PYRITIC SMELTING OF A NICKEL-COPPER

SULPHIDE ORE.

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I N D E X.

INTRODUCTION.

The subject of this thesis is pyritic smelting in
the Institute blast furnace of a mixture of copper-nickel matte
and cupriferous pyrite. With the ordinary reducing smelting in
the Institute blast furnace, 18% of coke is used which furnishes
a reducing atmosphere. In pyritic smelting, no coke or only a small
amount is used, and this causes the smelting to take place under
oxidizing conditions. The oxidation of the iron and sulphur of
the sulphide of iron and the formation of the slag, furnish the
whole or the greater part of the heat necessary. For the success
of the process, it is necessary to have an abundant supply of
air at the right pressure and a sufficient quantity of silica
to slag off the iron which is not required for the desired grade
of matte. The matte concentration is affected by the amount of
air furnished, by the quantity of silicia present and by the coke
added.The slag composition under given conditions is always
constant. An increase of silica will not change this composi-
tion, but causes the formation of a larger quantity of slag and
a rise in the grade of the matte.

MATERIALS.

The ore smelted consisted of equal parts of copper-
nickel matte and cupriferous pyrite.

Matte. The matte used was a mixture of four lots of copper matte
and one lot of nickel matte produced at the Institute in labora-
tory runs and in a thesis run of 1908. The five lots of matte

were separately broken by hand to 30 mm. and screwed on 8 mm.
sieve to remove the fines, as only the oversize was to be used.
This was sampled by fractional selection, one tenth part by
weight of each lot being reserved as sample. The samples were
combined and reduced to 1/4 inch in the Sturtevant roll-jaw
crusher. The combined sample was then halved in the Jones samp-
ler and the reserved portion put through the Hendrick-Bolthoff
sample grinder to pass a 30 mesh sieve, then split-shoveled down
to 485 grams and this ground on the bucking plate to pass a
100 mesh screen. The matte was found to be magnetic, hence the
metallic iron particles from the machines could not be removed
with a magnet.

The matte was analyzed for Cu, Ni, Fe, Pb, S, CaO,
Al_2 O_3 and SiO_2

The sample for analysis was treated with a solution
of bromide in HNO_3 (Sp.Gr.1.42). After action ceased, concen-
trated HCl was added, and the solution boiled until no more sub-
stance was dissolved. The residue was then filtered, fused with
Na_2 CO_3 and added to the main solution. The solution was then
evaporated to dryness, dehydrated, HCl and water were added,
and the silica filtered off, washed, ignited, and weighed.

x Foot-note from 1st. page:-- Thesis No. 341 by A. H.
Bradford and C. A. Gibbons, Jr.

H_2S was passed into the slightly acid filtrate, the sulphides of copper and lead were precipitated and filtered. The precipitate was dissolved in HNO_3 and the solution electrolyzed. The copper was weighed as Cu and the lead as PbO_2.

The filtrate was evaporated nearly to dryness with H_2SO_4, water was added, and the solution passed through a Jones reductor. The iron was determined by titrating with $KMnO_4$. After titrating the solution was evapotated to about 250 c.c., and the nickel precipitated by the dimethylglyoxime method and weighed as $C_8H_{14}N_4O_4Ni$.

A fresh sample was taken for the determination of CaO and Al_2O_3. It was put into solution as above, SiO_2, Cu and Pb were separated as shown, and the combined hydroxides of aluminum and iron thrown down by means of a double ammonia precipitation, filtered, ignited and weighed. As some nickel is carried down its amount has to be determined. This was done by fusing the ignited precipitate with $KHSO_4$, taking up with water, precipitating with dimethylglyoxime, and weighing. Deducting the weight of the previously determined oxides of iron and nickel gave the Al_2O_3.

The calcium was precipitated in the filtrate as calcium oxalate. The precipitate was dissolved in H_2SO_4 and titrated hot with $KMnO_4$.

Sulphur was determined in one sample by the Fresenius method of fusing with Na_2CO_3 and KNO_3 and in another by the Glaser method of fusing with Na_2O_2.

The matte was found to contain some magnetic oxide of iron. The analysis gave the following results:

	Cu	Ni	Fe	Pb	S	CaO	Al_2O_3	SiO_2	$O^{\#}$	Total
%	9.54	2.35	55.32	.42	25.94	.46	.45	.63	4.89	100

O as FeO and Fe_3O_4.

Pyrite. The pyrite used came from the Eustis mine at Capleton, Province of Quebec, Canada. The ore was a massive copper-bearing pyrite with some quartz as gangue. It was broken by hand to pass a 30 mm. screen, the smalls , finer than 8 mm. were removed by screening. The coarse ore was halved by fractional selection and one half sampled by taking pieces from it when spread on the floor. The sample was crushed in the Sturtevant roll-jaw crusher, cut in half by means of the Jones sampler and ground in the Hendrick-Bolthoff sample grinder. The pulp was then split-shoveled to 210 grams and this amount bucked through a 100-mesh sieve. The metallic iron from the wear of the machines was removed with a magnet.

The pyrite was analyzed for SiO_2, Fe, Al_2O_3 . S, and Cu. The SiO_2 , combined oxides of iron and aluminum and S were determined in one sample, as followd:

A sample of about 5/10 gram. of pyrite was dissolved in 20 c.c. of a freshly-made mixture of three volumes HNO_3 (Sp.gr.1.42) and one volume of HCl (Sp. gr. 1.20). When dis-integration was complete 5c.c. of sodium carbonate solution were added. The whole was evaporated to dryness, treated with 5c.c. HCl and dehydrated. The residue was moistened with

1c.c. HCl, 100 c.c. of hot water were added, the whole heated
to boiling and the silica filtered off, washed, and ignited
and weighed. A test with HF showed that the insoluble residue
was silica.

The filtrate was treated with bromine water to oxidize
the iron. The combined oxides of iron and aluminum were precip-
itated by pouring the hot filtrate into an excess of ammonia,
filtering off the hydroxides. They were re-dissolvedin HCl
and re-precipitated with ammonia. This second filtrate and
the washing were added to the first filtrate. The precipitate
was ignited and weighed as Fe_2O_3 and Al_2O_3 Sulphur was
determined as Ba SO_4 by precipitating with Ba Cl_2 in the hot
filtrate.

Iron was determined from the second sample of pyrite
by dissolving in the same mixture of nitric acid and hydro-
chloric acid as above , filtering, fusing the residue with sodi-
um carbonate, adding water and suphuric acid (conc.), evap-
orated until fumes are given off, passing through a Jones reduc-
tor and titrating with $KMnO_4$. Copper was determined in the
third sample of pyrite. It was dissolved as above, neutral-
ized with ammonia, made slightly acid with hydrochroric acid,
heated to boiling and hydrogen sulphide passed in. The precip-
itated copper sulphide was filtered off, dissolved in nitric
acid and electrolyzed. The following are the results of the
analysis.

	Fe	S	Cu	SiO_2	Al_2O_3	Total
%	40.62	45.11	1.25	10.12	2.07	99.17

The fluxes used were limestone and quartz.

Limestone.The limestone used was a very pure white marble. It was sampled, crushed, and ground to about 30-mesh in the same way as the pyrite. The sample was split-shoveled to 300 grams and then bucked through a 100-mesh screen. All metallic iron present was removed with a magnet. The analysis was carried out in about the same way as in the Spathic Iron Ore Proceedure, common in the Institute Laboratories.

The analysis was as follows:

	CaO	MgO	FeO	SiO_2	CO_2#	Total
%	54.16	1.13	.35	.21	43.89	99.74

Calculated.

Quartz. The quartz was the same used in the thesis of Messrs. Bradford and Gibbons, Jr., in 1908. Their analysis gave:

	SiO_2	FeO	Al_2O_3	Total
%	96.61	1.50	0.49	98.60

For use in the smelt the quartz was broken up by hand to pass through a 30 mm. screen. The fines were not removed.

