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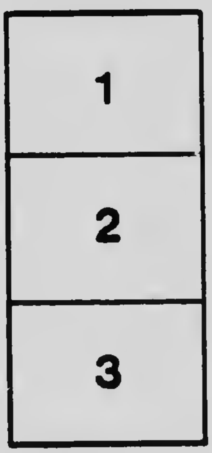
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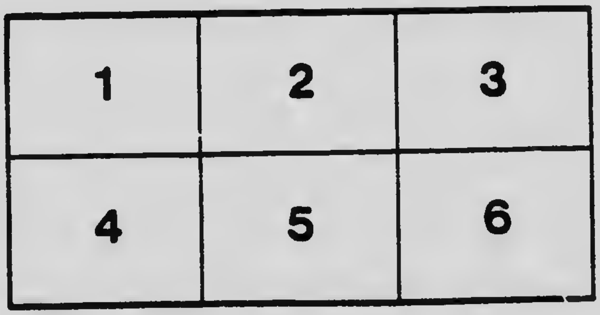
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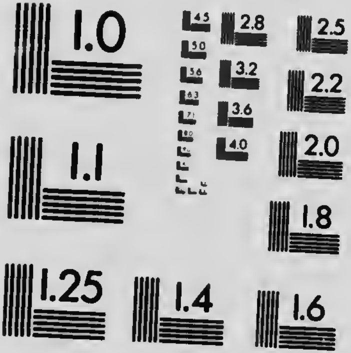

MINES BRANCH

DEPARTMENT OF THE INTERIOR.

HONOURABLE FRANK OLIVER, M.P., MINISTER.

EUGENE HAANEL, PH. D., SUPERINTENDENT OF MINES.

PRELIMINARY REPORT

ON THE

Experiments made at Sault Ste. Marie, Ont., under Goverment auspices, in the smelting of Canadian iron ores by the Electro-thermic Process.

BY

EUGENE HAANEL, Ph. D.

OTTAWA, CANADA
1906.

OTTAWA, 8th May, 1906.

SIR,

I have the honour to transmit herewith a Preliminary Report on the experiments made at Sault Ste. Marie, Ont., under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process.

I have the honour to be,

Sir,

Your obedient servant,

EUGENE HAANEL,

Superintendent of Mines.

HONOURABLE FRANK OLIVER, M.P.,

Minister of the Interior,

OTTAWA.

PRELIMINARY REPORT ON THE EXPERIMENTS MADE AT SAUTL STE. MARIE UNDER GOVERNMENT AUSPICES IN THE SMELTING OF CANADIAN IRON ORES BY THE ELECTRO-THERMIC PROCESS.

INTRODUCTION.

The only experiments which the members of the Commission appointed by the Government in December, 1903, to investigate the different electro-thermic processes for the smelting of iron ores and the making of steel in operation in Europe* were able to witness in the electric smelting of iron ores were those made by Dr. Heroult at La Praz and Mr. Keller, of Keller, Leleux & Co., at Livet, France. The first was a mere trial, furnishing no reliable quantitative results; the latter more extended experiments continued for a number of days were made with a very porous hematite containing 3.21% of manganese and only 0.02% of sulphur; an ore, therefore, easily reduced and easily desulphurized. Two sets of experiments were made at Livet. In the first experiment 0.475 E. H. P. years were required per ton of 2,000 lbs. of pig iron, corresponding to an output of 5.769 tons per 1,000 E. H. P. days. In the second experiment 0.226 E. H. P. years were required per ton of product, corresponding to an output of 12.12 tons per 1,000 E. H. P. days. In this experiment, moreover, most of the iron produced was white, for which cold working is required and consequently less energy consumed.

The difference in output of these two experiments was so great, being more than double that of the first in the second experiment, that no conclusion could be drawn as to the amount of energy required per ton of product and Mr. Harbord, the metallurgist of the Commission, was compelled to adopt 0.350 E. H. P. years, the mean of the two experiments, as the probable energy required per ton of product. This would correspond to an output of 7.827 tons per 1,000 E. H. P. days.

Before, therefore, a sound judgment could be formed as to the practicability of the electro-thermic process for the smelting of Canadian ores it was desirable to establish with some degree of exactitude the amount of electric energy required per ton of product and also the following important points referring to Canadian conditions, which were either not taken up or were left in doubt by the Livet experiments:—

1st: Can magnetite, which is our chief ore and which is to some extent a conductor of electricity be successfully and economically smelted by the electric process?

* Report of the Commission. Department of the Interior, Ottawa, 1904.

