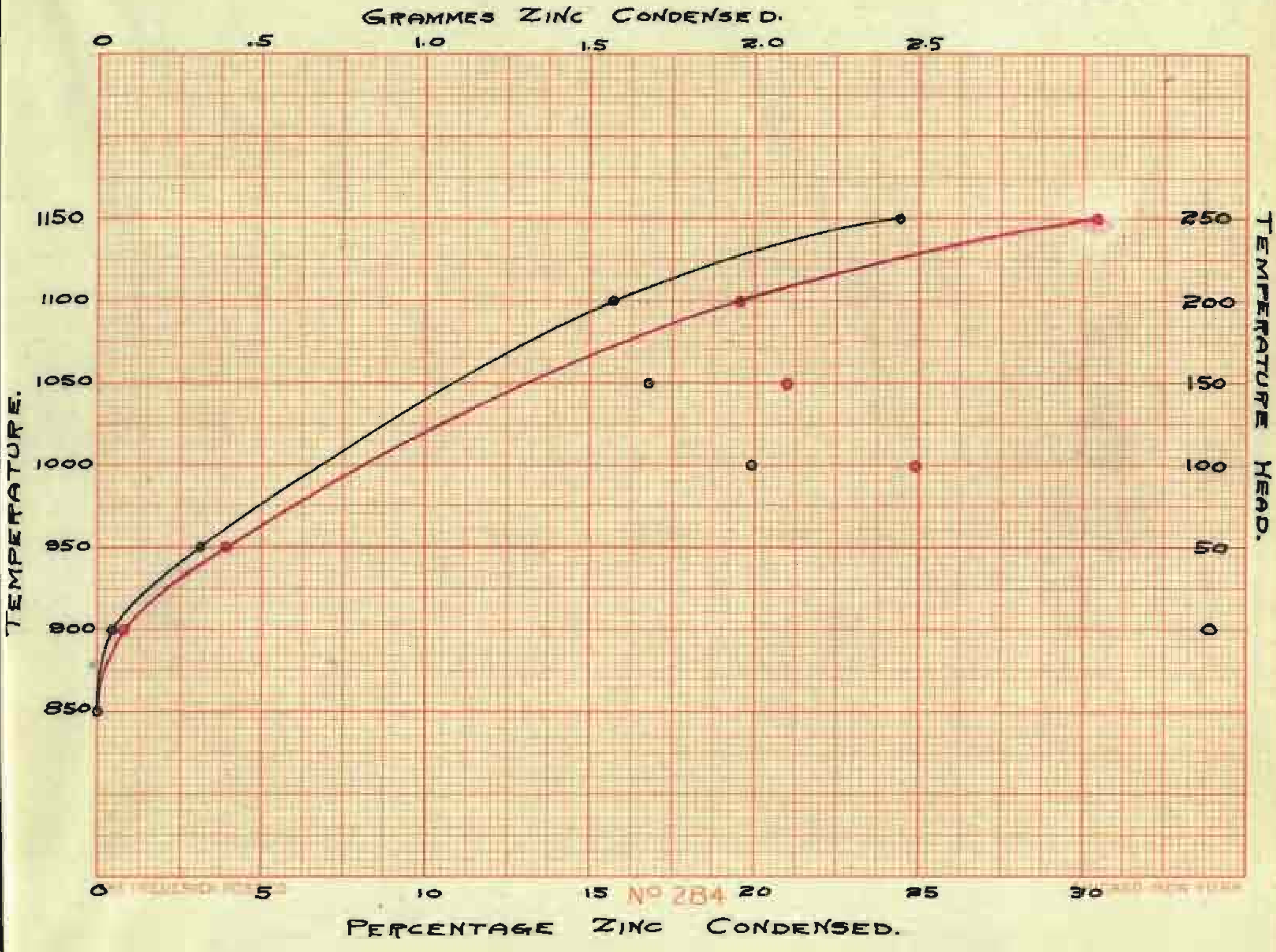

GRAMMES ZINC CONDENSED.
0 .5 1.0 1.5 2.0 2.5
TEMPERATURE.
1150 1100 1050 1000 950 900 850
TEMPERATURE HEAD.
250 200 150 100 50 0
0 5 10 15 20 25 30
No 284
PERCENTAGE ZINC CONDENSED.

TABLE NO. 1.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
1	ZnO	10		Charcoal	1.5	80	15	850	None	
2	"	"		"	"	"	"	900	0.054	0.7
3	"	"		"	"	"	"	950	0.310	3.9
4	"	"		"	"	"	"	950	0.975	12.2
5	"	"		"	"	"	"	1000	1.990	24.9
6	"	"		"	"	"	"	1050	1.680	21.0
7	"	"		"	"	"	"	1050	3.400	42.5
8	"	"		"	"	"	"	1100	1.570	19.6
9	"	"		"	"	"	"	1150	2.440	30.5

Table No. I.