Fuel. The fuel used was Everett coke taken from the Institute bins. A sufficient quantity was put aside for the run and sampled by reserving a piece from every fourth shovelful. The sample was broken by hand, then crushed and ground in the same way as the pyrite. It was split-shoveled down to 100 grams and this amount bucked through a 100-mesh screen. The following

is "approximate" analysis of the coke.

Fixed Carbon ....77.02 %

Volatile Matter.............. 6.76 %

Ash..........................16.22 %

Moisture (Undried Sample)...00.92 %

The ash gave, upon analysis,

	Al_2O_3	MgO	SiO_2	Fe_2O_3	Al_2O_3	SO_3	Alk's	Total
%	6.39	.253	32.10	35.10	15.75	3.75	4.38	100.00

In the subjoined Table I are assembled the results of the above analyses.

Materials	SiO_2	Fe	FeO	Fe_2O_3	CaO	MgO	Al_2O_3	CO_2	O	S	Cu	Ni	Pb.
Matte	0.63	55.32			0.46		0.45		4.89	25.94	9.54	2.35	0.42
Pyrite	10.12	40.62					2.07			45.11	1.25		
Limesté	0.21		0.35		54.16	1.13		43.89					
Quartz	96.61		1.50				0.49					SO_3	Alk's
Coke Ash	32.10			35.10	6.39	2.53	15.75					3.75	4.38

For convenience in calculating the slag the percentage of magnesia and alumina were changed into equivalent percentages of lime and added to the CaO column. This was done as follows.

$$\frac{\text{Mol. Wt. of CaO}}{\text{Mol. Wt. of } Al_2O_3} \text{ x \% } Al_2O_3 = \text{Equivalent \% of CaO}$$

$$\frac{\text{Mol. Wt. of CaO}}{\text{Mol. Wt. of MgO}} \times \% \text{ MgO} = \text{Equivalent } \% \text{ of CaO.}$$

Table No. I is thus changed as given below in Table No. II.

Materials	SiO_2	FeO	CaO	S	Cu	Ni	Pb
Matte	0.63	71.12	0.71	25.94	9.54	2.35	0.42
Pyrite	10.12	52.22	1.13	45.11	1.25		
Quartz	96.61	1.50	0.27				
Limestone	0.21	0.35	55.73				
Coke Ash	32.10	31.59	18.53	1.50			

DESCRIPTION OF THE BLAST FURNACE.

The blast furnace of the laboratory is similar to the Arizona copper blast furnace. It consists of a water-jacketed boiler shell resting on four cast iron columns. The working height is 46" and the distance from the bottom to the level of the tuyeres is 14". The diameter at the top of the furnace is 23-1/4" and at the bottom 17-1/2",

There are seven tuyeres -- four 1-3/8" and three 2" in diameter. The bustle pipe is 6" in diameter. This is shown in the drawing.

The crucible was put in the furnace as follows: the bottom plate was placed in position and clamped. Then a mixture of 3 parts coke, 1-1/2 part ashes and 1 part fire clay, was introduced through the charging door and tamped firmly into place. The furnace was filled up to the level of the tuyeres with this material firmly tamped down. Then the plate which closed the breast of the furnace was removed and the central part of the compact brasque dug out leaving the crucible with the cross section shown in the drawing.
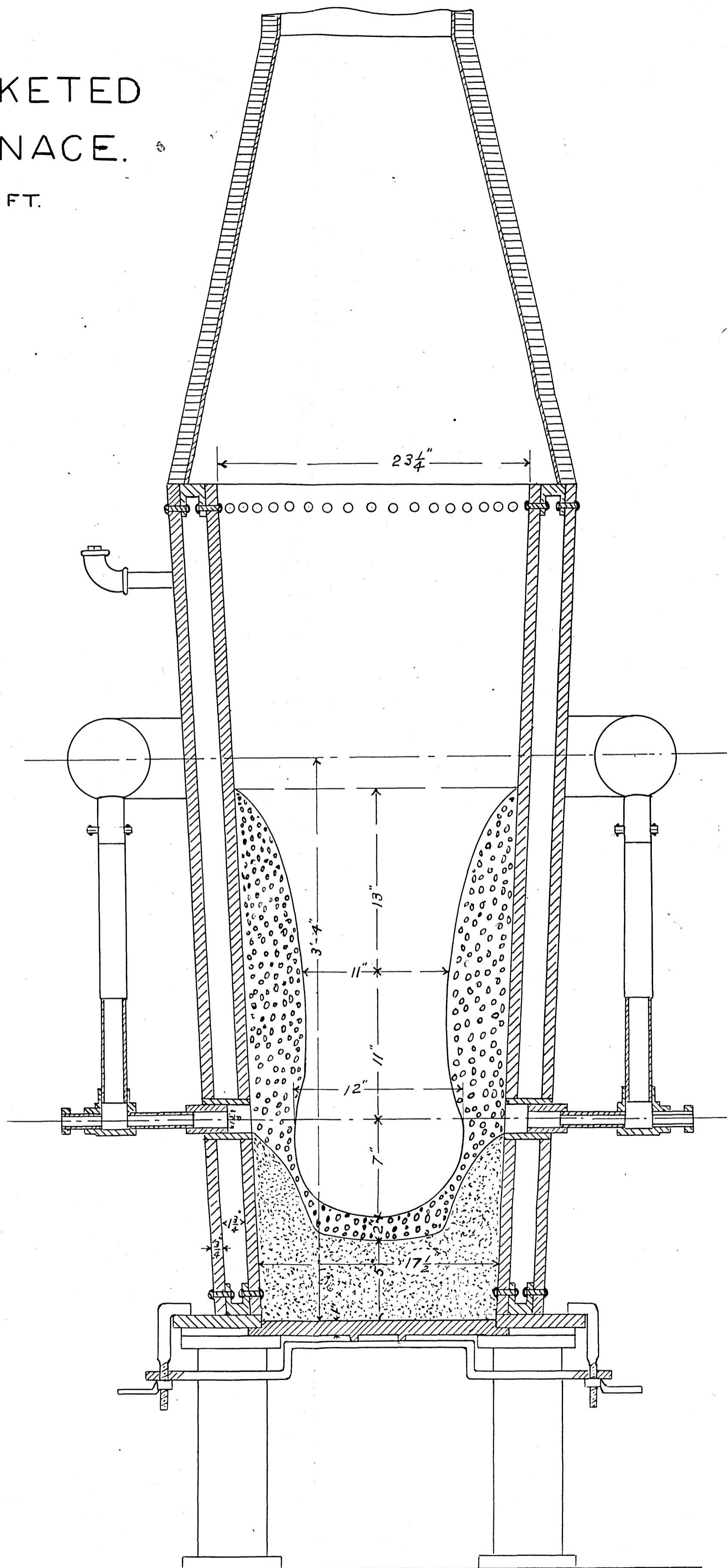
THE BLOWER. •

The blower which supplied the air to the furnace is a Root No. 1/2. It has a rated capacity of 487 cubic feet of free air per minute, running at a rate of 325 R. P.M. The blast main is 6" in diameter.

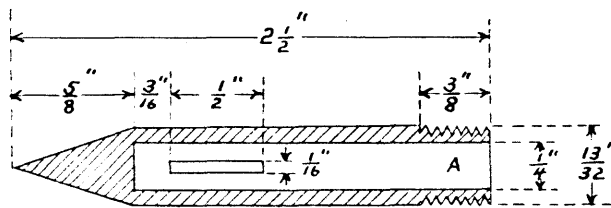# M.I.T.
WATER JACKETED
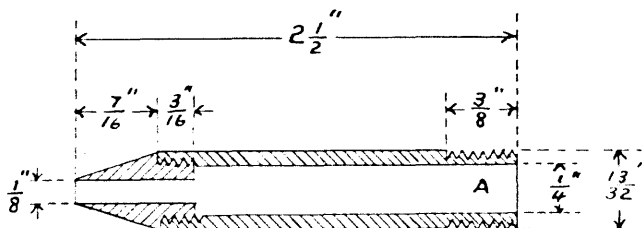# BLAST FURNACE.