2nd: Can iron ores with comparatively high sulphur content but not containing manganese be made into pig iron of marketable composition?

3rd: The experiments made at Livet with charcoal as a reducing agent in substitution for coke having failed, could the process be so modified that charcoal, which can be cheaply made from mill refuse and other sources of wood supply useless for other purposes, could be substituted for coke? This is especially important since charcoal and peat-coke constitute home products, while coal-coke for metallurgical processes requires to be imported into the provinces of Ontario and Quebec.

The settlement of these questions was of such paramount importance for the formation of a judgment as to the feasibility of introducing electric smelting of iron ores as an economic process in those provinces of Canada which lack coal for metallurgical coke, but are abundantly supplied with water powers and iron ore deposits, that the experimental investigation of the subject by the erection of an electric smelting plant was authorized.

LOCATION OF PLANT.

The Lake Superior Corporation at Sault Ste. Marie, Ont., offered, on the recommendation of Mr. Clergue, the use of a commodious building in which to erect the electric furnace and the power of one of their alternators free of expense for four months. At the same time the use of an office, their well equipped laboratory, the services of their chemist and machinery necessary for preparing the charge for the furnace were offered on reasonable terms. It was deemed that these advantages could not be secured elsewhere and the offer was, therefore, accepted and the plant ordered to be erected, under the superintendence of Mr. Erik Nystrom, member of the staff of the Mines Branch, in the building provided for this purpose.

DESCRIPTION OF EXPERIMENTAL FURNACE AND ELECTRODE HOLDER

The furnace* was designed by Dr. P. Heroult, who had consented to make the experiments. It consisted of an iron casing bolted to a bottom plate of cast iron 48 inches in diameter. The casing was made in two cylindrical sections to facilitate repairs. To render the inductance as small as possible the lines of magnetic force in the iron case were prevented from closing by the replacement of a vertical strip of 10 inches width of the casing

* See Plate 4.

by a copper plate. Carbon paste was rammed into the lower part of the furnace up to the bottom of the crucible. The lining consisted of common fire brick, which from the bottom of the crucible up for a distance a little above the slag level was covered with carbon paste to a thickness of a few inches. The crucible, therefore, consisted entirely of carbon.

The lining of the furnace was given the shape of a double cone set base to base. Changes in the dimensions of the interior were made from time to time, as indicated by experience, but for the majority of the experiments they were as follows:—

Diameter of bottom of crucible	24 inches.
Height of lower cone	11 "
Height of upper cone	33 "
Diameter of joint base of the two cones	32 "
Diameter at top of furnace	30 "

The electrodes, manufactured by the Heroult process and imported from Sweden, were prisms of square cross-section, 16 x 16 inches by 6 feet long. The contact with the cables carrying the electric current to the electrode consisted of a steel shoe riveted to four copper plates which ended in a support for a pulley. The electrode with its contact was supported by a chain passing under the pulley, one end of the chain being fastened to the wall, the other end passing over a winch operated by a worm and worm-wheel. This formed a convenient arrangement for regulating the electrode by hand.

ELECTRICAL MACHINERY.

The electrical energy was furnished by one phase of a 3 phase, 100 K. W., 30 cycle, 2,400 volt, alternating current generator coupled by belt to a 300 H. P., 500 volt, direct current motor A current of 2,200 volts was delivered to an oil cooled transformer of 2?? K. W. capacity, designed to furnish current to the furnace at 50 volts. The transformer was placed in a separate room in the furnace building, close to the furnace. From the transformer the current was led to the bottom plate contact of the furnace and to the electrode contact by conductors consisting each of 30 aluminium cables, ⅜ inch in diameter.

The measuring instruments consisted of a voltmeter, an ammeter, a power factor meter and a recording wattmeter. The transformer and electric meters were manufactured by the Westinghouse Electric and Manufacturing Company.

An additional voltmeter reading from 10 to 80 volts, supplied by the Keystone Electric Company, which proved very satisfactory, was also placed in circuit to serve as a check

EXPERIMENTS.

A number of experiments required to be made to adjust the capacity of the crucible of the furnace to the energy available and to determine the shape to be given to the interior of the furnace to insure easy passage of the charge into the reducing and melting zones. After this, attempts were made to utilize the calorific energy of the carbon monoxide resulting from the reduction of the ore, which in all experiments so far recorded had been wasted: To accomplish this air under pressure was introduced into the furnace about 12 inches below the upper level of the charge. The carbon of the charge, in the form of coke dust, was mixed with fire clay and briquetted to prevent it from being consumed by the air blast. It was hoped that by thus utilizing the carbon monoxide in preheating the charge and partially reducing the ore the output would be materially increased.