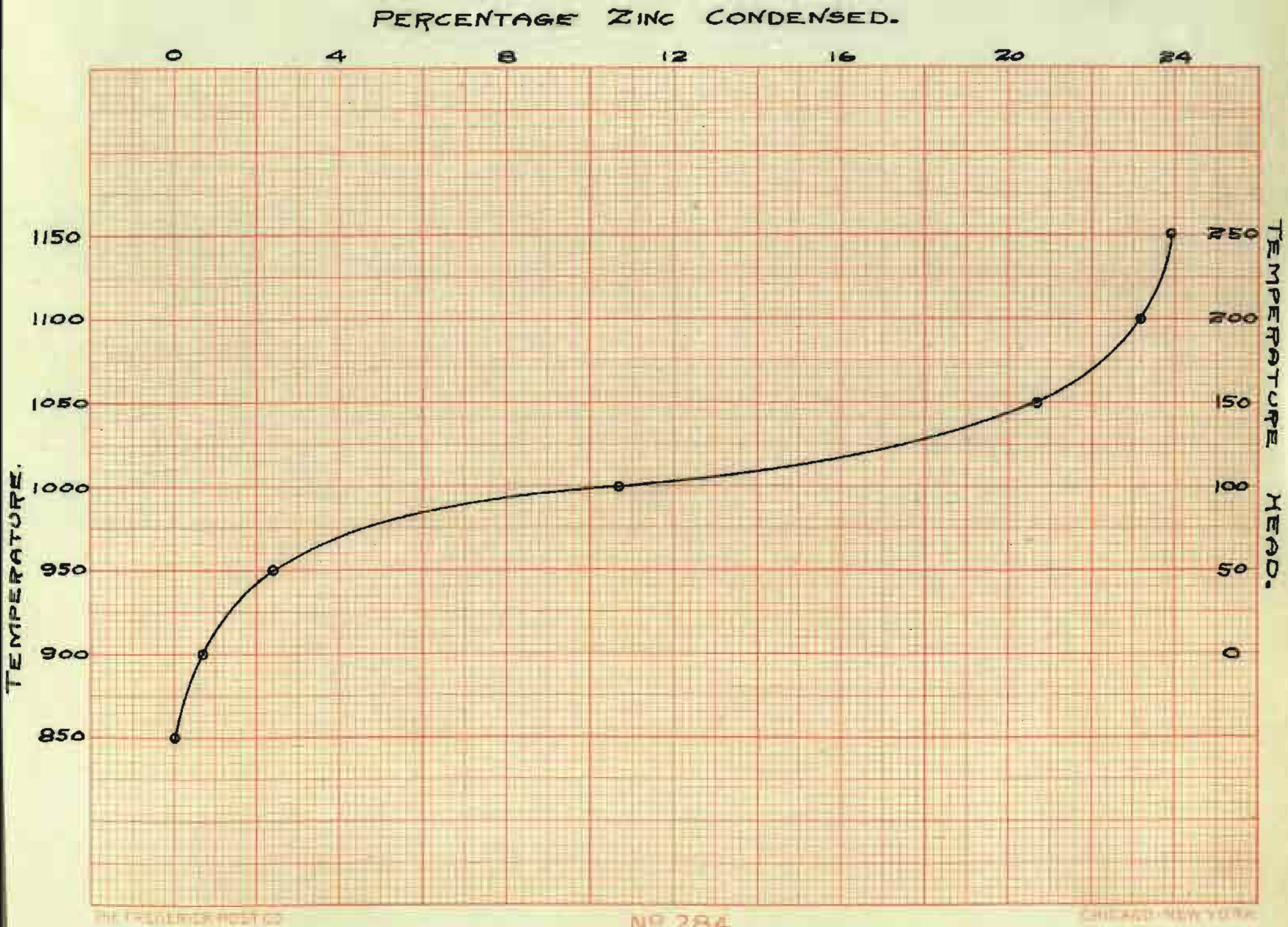
Constants......charge and time.

Variables......temperature.

The above set of experiments was performed for the purpose of ascertaining, if possible, the effect of increasing temperature head, above the critical point, on the distillation of zinc, all other factors remaining constant.