SCALE 2 IN = 1 FT.
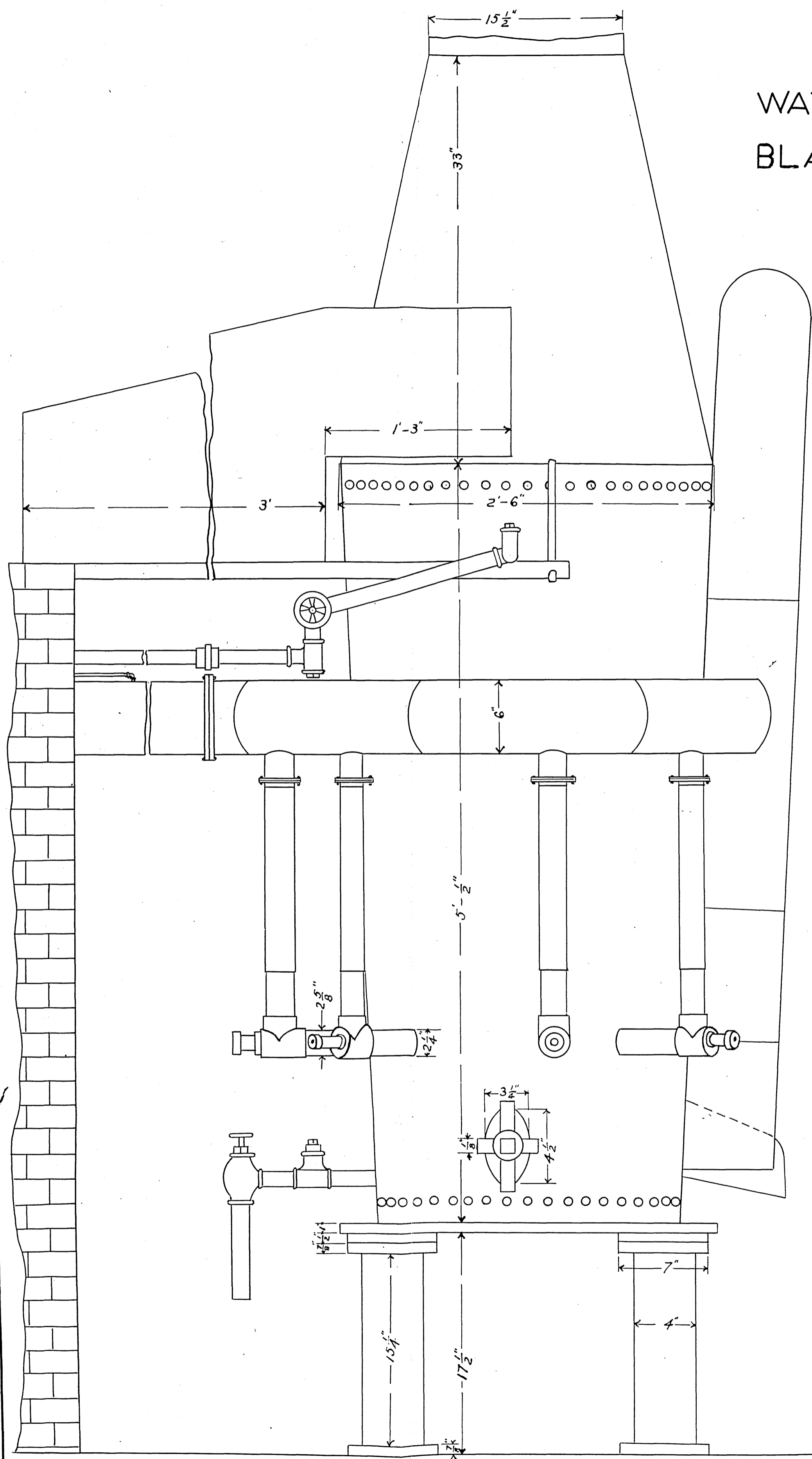
Side Elevation

Section Showing Crucible
And Artificial Bosh Formed

W. & C.
1910

The volume of air furnished to the furnace was measured with a Pitot tube and two U-tube manometers , giving respectively the static and velocity pressure heads.
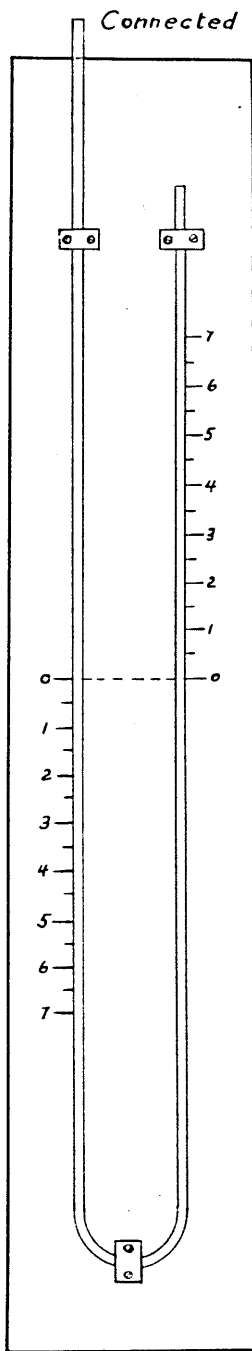
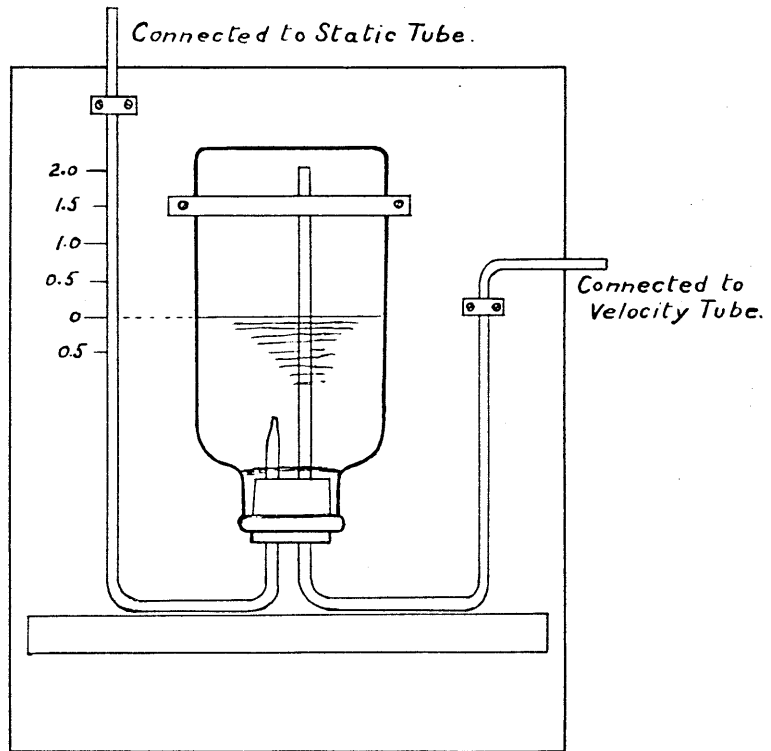# PITOT TUBES

Slots are in each side diametrically opposite.

Fit at A with standard $\frac{1}{8}$" elbow.

Scale — Full Size.

APPARATUS.
for
BLAST MEASUREMENTS.

Connected to Static Tube.

Connected to Static Tube.

Connected to
Velocity Tube.

Velocity Pressure.

Static Pressure.

CALCULATION OF CHARGE.

It was decided to smelt a mixture of equal parts of matte and pyrite and to produce a matte with 30% copper and nickel.

Starting with 50 Kgs. matte and 50 Kgs. pyrite. The mixture contains 5.40 Kgs. Cu, 1.17 Kgs. Ni and .21 Kgs. Pb. Total = 6.78 Kgs. Cu, Ni, Pb.

These 6.78 Kgs. = 30% of Wt. of matte,

Hence $\frac{6.78}{30}$ x 100 = 22.6 Kgs. is the Wt. of matte to be produced per 100 Kgs. ore.

Now 5.40 Kgs. copper = 6.76 Kgs. Cu_2S

$$1.17 \quad " \quad Ni \quad = 2.13 \quad " \quad Ni_3S_2$$

$$0.21 \quad " \quad Pb \quad = 0.24 \quad " \quad Pb\,S$$

$$\text{Total} \quad = \overline{9.13} \quad " \quad \text{Matte.}$$

The FeS in the matte will be

$$22.60 - 9.13 = 13.47 \text{ Kgs.}$$

To supply the FeO necessary for this 13.47 x $\frac{FeO}{FeS} = 11.03$ Kgs. 12 Kgs. coke per 100 kgs. matte and pyrite were used.

A former run, similar in character to the present one showed that an addition of 12 Kgs. coke to 100 Kgs. of ore would supplement the heat generated by the combustion of iron and sulphur -- hence the same amount of fuel this time.

The slag chosen had the following composition: Si O_2, 36.8 %; FeO, 51.2 %; CaO, 12.0%. It lies within the range of pyritic slag.

The table No. III shows that the proposed charge

contains 62.29 Kgs. FeO.

From this total will have to be deducted the number of Kgs. FeO going into the matte.

62.29 - 11.03 = 51.26 Kgs. FeO to be fluxed.

The Silica necessary for this FeO equals $\dfrac{36.8}{51.2}$ x 51.26

= 36.84 Kgs.

Table No. III shows that there is 6.00 Kgs. silica present.

Hence, SiO_2 to be supplied equals 36.84 - 6.00 = 30.84 Kgs.

The quartz used contains 95.53 % available SiO_2,

Therefore quartz that has to be added $\dfrac{30.84}{95.53}$ x 100 = 32.29 $^{Kgs.}$

To find the CaO necessary the silica was used as the basis of calculation. As shown by table No. III there are now present 37.20 Kgs. of SiO_2.
CaO necessary for this is

$$\dfrac{12}{36.8} \text{ x } 37.20 = 12.14 \text{ Kgs.}$$

There are already present 1.37 Kgs. CaO.

Hence the CaO to be supplied is

$$12.14 - 1.37 = 10.77 \text{ Kgs.}$$

The limestone contains .35% FeO. As this is equivalent to $\dfrac{12}{51.2}$ x .35 % FeO = .08% CaO, there is

55.73 - .08 = 55.65% CaO available in the limestone.

Hence, the limestone necessary to furnish the CaO is

$$\dfrac{10.77}{55.65} \text{ x } 100 = 19.36 \text{ Kgs.}$$

TABLE NO. III.

Materials	Wt Kgs.	SiO₂ %	SiO₂ wt.	FeO %	FeO wt.	CaO %	CaO wt.	S %	S wt.	Cu %	Cu wt.	Ni %	Ni wt.	Pb %	Pb wt.	Charge.
Matte	50	0.63	0.31	71.12	35.56	0.71	0.36	25.94	12.97	9.54	4.77	2.85	1.17	0.42	0.21	32.97
Pyrite	50	10.12	5.06	52.22	26.11	1.13	0.56	45.11	22.56	1.25	0.63					
Coke Ash	1.95	32.10	0.63	31.59	0.62	18.53	0.36	1.50	.03							
Total	101.95		6.00		62.29		1.28		35.56		5.40		1.17		0.21	
Quartz	32.29	96.61	31.20	1.50	0.48	0.27	0.09									21.29
Limesteʼ	19.36	0.21*	0.04	0.35	0.07	55.73	10.78									12.77
Total	153.60		37.24		62.84 +		12.15									100.00
Coke.	12.00															7.91 φ
Slag		36.8		51.2		12.0										

* SiO₂ in limestone is neglected.
+ Includes FeO for Matte and Slag. 1,103 Kgs FeO for matte
φ 8.0 Kgs for Coke contains .92% moisture.

DESCRIPTION OF RUN AND DATA SHEETS.

The furnace was blown in at 8.45 AM . The blowing in charge consisted of paper, kindling wood, charcoal, coke, copper slag and some fine copper matte. The individual charges and the order in which they were fed are shown in the weigher and feeder's data sheets. The blowing in charges were the same as those used in the laboratory for blowing in the blast furnace for a normal reducing fusion. The furnace, filled with the blowing in charge, was lighted, later, a tuyere was inserted in the tap-hole and a gentle blast turned on. This was kept going until the charcoal and coke were burning freely. Then the four 1-3/8" tuyeres were inserted and the furnace run a while until it got hot enough for the pyritic charge. Now the three 2" tuteres were put in and the regular pyritic charges of 100 Kgs. of ore and flux with 8 Kgs. of coke fed.

During the run the following reads were taken: temperature of jacket water at inlet and outlet, static and velocity heads of the blast, moisture (Grains per cubic foot) in the air, barometric pressure, atmospheric temperature, and the temperature of the slag. The jacket water was measured at intervals by weighing the overflow during a half minute. Chilled slag samples were obtained from every slag part. Two flue gas analyses were also made during the run.

The furnace worked very well, the slag showed great
fluidity and the same was the case with the matte of which
a very large amount was produced. An artificial bosh was
formed in the furnace as shown by the drawing, the tuyeres
were black most of the time, but the blast penetrated the
wall accretion without difficulty.

The run lasted till 2.15 P. M. The total amount of
materials fed was 230 Kgs.,slag; 236.8 Kgs., matte; 216.9
Kgs., pyrite; 139.9 Kgs., quartz; 72.1 Kgs., limestone;
and 84.1 Kgs. , coke.

WEIGHER.

Time. weighed	Charge No.	Coke.	Ore.		Slag.	Flux.		Signature.
			Matte.	Pyrite.		Quartz	Limest!	
8.45	1		3 hods Kindling 3 hods Charcoal					
	2	36						
	3	18			50			
9.10	4	18			100			
9.20	5	18	20	0	80	0	0	N. R. Perry
9.45	6	8	33.0	33.0		21.3	12.8	" "
10.00	7	8	33.0	33.0		21.3	12.8	" "
10.37	8	8	33.0	33.0		21.3	12.8	" "
10.47	9	8	33.0	33.0		21.3	12.8	" "
10.55	10	8	33.0	33.0		21.3	12.8	" "
11.15	11	8	33.0	33.0		21.3	12.8	" "
11.45	12	4.6	18.8	18.8		12.1	7.3	used a ratio of .57 in reducing charge to 18.8 of mat
12.43	13	N.	—	—		—	—	End of Pyritic Smelt 6 Pf Jones
12.59	14				100			R. T. Jones

FEEDER.

Time		Chrg	Feed door	Top	Flue Gas		Signature.
Coke	Charge	No.	Top to Chrg	Hot-Cold	Time	Temp	
		1	3 hods Kindling				
			3 hods Charcoal				
		2					
		3					
		4					
	9.25	5	3 inches	Cold			N. R. Perry
	10.31	6	2'.6"	Hot			" " "
	10.37	7	1.	Cold			" " "
	10.45	8	1.'	Warm			" " "
	10.55	9	,6"	"			" " "
	11.32	10	1'.3"	Cold			" " "
	12.04	11	2'.0"	Warm			R. L. Jones
	12.23	12	1'.6"	812°F			Temp 812°F at 12.15
18.	12.43	13	2'.0"	Hot			R.L.Jones
	1.25	19	2'.0"	Hot			R.L.Jones

gas analyz made at 11.15
gas analyzis made at 11.55

ASSISTANT TAPPER.