From this table it seems that the reduction of zinc by carbon begins at about 900 degrees centigrade or possibly a little above, and increases very rapidly with an increase in temperature. Although some of the results are apparently inconsistent there is plainly a decided increase in the amount of zinc distilled with an increase in temperature this increase being more than the temperature increase would indicate In as much as the starting temperature is about 925 degrees then it is evident that any increase in temperature would give a certain head of heat tending to force the reaction. it does seem that the increase in speed is more nearly proportional to the increase of temperature head above the critical point than to the actual temperature increase. Noting the table it can be readily seen that at 950 degrees there is a distillation of 12.2 % and at 1000 degrees there is 24.9 % showing that in doubling the actual temperature head the amount of zinc distilled was doubled.

NUMBER 2.



PERCENTAGE ZINC CONDENSED.
0
4
8
12
16
20
24
TEMPERATURE.
1150
1100
1050
1000
950
900
850
TEMPERATURE HEAD.
250
200
150
100
50
0
Nº 284

TABLE NO. 2.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
10	ZnO	10		Charcoal	15	40	15	850	None	0
11	″	″		″	″	″	″	900	0.06	0.7
12	″	″		″	″	″	″	950	0.19	2.4
13	″	″		″	″	″	″	1000	0.85	10.7
14	″	″		″	″	″	″	1050	1.66	20.7
15	″	″		″	″	″	″	1100	1.86	23.2
16	″	″		″	″	″	″	1150	1.91	23.9

Table No. 2.

Constants.......Charge and Time.

Variables.......Temperature.

The purpose of this experiment was to note the effect of the size of the reduction material on the distillation of zinc.

These experiments are identical with those in table one with the exception that 40 mesh reduction material being used instead of 80 mesh. There seems to be a tendency toward a slower reaction since at 1150 degrees there is a distillation of about 24. % compared with 30 % when using 80 mesh material at the same temperature. As in table number one the increase in the amount of zinc distilled seems to be more a function of the temperature head than of the actual temperature.

TABLE NO. 3.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
17	ZnO	20		Charcoal	3	80	15	1000	1.85	11.5
18	"	"		"	"	"	"	1100	4.10	24.8
19	"	"		"	"	"	"	1150	8.05	48.8
20	"	40		"	6	"	"	1000	1.70	10.3
21	"	"		"	"	"	"	1100	4.10	24.8
22	"	"		"	"	"	"	1150	8.20	49.7

Table No. 3A and 3B.

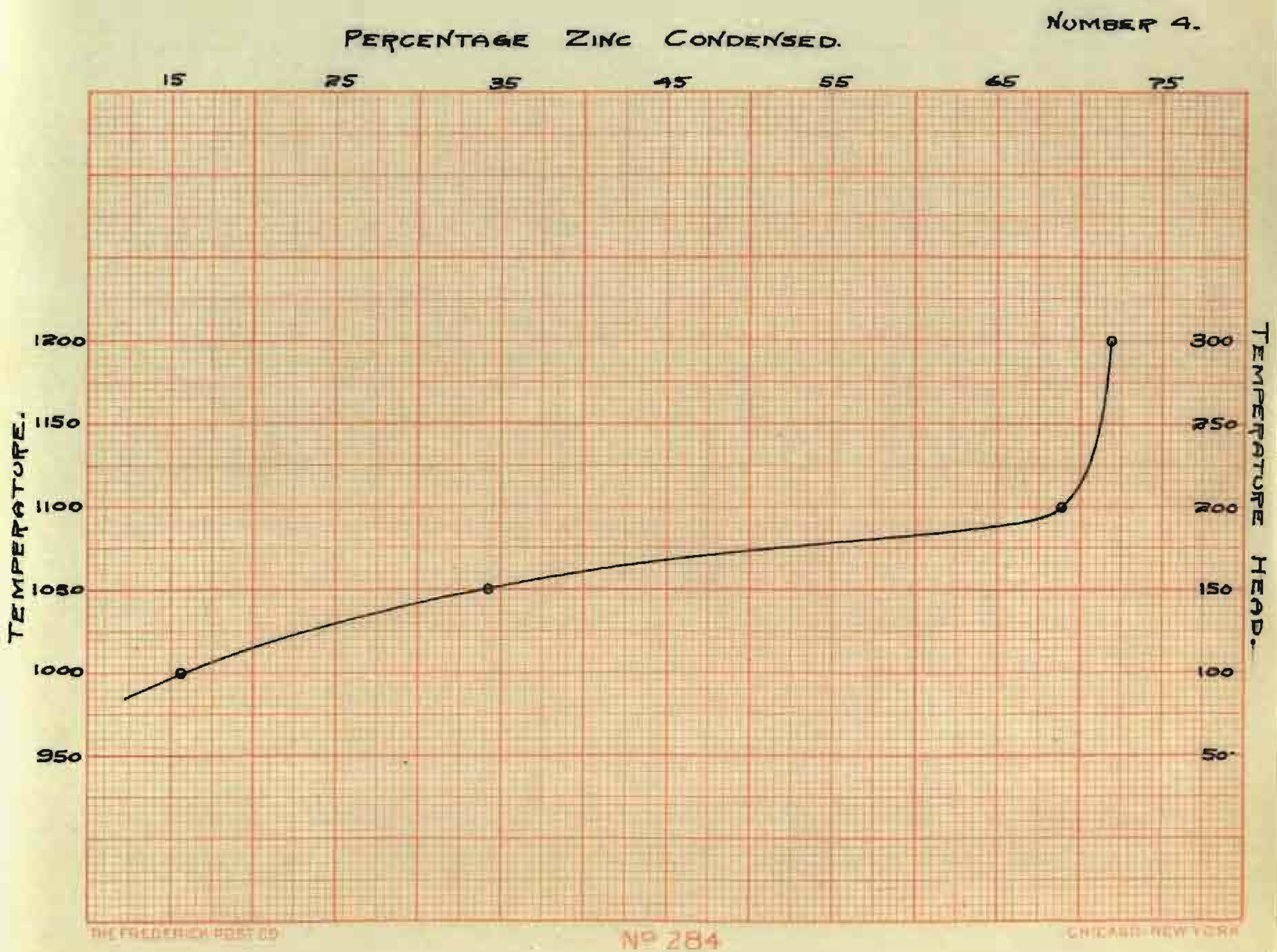
Constants......(3-A)..Time and Charge.