Time	Blast Press		Overflow Water		Fd Water	Athmo	Signature.
	Static	Vel.	Temp.	Wt.	Temp.	Temp.	
9:55	5.5	.36	51°	per ½ min	12.5°	68°	R A Beckman
10:05	6.45	.36	78°		12.5	63.7	"
10:10	6.45	.36	96.2		12.1	64.2	"
#10:16	6.25	.37	78.2		12.1	64.0	"
10:26	6.35	.37	65.0		12.1	66.0	"
10:35	4.9	.59	78.0		12.1	65.9	"
10:40	4.9	.60	82.0		12.1	66.3	"
10:44	5.2	.58	92.0		12.01	66.0	"
10:49	5.45	.58	96.5		12.1	{67.0	"
10:55	5.95	.58	99.0	6.8 K	12.01	67.3}	"
(x)11:03	6.40	.59	95.5		12.1	67.7	"
11:14	6.40	.60	93.0	7.0 K.	12.1	67.2	"
11:22	6.80	.60	92.0		12.1	68.2	"
11:31	6.75	.61	92.0		12.2	68.0	"
11:36	6.70	.62	92.0	7.5 K	12.0	68.0	"
11:47	6.9	.62	93.0		12.1	69.0	"
12:00	6.71	.62	91.2°	6.9 K	12.3	69.1	"
12:16	7.35	.61	89.0°		12.4	68.8	"
12:22	7.85	.61	87.0	7.2 K	12.1	69.0	"
12:32	7.20	.61	84.5°		12.1	69.0	"
12:44	7.15	.61	83.5°	4.1 K	12.1	70.0	"
12:55	7.05	.62	68.7°		12.0	70.3	"
1:10	6.75	.61	90.5°		12.1	70.3	"
1:26	7.10	.62	86.2°		12.0	70.1	"
1:37	7.05	.62	67.°		12.1	70.0	"
(x) 1:53	7.55	.62	64.0°		12.1	69.0	"
2:08	7.55	.62	66.3		12.1	68.7	"

X Pyritic Smelt.

TAPPER.

Time.		Elapsed Time.	Appearance of Tuyeres.							Slag Notes. Remarks.	Signature.
Tap.	Plug.		1.	2.	3.	4.	5.	6.	7.		
										Furnace lighted 8.45 a.m.	
										Front tuyer in at 9. a.m. Tuyeres 4 & 6 9.15 Tuyeres 1 & 2 9.15	
9.50	9.53										Hj. N. Crichton.
10.02	10.04	12									
10.33	10.35									Pyritic slags 7 tuyeres	
10.45	10.47									Gates of 3 large tuyeres half closed	
10.55	10.57									"	
11.03	11.04	1	dk	dk	dk	dk	dk	dk	dk	Gates of large tuyeres open	B Wohlgemuth
11.14	11.15	1	"	"	"	"	"	br	"	matte, liquid	"
11.24	11.26	1	"	"	"	"	"	br	"	large amnt	"
11.30	11.32	2	bk	bk	bk	bk	bk	bk	bk	"	"
11.36	11.37	1	"	"	"	"	"	br	"	Slag acid	"
11.46	11.47	1	"	"	"	"	"	"	"	"	
12.00	12.01	1	"	"	"	"	"	"	"	"	
12.16	12.17	1	"	"	"	"	br	dr	br	"	"
12.22	12.23	1	dk	dk	dk	dk	dk	dk	dk	"	"
12.32	12.33	1	"	"	"	"	"	"	"	"	
12.44	12.45	1	"	"	"	"	"	"	"	"	
12.55	12.56	1	"	"	"	"	"	"	"	"	"
1.10	1.11	1	"	"	"	"	"	"	"	"	
1.25	1.26	1	"	"	"	"	"	"	"	"	"
1.38	1.39	1	"	"	"	"	"	"	"	"	"
1.53	1.55	2	"	"	"	"	"	"	"	"	"

br = bright bk = black
dr = dark

SLAGMAN.

Time.	Slag No.	Hygrom. Reading.	Barom. Pressure.	Remarks.	Signature.
9.50	1	41.3	29.88	Thick – Quite warm	R. L. BEALES
10.02	2	39.50	29.88	Hot – More fluid.	R. L. BEALES
10.10	3	40.50	,,	,, ,, ,,	,, ,,
10.13	4	,,	,,	,, fluid	,, ,,
10.20	5	,,	,,	,, ,,	,, ,,
10.26	7	45	,,	,, first matte	,, ,,
10.33	9	,,	,,	,, Very liquid -	,, ,,
10.40	10	,,	,,	,, ,,	,, ,,
10.55	11	50	29.90	,, ,,	B Wohlgemuth
11.00	12	,,	,,		
11.03	13	,,	,,	Pyritic smelt	B Wohlgemuth
11.14	14	44	,,	,,	,,
11.24	15	45	,,	Liquid hot	,,
11.32	16	,,	,,	Temp slag 1000° C	,,
11.36	17	,,	,,	Temp slag 1120° e	,,
11.46	18	,,	,,	Large amt mutte	,,
12.00	19	3.6 gr per cwft		,,	,,
12.16	20	3.6 gr	,,	Temp 1120°c	,,
12.22	21	,,	,,	,, 1130	,,
12.32	22	,,	,,	,, 1140	,,
12.44	23	,,	,,	,, 1140	,,
12.55	24			18.30	
1.10	25	,,	,,	At 1 o'clock power cutoff	,,
1.25	26	,,		,, 1.3mm power on.	
1.37	27	,,			,,
1.53	28	,,		Blowing out 2.15	,,

(Relative humidity — noted vertically in Hygrom. Reading column)

CLEAN UP.

The products of the smelt were divided into pyritic slag, pyritic matte, preliminary matte, preliminary and final slag and odds and ends. Towards the end of the preliminary run, the pots were kept in the order in which they were filled, so as to keep separate the preliminary slag and matt from the pyritic and to distinguish them when cold by the difference in appearance of the slag. The preliminary and also the final slag were black in color, vitreous in lustre while the pyritic slag was black but was dull and non-vitreous. All the matte produced after that which had been fed with the blowing in charges was considered to be pyritic matte. The odds and ends included the crust forming the bosh or wall accretion, the matte-soaked portion of the crucible, and the material drawn from the furnace after the last tap excepting the unburned coke which was picked out by hand.

It was decided not to sample and analyze the preliminary matte,as,being equal in weight to the matte added during the preliminary run,its composition was assumed to have remained unchanged, excepting the amount of copper that it probably took up from the blowing in slag. All other products were broken by hand to about egg-size and then sampled by fractional selection. A hod of each was preserved as a sample, and a hodful crushed, ground, and bucked to pass a 100-mesh screen in the same way as was done with the samples of ore for the smelt.

Analysis of Products. The products of the run were anal-
yzed for their copper, nickel, and sulphur contents.
In addition, there were determined, in the pyritic matte,
the iron, in the chilled sample of the pyritic slag, the
FeO, SiO_2 CaO, MgO, and Al_2O_3. The methods of analysis
were similar to those used with the raw materials of the
smelt. Some difficulty was experienced in determining the
copper electrolytically in the pyritic slag and in the
odds and ends. The results were checked by the method of
titration with potassium iodate (KIO_3) devised by C. S.
Jamieson, L. H. Levy, and H. I. Wells and published in
the journal of the American Chemical Society, 1908, Vol.
I, Page 760.

ANALYSIS OF PRODUCTS. TABLE NO. IV.

Materials	Cu	Ni	S	Fe
Matte	8.73	1.95	26.25	58.65
Pyritic Slag	0.76	0.06	2.75	
Prel. & Final Slag.	0.28	0.00	1.48	
Odds & Ends	1.59	0.29	2.51	

Materials	S	FeO	SiO_2	CaO	MgO	Al_2O_3
Pyritic Slag Chilled Sample	2.57	28.80	37.35	18.34	0.86	4.61

GAS ANALYSIS.

	CO_2 & SO_2	O	CO	N
I	19.6%	0.6%	1.8%	78.0%
II	20.6%	0.4%	3.4%	75.6%

	No. I	No. II
SO_2	0.35%	0.15%

ACCOUNT OF STOCK.

The blowing in charges contained 20 Kgs. of matte, the analysis of which was not known. For this reason, a complete account of the copper is not possible.

The first 20 Kgs. of matte produced resulted from the matte mixture and foul slag used in the blowing in and was assumed to contain all copper not accounted for in other products. The balance sheet was made, using this assumption.

The balance sheet of sulphur was calculated only forthe pyritic run.

BALANCE SHEET OF MATERIALS.

TABLE NO VI.

Materials Fed	Wt.in Kgs.	Copper			Nickel		
		%	Kgs	% of Total	%	Wt.kg.	% of Total
Matte	216.8	9.54	20.68	80.79	2.35	5.09	100
Pyrite	216.8	1.25	2.70	10.54			
Matte Mix	20.0#						
Foul Slag	330.0	0.67	2.22	8.67			
Quartz	139.9						
Limestone	84.1						
Coke	160.6						
Total	1168.2		25.60			5.09	

\# This analysis unknown as it was decided just before the

run to add the matte mixture.

TABLE NO. VII.

Materials Produced	Wt. in Kgs.	Copper			Nickel		
		%	Kgs	% of Total	%	Kgs	% of Total
Matte	216.4	8.73	18.89	73.80	1.95	4.22	88.65
Prelim.Matte	20.0		1.90#	7.41			
Pyritic Slag	256.0	0.76	1.95	7.62	0.06	0.15	3.15
Prelim & Fin Slag	255.6	0.28	0.72	2.81			
Odds & Ends	134.4	1.59	2.14	8.36	0.29	0.39	8.20
Total	88.24		25.60			4.76	

\# Since the Cu in the matte used when blowing in is notknown

a complete account of the Cu is not possible.

BALANCE SHEET OF SULPHUR.

TABLE NO. VIII.

Materials Charged.	Weight Kgs.	Sulphur.		
		%	Wt.Kgs.	% of total.
Matte	216.8	25.94	56.24	36.50
Pyrite	216.8	45.11	97.80	63.46
Coke	52.6	0.14	0.07	0.04
Total	486.2		154.11	100.00

TABLE NO. IX.

Materials Produced.	Weight Kgs.	Sulphur.		
		%	Wt. Kgs.	% of total
Matte	216.4	26.25	56.80	84.49
Pyritic Slag	256.0	2.75	7.04	10.50
Odds & Ends	134.4	2.51	3.37	5.01
Total	606.8		67.21	100.00

CALCULATION OF THEORETICAL BALANCE SHEET OF MATERIALS

FOR ONE PYRITIC CHARGE.

There are three methods of calculating a Theoretical
Balance Sheet of Material. They are based on, (1) total
materials; (2) definite weight of matte produced; (3)
materials of a single charge.

The irregularities in the running of the furnace dur-
ing blowing in and blowing out make it difficult to ob-
tain reliable data for these two periods and also to de-
fine the limits of the run proper. The same holds good
for making a definite amount of matte produced, the basis
of calculation. In the third method, these errors are
avoided, as the calculations are based upon data taken
while the furnace is running normally. It was therefore
chosen for making a theoretical balance sheet of material.

Since the heat required to smelt the charge depends
largely upon the form in the elements are chemically com-
bined, it is necessary to calculate a rational analysis
of the materials charged. This is done as follows:

Matte. From the analysis of the matte it is known that the
iron is present as FeS, FeO, Fe_3O_4 and the remainder is
assumed to exist as metallic iron. The amount of oxygen
present is assumed to be the per cent not accounted for
in the chemical analysis. With these assumptions, the
amounts of FeS, FeO, Fe_3O_4 and Fe were calculated as
follows:

Iron present is FeS.

This is found by calculating the sulphur necessary to unite with the Cu, Ni, and Pb present to form Cu_2S, Ni_3S_2 and PbS and assuming the remaining S to exist as FeS.

Total sulphur present $= 25.94\%$

S as Cu_2S Ni_3S_2 and PbS $= 3.34\%$

S to form FeS is $25.94 - 3.34 = 22.60\%$

Fe equivalent to this Sulphur as FeS

$\frac{56}{32}$ x $22.60 = 39.46\%$

FeS present equals 62.06%

The amount of FeO present is determined by assuming it is in the ratio $\frac{40}{30}$ to the silica present, that is, that it is in the form of slag pellets.

Silica present equals $.63\%$

FeO present equals $\frac{40}{30}$ x $.63 = .84\%$

This is equivalent to $.65\%$ iron and $.19\%$ Oxygen.

The remainder of the iron exists as Fe_3O_4 and metallic Fe. The amount of oxygen in the Fe_3O_4 is obtained by subtracting from 100% the total percentage as found by analysis (95.11%) and the percent oxygen in the FeO($.19\%$). This leaves $.70\%$ as the amount of oxygen combined with iron in the form of Fe_3O_4.

Fe in Fe_3O_4 that is equivalent to 4.70% $O = 12.34\%$. This gives 17.04% of Fe_3O_4.

The remaining iron is the metallic iron and its per cent is found by subtracting from the total Fe, the amount present as FeS, FeO, and Fe_3O_4.

Total Fe equals 55.32%

Metallic Fe equals $55.32 - (39.46 \quad .65 \quad 12.34) = 2.87\%$

The $Al_2 O_3$, $Ca O$ and $Si O_2$ are assumed to exist in that form.

Pyrite. The pyrite contains 1.25% Cu which is assumed to exist as Cu_2S. The remaining S is considered to be in the form of FeS and FeS_2 , the amount of each being calculated as follows:

S as FeS and Fe S_2 = total S - S as Cu_2S.

Total S equals 45.11%.

S as $Cu_2 S$ equals .32%.

S as FeS and $FeS_2 = 45.11 - .32 = 44.79\%$.

Fe as FeS and FeS_2 = total Fe = 40.62%.

Now Let X = % FeS, then $\frac{32}{88}$. X = % S as FeS.

" Y = % FeS_2 , " $\frac{64}{120}$ Y = % S as Fe S_2.

Also the % FeS + % FeS_2 = % Fe + % S as FeS and FeS_2.

(1) S as FeS and $FeS_2 = 44.79 = \frac{32}{88}$ X $\frac{64}{120}$ Y

(2) X + Y = 40.62 + 44.79 = 85.41

From equations (1) and (2)

%FeS = X = 4.51%

% FeS_2 = Y = 80.90%

The Al_2O_3 and $Si O_2$ are assumed to exist in that form.

The remaining .83% unaccounted for by analysis is assumed to be water of crystallization in the aluminum silicate.

Quartz The SiO_2 , FeO and Al_2O_3 are assumed to exist in that form. The remaining 1.40% unaccounted for by the analysis is designated in the table No. XII as X. It is assumed to be slag-forming material.

Limestone. The CaO, MgO, FeO, and SiO_2 are recorded as obtained by analysis. The 44.15% unaccounted for is assumed to be CO_2.

Coke. The proximate analysis based on dry coke gave 77.02% fixed carbon and 16.22% ash. The sulphur in the latter probably exists as SO_3 (.61%). The SO_3 is volatile at the furnace temperature leaving 15.61% of slag-forming material. The 6.76% unaccounted for is the volatile matter in the coke. The moisture accompanying the 7.91 Kgs. of coke, as obtained by analysis, is .73 Kgs.

Calculation of Blast.

There are two methods of calculation of the blast, one using the flue gas analysis and the amount of carbon per charge, the other by means of Pitot tube measurements of velocity head and static pressure head.

Method Using Gas Analysis.

The volume of flue gas is first calculated by dividing the total weight of carbon in one charge by the weight of carbon (as CO and CO_2) in $1 m^3$ of gas.

Average Gas Analysis.

CO_2, 19.85%; CO, 2.60%; SO_2 , .25%; O, .50%; N, 76.80%.

C in 1 m^3 of flue gas = (% of CO_2 in flue gas % CO

in flue gas) x (Wt. of C in 1 m^3 of CO or CO_2 under standard conditions).

Wt. of C in 1 m^3 of CO or CO_2 under standard conditions = .54 Kg.

. C " " " " flue gas = (.1985 .026) x .54 = .12 Kg.

Carbon entering gas from coke = 6.09 Kgs. (See Table XII.)