" (3-B).. " " " .

Variables......(3-A)..Temperature.

" (3-B).. " .

The experiments as shown in the tables were performed for the purpose of ascertaining the effect of increasing the amount of total charge on the amount of zinc distilled, the ratios of reduction material to ore being constant. It can be seen by comparing these two tables with table number one that the effect is small.


NUMBER 4.
PERCENTAGE ZINC CONDENSED.
15
25
35
45
55
65
75
TEMPERATURE.
1200
1150
1100
1050
1000
950
TEMPERATURE HEAD.
300
250
200
150
100
50
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Nº 284
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TABLE NO. 4.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
23	ZnO	20		Cinder	5	80	15	950	Lost	0
24	"	"		"	"	"	"	1000	2.50	15.6
25	"	"		"	"	"	"	1050	5.50	34.3
26	"	"		"	"	"	"	1100	11.05	69.0
28	"	"		"	"	"	"	1200	11.50	71.0
29	"	"		"	"	"	10	1150	6.75	42.2

Table No. 4.

Constants......Charge and Time.

Variables......Temperature.

The above set of experiments were made with an idea of comparing the effect of reduction with lean coal to the effect of reduction by charcoal and cinder.

Noting the results of this set of experiments and comparing them with table one, it can be seen that lean coal in other words cinder gives a decidedly increased distillation over that obtained when using a reduction material without volatile matter.It is also true that the cinder is superior in ability to rapidly reduce zinc than is a material with much volatile matter as in the case of some bituminous coals.

NUMBER 5.