"   "   "   " limestone = $\frac{12}{44}$ x 5.64 = 1.54 Kgs.

Total carbon in gas = C from coke + C from limestone.

"   "   "   " = 6.09 + 1.54 = 7.63 Kgs.

Volume of flue gas per charge at 0°C and 760 mm.

= $\frac{7.63}{.12}$ = 63.58 m^3 .

It was assumed that all the nitrogen in the flue gases

was that introduced by the blast.

Volume of N = %N in flue gas x volume of flue gas.

Volume of N = .768 x 63.58 = 48.83 m^3 .

Volume of air = $\frac{\text{volume of N}}{\text{% of N in air}}$ x 100.

% of N in air = 79.2 % by volume.

Volume of air to furnish 48.83 m^3 N equals

$\frac{48.83}{79.2}$ x 100 = 61.65 m^3 dry air at 0° and 760 mm.

Wt. of 1 m^3 dry air at 0° and 760 mm. = 1.293 Kgs.
" "61.65"" " " " "" " " " = 79.71 "

Conditions at time of run.

Atmospheric temp. = 69° F = 20°.5 C
Barometric pressure = 29.90 " = approx. standard.

61.65 m^3 dry air at 0° and 760 mm. = $\frac{293.5}{273}$ x 61.65

= 66.28 m^3 dry air at 20°.5 C and 760 mm.

The moisture accompanying this air is calculated as follows:

Hygrometer readings gave 3.6 grains water to cubic foot air.

3.6 grains per cubic foot equals 8.27 grams per m^3.

Wt.H_2O in blast per charge = Vol. of blast x Kgs. H_2O per m^3

" " " " " " = $\frac{66.28 \times 8.27}{1000}$ = .55 Kgs. H_2O.

Method using Pitot Tube measurements.

The volume of the blast was calculated from the Pitot tube measurements as follows:

Vol. of air per charge = (Vel. per Sec.) x (A. of cross section of pipe) x (of one charge in passing through furnace in seconds).

The velocity is calculated by the formula V = $\sqrt{2\ gh}$ where h is the velocity head in terms of air.

Velocity head = .61" water.

Water is 772 x as heavy as air at $0°$ and 760 mm.

Therefore velocity head = .61 x 772 = 470.9" air = 39.24' air.

Substituting in the formula

V = $\sqrt{64 \times 42.55}$ = 52.08' per sec.

Area of cross section of blast main = .195 sq. ft.

Rate of charging equals one charge in 21 minutes or 1,260 sec.

Static pressure head = 6.97" water = 1/4 lb. per sq. inch.

Therefore Vol. of air per charge = 52.08 x .196 x 1260

= 12865 cu.ft. air at $20°.5$ and 1/4 lb.

12865 cu. ft. air at 20.5° and 1/4 lb. $= 364$ m^3 at 20.5° &1/4#

364 m^3 " " " " " " $= 344$ " air at 0°

and 760 mm.

NOTE. There is a great difference between the volumes of air obtained by the two methods. This is due either to faulty gas samples or to the lack of calibration of the Pitot tubes or to both. The volume calculated from the gas analysis was used in the calculations , and not that obtained from the Pitot tube measurements, as the gas analysis had to enter the calculation of the heat balance.

The materials are distributed under the heads of Matte, Slag and Gas. The copper, nickel, and lead are all figured as entering the matte, the small amounts in the slag are assumed to exist there as matte particles . The weight of matte produced from one charge was calculated from the weight of copper in the charge and the per cent of copper in the matte produced. The weights of iron and sulphur entering the matte were calculated from the analysis of the matte formed. All solid substances not entering the matte were assumed to form slag and the remaining volatile and combustible matter to enter the gas.

Wt. matte produced per charge $= \dfrac{\text{wt. Cu per charge}}{\% \text{ Cu in matte}} \times 100.$

Wt. Cu per charge $= 3.55$ Kgs.

% Cu in matte $= 8.73\%$.

Matte produced per charge $= \dfrac{3.55}{8.73}$ x 100 $= 40.67$ Kgs.

The sulphur is assigned as follows:

The Cu_2S , Ni_3S_2 , Pbs, and FeS (amounting to 27.62 Kgs), were assigned to the matte. These contained 9.20 Kgs. sulphur. The sulphur in the matte produced is 26.25% (by analysis). Therefore, the 40.67 Kgs. of matte contain 10.68 Kgs. sulphur. The amount of S still to be furnished $= 10.68 - 9.20 = 1.48$ Kgs.

This is equivalent to 3.67 Kgs. FeS which must be furnished by the FeS_2 .

The remaining sulphur is assigned to the gas.

The iron is assigned as follows:

The total iron entering the mate as indicated above equals 16.30 Kgs.

The matte produced contains both metallic iron and magnetic oxide of iron. The amount of the latter was not determined but is estimated to correspond to 3% of oxygen.

Total wt. of sulphides $= 31.29$ Kgs.

The weight Fe and $Fe_3O_4 = 40.67 - 31.29 = 9.38$ Kgs.

Wt. O in matte $= .03$ x $40.67 = 1.22$ Kgs.

This is equivalent to 4.42 Kgs. Fe_3O_4 .

Wt. metallic Fe $= 9.38 - 4.42 = 4.96$ Kgs.

The Fe_3O_4 is assumed to be supplied by the Fe_3O_4 in the matte charged. The remainder of the latter Fe_3O_4 is assumed to be reduced to FeO and O and to enter the slag and gas

respectively. The metallic iron (4.96Kgs.) is assumed to c
come from the FeS_2. Of the FeS_2, 8.63 Kgs. (4.96 Kgs.
as Fe and 3.67 Kgs. asFeS) enter the matte,. The Fe
(5.30 Kgs) is assigned to the slag and remaining S (12.74
Kgs.) to the gas.

The assignment of the remaining materials requires
no comment except that of the 1.76 Kgs. of O from the
blast which is assigned to the slag. It is the O required
to oxidize the metallic iron from the matte charged and
the iron which enters theslag from the FeS_2.

THEORETICAL BALANCE SHEET OF MATERIALS.

TABLE No. XII.

DEBIT	%	Wt. kg.	Matte	Slag	Gas
Matte (32.97 kg.)					
Cu_2S	11.95	3.94	3.94		
Ni_3S_2	3.21	1.05	1.05		
PbS	0.49	0.16	0.16		
FeS	62.06	20.46	20.46		
FeO	0.84	0.28		0.28	
Fe_3O_4	17.04	5.62	4.42	1.11	0.09
Fe	2.87	0.95		0.95	
Al_2O_3	0.45	0.15		0.15	
SiO_2	0.63	0.21		0.21	
CaO	0.46	0.15		0.15	
Pyrite (32.97 kg.)					
Cu_2S	1.57	0.52	0.52		
FeS	4.51	1.49	1.49		
FeS_2	80.90	26.67	8.63	5.30	12.74
Al_2O_3	2.07	0.68		0.68	
SiO_2	10.12	3.34		3.34	
H_2O	0.83	0.27			0.27
Total Weight.		65.94	40.67	12.17	13.10

TABLE No. XII. (continued)

	%	Wt.kg.	Matte	Slag	Gas
DEBIT			**CREDIT**		
Quartz (21.29kg.)					
SiO$_2$	96.61	20.57		20.57	
FeO	1.50	0.32		0.32	
Al$_2$O$_3$	0.49	0.10		0.10	
X	1.40	0.30		0.30	
Limestone (12.77)					
CaO	54.16	6.92		6.92	
MgO	1.13	0.14		0.14	
FeO	0.35	0.04		0.04	
SiO$_2$	0.21	0.03		0.03	
CO$_2$	44.15	5.64			5.64
Coke (dry) (7.91)					
Fixed C	77.02	6.09			6.09
Ash	15.61	1.24		1.24	
SO$_3$	0.61	0.05			0.05
Volatile Matter	6.76	0.53			0.53
Moisture (0.07)		0.07			0.07
Blast (dry) (79.71)					
N	76.90	61.30			61.30
O	23.10	18.41		1.76	16.65
H$_2$O (0.55 kg.)		0.55			0.55
Total		122.30	00.00	31.42	90.88
Wts. from page 36.		65.94	40.67	12.17	13.10
TOTAL WEIGHTS		188.24	40.67	43.59	103.98

THERMAL BALANCE.