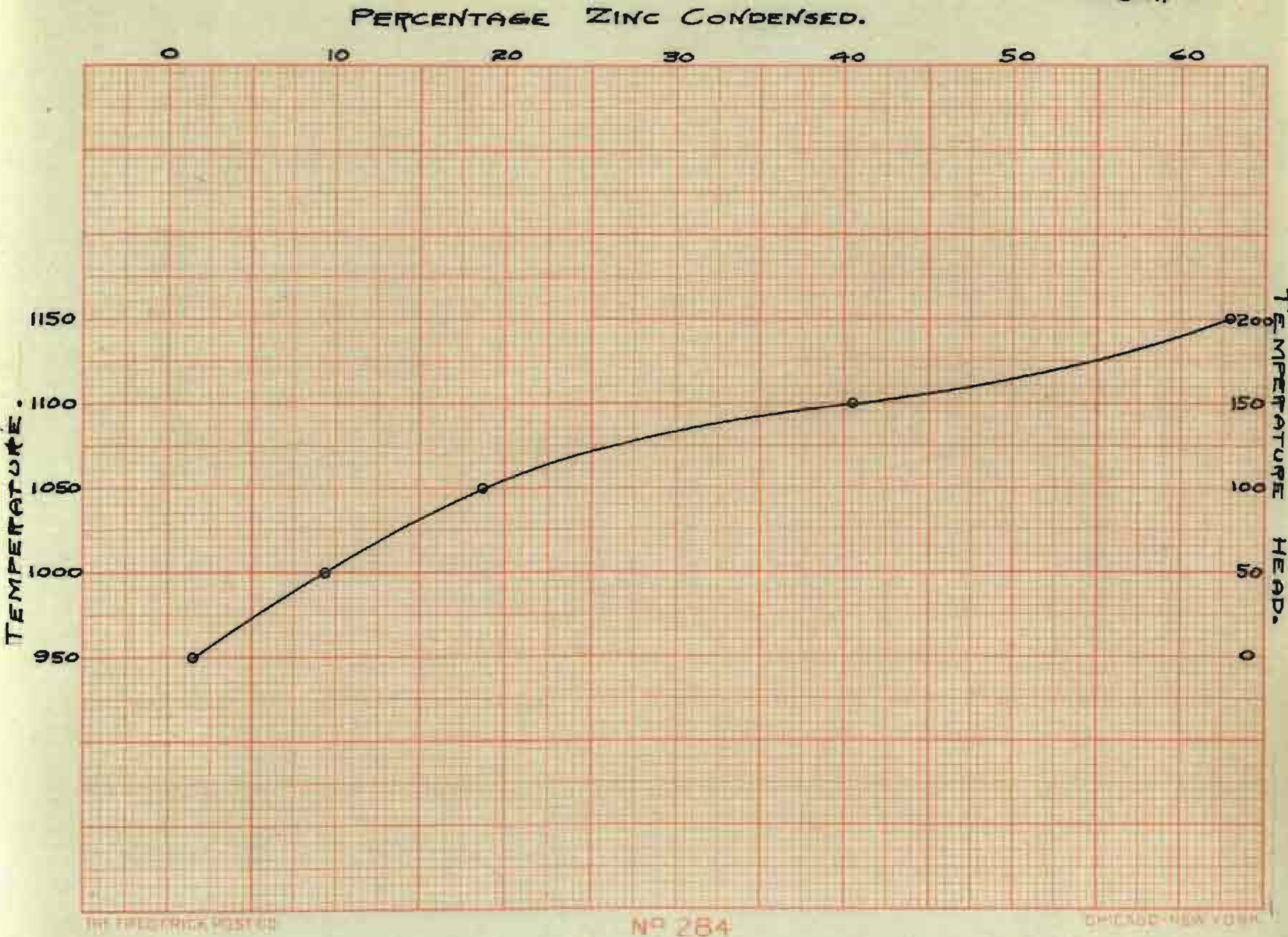
PERCENTAGE ZINC CONDENSED.
0
10
20
30
40
50
60
TEMPERATURE.
1150
1100
1050
1000
950
TEMPERATURE HEAD.
200
150
100
50
0
Nº 284

TABLE NO. 5

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
30	ZnO	20		Coal	5	80	15	950	0.25	1.5
31	"	"		"	"	"	"	1000	1.50	9.3
32	"	"		"	"	"	"	1050	3.00	18.7
33	"	"		"	"	"	"	1100	6.50	40.6
34	"	"		"	"	"	10	1150	10.10	63.0
35	"	"		"	"	"	10	1200	7.40	46.0

Table No. 5.

Constants...... Charge and Time.

Variables...... Temperature.

The above experiments were made to show the change in the amount of zinc distilled with the increase in temperature using coal as the reduction material.

This shows a marked increase over charcoal but gives considerably less distillation than was obtained when using coke as the reduction material. From this it might be argued that it is possible for the reduction material to contain too much volatile matter. This however is difficult to explain since the cinder was partially coaked coal of the same kind as the coal used, and this coal certainly passed all degrees of coaking during the reduction.

TABLE NO. 6.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
36	ZnO	20		Charcoal	3	80	15	850	Trace	0
37	"	"		"	"	"	"	900	0.50	3.1
38	x 1 PbSO4 x 1 PbO	"		"	"	"	"	950	2.00	12.5
39				"	"	"	"	1000	4.44	27.8
40	"			"	"	"	"	1050	4.69	29.3
41	"	"		"	"	"	"	1100	4.00	25.0
42	"	"		"	"	"	"	1150	4.80	30.0
43	"	"		"	"	"	"	1200	5.75	36.0

Table No. 6.

Constants......Charge and Time.

Variables......Temperature.

The results of this table were obtained by using a charge corresponding to that used in table number one with the addition of lead sulphate and lead oxide as impurities. The lead contents of the charge was about ten per-cent of the metallic part of the charge.

The principle effect of the lead addition was in retarding the reaction. This, of course, would be fatal with the commercial zinc smelter in as much as the temperature they are able to attain is limited to the fusibility of the refractories.

NUMBER-EXTRA.

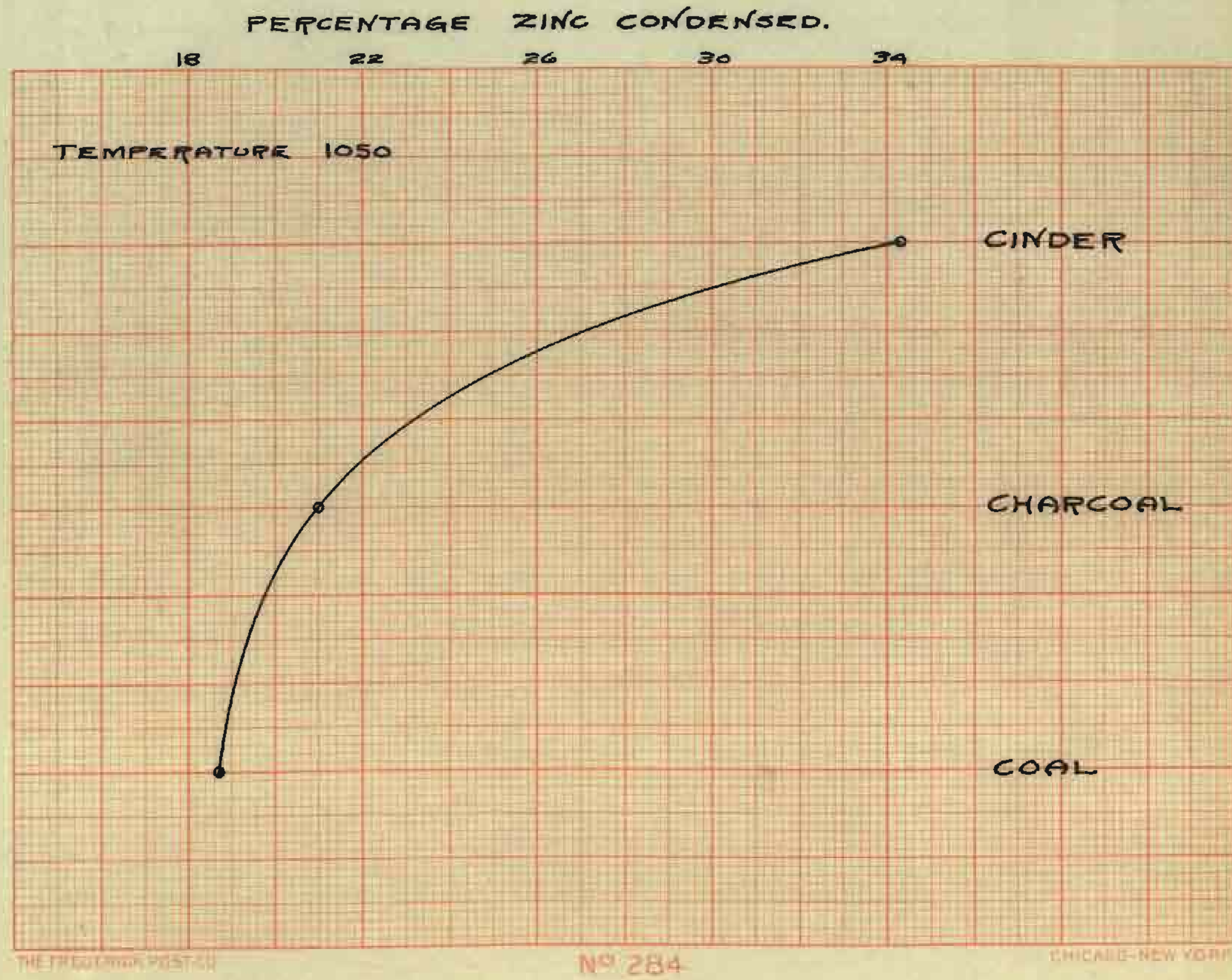

TABLE NO. -EXTRA-

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
44	ZnO	20	10	Coal	5	80	15	1050		18.7
45	"	"	"	Charcoal	3	"	"	"		21.0
46	"	"	"	Cinder	5	"	"	"		34.0

Table No.Extra.

Constants...... Ore, Temperature, and Time.

Variables...... Kind of Reduction Material.

This table shows the relative advantages of charcoal, coal and cinder as reduction materials.

Cinder running about 28% volatile matter shows a decided increase in amount of zinc distilled,while charcoal with no volitale matter and coal with an excessive amount of volatile matter show a lesser reducing power.