The figures used for heats of formation, specific heats, etc. are those given by J.W.Richards in his "Metallurgical Calculations". Those marked "approx". do not apply directly to the materials in this case. But since determinations of specific heats, heats of fusion, etc. on the different materials were not practicable, figures were selected which seemed to apply most nearly to each case.

Heat Generated.

(I) Oxidation C to CO_2 (8I00 Cal. per Kgs. of C)

C burned to CO_2 = (Vol. of gas X % CO_2 X Wt. C in 1 m^3 CO_2) - (Wt. C in CO_2 from lmste)

63.58 x .1985 x .54 = 6.83 Kgs.

6.83 - 1.54 =5.29 Kgs.

5.29 x 8100 = 44,793 Cal.

(2) Oxidation C to CO. (2430 Cal. per Kg. C.)

C burned to CO = Total C in coke - C burned to CO_2.

6.09 -5.29 = .80 Kg.

.80 x 2430 = 1944 Cal.

(3) Oxidation S to SO_2 (2164 Cal. per Kg. S)

% SO_2 in gas x m^3 of gas = m^3 of SO_2 . (Gas analysis)

Wt. of 1 m^3 H x Density of SO_2 x $\frac{S}{SO_2}$ = Wt. S in 1 m^3 of SO_2.

.0025 x 63.58 =.159 m^3 of SO_2

.159 (.0896 x 32 x $\frac{32}{64}$) = .227 Kgs. S burned.

This does not agree with the of S assigned to gas in the theoretical balance sheet. The difference is assumed

to have been distilled off as free sulphur.

.227 x 2164 = 491 Cal.

(4) Oxidation of Fe to FeO. (1173 Cal. per Kg. Fe.)

Wt. Fe oxidized = .95 5.30 = 6.25 Kgs. (See

Table No. XII)

6.25 x 1173 = 7331 Cal.

(5) Heat of Formation of Matte.

All copper and iron exist as sulphides in the ore.

The heat of union of FeS and Cu_2S is unknown.

(6) Heat of Formation of Slag. (150 Cal. per Kg. approx.)

Wt. slag made = 43.59 Kgs.

43.59 x 150 = 6538 Cal.

(7) Sensible Heat in Blast at room temp. (20.5°) (Sp.

Heat .25 approx.)

Vol. x Sp. Ht. x Temp. = 66.28 x .3036 x 20.5. =

413 Cal.

(8) Sensible Heat in Charge at room temp. (20.5°)

(Sp. Heat = .25 approx.)

Wt. x Sp. Ht. x Temp. = 107.91 x .25 x 20.5 =

553 Cal.

HEAT ABSORBED.

(a) Reduction of Fe_3O_4 to FeO. (1023 Cal. per Kg. FeO.)

Wt. FeO from Fe_3O_4 = 1.11 Kgs.

1.11 x 1023 = 1135 Cal.

(b) Reduction FeS_2 to Fe (428 Cal. per Kg. Fe Approx.)

The heat of reduction of FeS_2 to Fe is not known.

Since it probably is not much larger than FeS to Fe,

the latter figure is used.

Wt. Fe from FeS_2 = 10.26 Kgs. (See distribution of matte

    constituents , page 34.)

10.26 x 428 = 4391 Cal.

(c) Decomposition of Limestone. (1026 Cal. per Kg. CO_2) #

    # Figure for $CaCO_3$ to CO_2 used since the amount of

    $MgCO_3$ is small.

    Wt. CO_2 from $CaCO_3$ = 5.64 Kgs.

    5.64 x 1026 = 5787 Cal.

(d) Heat in Slag (Temp. = 1130° C.)

    Heat in melted slag at 1100° = 300 Cal. per Kg. (approx.)

    43.59 x 300 = 13077 Cal.

    To heat from 1100° to 1130° C. (Sp. Ht. = .27 approx.)

    43.59 x .27 x 30 = 353 Cal.

    Total Heat = 13077 + 353 = 13430 Cal.

(e) Heat in Matte. (Temp. = 1130° C)

    Heat in melted matte at 1000° = 200 Cal. (approx.)

    40.67 x 200 = 8134 Cal.

    To heat from 1000° to 1130° (Sp. Ht. = .285 approx.)

    40.67 x .285 x 130 = 1507 Cal.

    Total Heat = 8134 + 1507 = 9641 Cal.

(f) Heat in Gases. (212° F = 100° C.)

    (1) CO + N + O = 79.90% .

    (These gases have same specific heat.)

    .7990 x 63.58 = 50.80 m^3

    Sp. Ht. per m^3 = (.303 + .000027t)

    Heat = 50.80 x 100 (.303 + .000027 x 100) =

        1553 CAL.

(2) Vol. of CO_2 = .1985 x 63.58 = 12.62 m^3.

Sp. Ht. per m^3 = (.37 + .00022t).

Heat = 12.62 x 100 (.37 + .00022 x 100) =

495 Cal.

(3) Vol. of SO_2 = .0025 x 63.58 = .16 m^3.

Sp. Ht. per m^3 =(.36 + .0003t).

Heat = .16 x 100 (.36 + .0003 x 100) = 6 Cal.

(4) Wt. evaporated = .73 +.27 + .55 = 1.55 Kgs.

Heat of Vaporization at 0° = 606.5 Cal. per Kg.

1.55 x 606.5 = 940 Cal.

Sp. Ht. of Gas per Kg. = (.42 + .000188t).

Heat = 1.55 x 100 (.42 + .000188 x 100) =

68 Cal.

Total Heat in gases = 1553 + 495 + 6 + 940

+ 68 = 3162 Cal.

(g) Heat in cooling water.

Temp. of Feed Water = 12.1^o C.

Temp. of Overflow = 92.1^o C.

Rate of Flow = 14 Kgs. per minute.

"   "   " =147 Kgs. per charge.

147 x(92.1 - 12.1) = 11,613 Cal.

XIII.

THERMAL BALANCE FOR ONE CHARGE.

Debit, Kg. Calories.	Credit, Kg. Calories.
Burning C to CO_2 - 44,793	Reduction Fe_3O_4 to FeO - 1,135
Burning C to CO - - 1,944	Reduction FeS_2 to Fe - - 4,391
Burning S to SO_2 - 491	Decomposition of $CaCO_3$ - 5,787
Burning Fe to FeO - 7,331	Heat in Slag - - - - - 13,430
Formation of Slag - 6,538	Heat in Matte - - - - - 9,641
Sensible Heat in Blast 413	Heat in Gases - - - - - 3,162
Sensible Heat in Charge 553	Heat in Cooling Water 11,613
Formation of Matte(?)	49,159
	Radiation(by Difference)12,904
62,063	62,063

SUMMARY.

The sulphur elimination obtained in this run was 56.38 per cent of the sulphur present, instead of 79.64% as expected. If the analysis of the flue gas is correct about 98% of the sulphur eliminated was driven off in the form of sulphur vapor and not as sulphur dioxide. The sample of gas must have been faulty, as the concentration obtained, -- 1.6 into 1 -- gives a greater pyritic effect although it falls below the calculated concentration of 4.4 into 1.

The thermal balance shows thatthe larger part of the heat in the furnace was furnished by the coke and not by the oxidation of the iron and sulphur as should have been the case.

The slag formed contained 32.37 % FeO instead of the calculated 51.2%, the silica contents was 41.98% instead of the calculated 36.08%. The percentage of lime ran much higher than was intended. These facts show that sufficient silica was present but thatthe iron was not oxidized and therefore could not enter the slag but went into the matte. Assuming the air supply to be sufficient, the coke must have prevented the desired pyritic effect.

A decrease in the amount of coke used would therefore correct the smelting conditions.