All this goes to prove that while some volatile matter is necessary an excessive amount is a hindrance.

TABLE NO. 7

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
47	Zinc	20	10	Charcoal	80	3	10	900	0.9	10.5
48	Silicate	"	"	"	"	"	"	950	2.0	23.2
49	"	"	"	"	"	"	"	1000	3.6	41.8
50	"	"	"	"	"	"	"	1050	4.25	49.4
51	"	"	"	"	"	"	"	1050	1.20	14.0
52	"	"	"	"	"	"	"	1100	6.40	74.4
53	"	"	"	"	"	"	"	1150	3.60	41.8
54	"	"	"	"	"	"	"	1150	1.45	16.9
55	"	"	"	"	"	"	"	1200	3.75	43.5

Table No. 7.

Constants...... Charge and Time.

Variables...... Temperature.

TABLE NO. 8.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
56	Zinc	20	10	Charcoal	3	80	10	900	2.90	
57	Silicate	"	"	"	"	"	"	950	3.50	
58	"	"	"	"	"	"	"	1000	3.50	
59	"	"	"	"	"	"	"	1050	4.25	
60	"	"	"	"	"	"	"	1100	5.90	
61	"	"	"	"	"	"	"	1150	5.25	
62	"	"	"	"	"	"	"	1200	7.00	

Table No. 8.

Constants...... Charge and Time.

Variables...... Temperature.

TABLE NO. 9

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
63	Zinc	20	80	Coal	5	80	5	1100	1.15	13.4
64	Silicate	"	"	"	"	"	10	1100	1.50	17.4
65	"	"	"	"	"	"	20	1100	3.30	38.4

Table No. 9.

Constants...... Charge and Temperature.

Variables...... Time.

TABLE NO. 10.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
66	Zinc	20	80	Cinder	5	80	5	1100	4.30	
67	Silicate	"	"	"	"	"	10	"	5.75	
68	"	"	"	"	"	"	20	"	6.75	

Table No. 10.

Constants..... Charge and Temperature.

Variables...... Time.

TABLE NO. 11.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
69	Zinc	20	10	Charcoal	3	80	10	1050	4.25	
70	Silicate	"	20	"	"	"	"	"	4.25	
71	"	"	40	"	"	"	"	"	5.80	
72	"	"	80	"	"	"	"	"	10.80	

Table No. 11.

Constants....... Time, Temperature, and Charge.

Variables....... Mesh of the Ore-Part of the Charge.

TABLE NO. 12.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
73	Zinc	20	10	Charcoal	3	80	10	1200	3.75	
74	Silicate	"	20	"	"	"	"	"	7.00	
75	"	"	40	"	"	"	"	"	6.50	
76	"	"	80	"	"	"	"	"	12.00	

Table No. 12.

Constants...... Time, Temperature and Charge.

Variables...... Mesh of the Ore-Part of the Charge.

TABLE NO. 13.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
77	Zinc	20	80	Coal	3	80	15	1050	2,50	
78	Silicate	"	"	"	"	"	"	1150	3.90	
79	"	"	"	"	"	"	"	1200	5.30	

Table No. 13.

Constants...... Charge and Time.

Variables...... Temperature.

TABLE NO. 14

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
80	Zinc	30	80	Cinder	3	80	15	1050	5.20	
81	Silicate	"	"	"	"	"	"	1150	5.50	
82	"	"	"	"	"	"	"	1200	9.30	

Table No. 14.

Constants...... Charge and Time.

Variables...... Temperature.

NOTES ON SILICATE CHARGE.

The preceeding tables, Nos. 7 to 14 inclusive, where zinc silicate was used as the ore-part of the charge, show the developement of no new information, excepting that it seems that the distillation was to some extent more rapid. Perhaps this added distillation is due to decrepitation of the ore during the operation.

The same critical temperature and the same increase of distillation with an increase of temperature head was noted here as in the experiments using ZnO as the ore-part of the charge.

TABLE NO. 15

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
83	Roasted	10	10	Charcoal	3	80	15	950	0.91	13.6
84	ore	↓	↓	↓	↓	↓	↓	1000	1.46	21.8
85	↓	↓	↓	↓	↓	↓	↓	1050	1.66	24.8
86	↓	↓	↓	↓	↓	↓	↓	1100	2.88	43.1
87	↓	↓	↓	↓	↓	↓	↓	1150	2.30	34.4
88	↓	↓	↓	↓	↓	↓	↓	1200	4.02	60.2

Table No.15.

Constants...... Charge and Time.

Variables ..... Temperature.

The above table shows as in the case of ZnO and $ZnSiO_3$ that the distillation increases with an increase in temperature head and also that the critical point is about 925° C.

A comparison of this table with table No.1 brings out the point that roasted ore is slower to reduce than the pure ZnO and strengthens our statement that impurities in the charge tend to retard and lessen the distillation.

TABLE NO. 16

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
89	Roasted Ore	10	60	Charcoal	3	80	15	950	0.98	14.8
90	↓	↓	↓	↓	↓	↓	↓	1000	0.97	14.8
91	↓	↓	↓	↓	↓	↓	↓	1050	2.0	30.3
92	↓	↓	↓	↓	↓	↓	↓	1100	2.2	33.3
93	↓	↓	↓	↓	↓	↓	↓	1150	2.25	34.1
94	↓	↓	↓	↓	↓	↓	↓	1200	3.56	54.0

Table No. 16.

Constants..... Charge and Time.

Variables...... Temperature.

This table shows a steady increase in recovery with an increase in temperature head but not so much as in the preceeding table, due, it is thought, to the fact that when a fine mesh is used the residue is generally a sintered mass that holds back values.

TABLE NO. 17

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
95	Roasted	20	60	Charcoal	2	60	15	1050	1.18	16.0
96	Ore	↓	↓	↓	↓	↓	↓	1100	1.97	26.4
97	↓	↓	↓	↓	↓	↓	↓	1150	3.64	48.7
98	↓	↓	↓	↓	↓	↓	↓	1200	4.37	58.7

Table No. 17.

Constants...... Charge and Time.

Variable....... Temperature.

This table shows a general increase with an increase of temperature head.

TABLE NO. 18

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
99	Roasted	20	60	Coal	5	80	15	1050	1.22	16.4
100	Ore	↓	↓	↓	↓	↓	↓	1100	1.40	18.8
101	↓	↓	↓	↓	↓	↓	↓	1150	3.00	40.2
102	↓	↓	↓	↓	↓	↓	↓	1200	5.07	68.0

Table No.18.

Constants...... Charge and Time.

Variables...... Temperature.

This table in comparison with preceeding tables shows the value of coal as a reduction material when compared with coke and charcoal.

TABLE NO. 19.

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
103	Smelter	40	8	—	—	—	10	1050	3.32	17.5
104	Mix	}	}	—	—	—	15	}	3.78	19.9
105	↓	↓	↓	—	—	—	20	↓	5.50	29.0

Table No.19.

Constants...... Temperature and Charge.

Variables...... Time.

This table shows the increase of distillation with an increase of time in retort but does not give us any data that would be of value to the zinc metallurgist because these results could not be compared with the actual commercial retorting because of the great difference in amount of charge used.

While these results may not be of value still they tend to show a similarity to our other experiments where Chemically Pure stuff was used instead of the commercial products.

TABLE NO. 20

NO.	CHARGE						TIME	TEMP.	ZINC CONDENSED	
	ORE			REDUCTION MATERIAL						
	KIND	AMT	MESH	KIND	AMT	MESH	MINUTES	DEGREES C	GRAMS	PER CENT
106	Smelter	40	8	—	—	—	15	950	1.9	10.0
107	Mix	↓	↓	—	—	—	↓	1000	2.9	15.3
108	↓			—	—	—		1050	3.32	17.6
109				—	—	—		1100	4.97	26.2
110				—	—	—		1150	5.50	28.9
111	↓	↓	↓	—	—	—	↓	1200	7.25	38.2

Table No.20.

Constants...... Charge and Time.

Variables...... Temperature.

This table a steady increase in distillation with an increase of temperature head as did our results using theoretical charges instead of the commercial charge, and tends to show that any conclusions we might draw from our experiments on theoretical charges would be applicable to the commercial retorting .

SUMMARY.

In summing up the data from the preceeding experiments together with a stady of the accompanying curves, we are lead to make the following statements:-

First, that the critical temperature for the reduction of zinc by carbon from pure zinc oxide lies between 900° C and 950° C,possibly more nearly 925° C ,and that this temperature is required before the reduction from commercially roasted ores can begin.

Second, that the speed of the reaction is directly proportional in all cases to the head of temperature above the critical temperature. That the kind of reduction material,the fineness of the reduction materail, and the amount of reduction material are important factors in determing the speed of distillation.

Third, that lead and iron tend to raise the critical temperature and also to hold back the reactions , thus requiring a higher temperature for the same percentage distillation as with the pure materials.

Fourth, that the reduction temperature of zinc silicate is at least as low as that for zinc oxide

Fifth, that the fineness of grinding on a small scale like ours has a bearing on the speed of the reduction.This however would probably not be true to the same extent in commercial distillation.