It was found, however, that the great heat evolved by the combustion of the carbon monoxide caused the charge too become sticky and to hang. Nor could this be remedied by stoking, the space between the walls of the furnace and the electrode being too narrow. Moreover, the electrode, although it had been protected with asbestos and iron sheeting, was found after the experiment to have been badly corroded. The furnace was not at all adapted for these experiments and further attempts in this direction were abandoned. The experiments, however, showed that with a differently constructed furnace, in which the electrode is isolated from the charge, the output might be greatly increased by the introduction of an air blast.

The official experiments were begun about the middle of January, the furnace being in operation night and day, with some few intermissions, until the 5th of March. During that time about 150 casts were made, yielding about 55 tons of pig iron.

The following classes of ore were treated:

1. Hematite, (Negaunee)
2. Magnetite from the Wilbur mine, Ont. (Wm. Caldwell, Esq.)
3. " " " Blairton mine, Ont. (Pierce Co., Marmora).
4. " " " Calabogie Mining Co. (J. G. Campbell, Esq., Perth).
5. " " " " " " " " "
6. " " " Calabogie mine, (T. B. Caldwell, Esq., Lanark).
7. Roasted pyrrhotite from Lake Superior Corporation.
8. Titaniferous iron ore from Quebec, (I. G. Scott, Quebec).

The materials for the charge: ore, flux and carbon, were crushed to pass through a ¾ inch ring and roughly mixed. The composition of the charge in each run as given in this preliminary report was slightly modified from time to time by varying the percentage of charcoal and flux.

RUN No. 8.*

Ore treated	Hematite.
Reducing agent.	Briquettes.
Flux	Limestone.

ANALYSIS OF RAW MATERIAL.

HEMATITE:	SiO_2	5.42%	LIMESTONE:	SiO_2	1.71%
	Fe_2O_3	88.90%	Fe=62.23%	$Fe_2O_3 + Al_2O_3$	0.81%
	Al_2O_3	2.51%		$CaCO_3$	92.85%
	CaO	0.61%		$MgCO_3$	4.40%
	MgO	0.30%		P	0.004%
	Mn	0.16%		S	0.052%
	P	0.044%			99.826%
	S	0 002%			
	Loss on ignition	2.48%			
		100.426%			

The briquettes were made of 80% coke dust and 20% fire-clay.

BRIQUETTES:	Volatile matter	4.05%
	Fixed carbon	69.73 "
	SiO_2	15.26 "
	$Fe_2O_3 + Al_2O_3$	8.92 "
	CaO	0.90 "
	MgO	0.30 "
	S	0.84 "
		100.00%

The charge, which was slightly modified for subsequent charges by increasing the amount of briquettes and decreasing the limestone, had the following composition:—

Ore	200 lbs.
Briquettes	60 "
Limestone	50 "

ANALYSIS OF IRON PRODUCED.**

	CAST No. 28. GREY IRON.	CAST No. 30. GREY IRON.
Total carbon	4.85%	4.35%
Si	0.87%	1.03%
S	0.018%	0.019%

ANALYSIS OF SLAG PRODUCED.

SiO_2	34.40%
Al_2O_3	15.73%
CaO	43.53%

* Only those runs are given in this preliminary report which are of special interest

** A redetermination for the final report of the composition of slags and iron produced renders the analyses here given subject to amendment.

MgO	2.00%
Fe	1.35%
S	0.55%

$$\frac{\text{Slag (obtained)}}{\text{Iron (obtained)}} = \frac{1162}{2665} = 0.44$$

Length of run	12 hours.
Mean volts on furnace	38.5
Mean amperes	4856
Power factor	0.919
Pig iron produced	2665 lbs.
Watts=38.5 × 4856 × 0.919	171812

$$\text{Electrical horse power} = \frac{171812}{746} = \ldots\ldots 230.3$$

Output of pig iron per 1,000 El. horse power days=

$$\frac{2665 \times 24 \times 1000}{12 \times 230.3 \times 2000} = 11.57 \text{ tons.}$$

Electric horse power year of 365 days per ton of pig = 0.236.

Subsequent experiments indicate that had charcoal or coke been used as a reducing agent instead of briquettes, thereby greatly reducing the amount of slag produced, the output would have been considerably increased.

RUN No. 13.

Ore treated	magnetite from Wilbur mine.
Reducing agent	charcoal.
Flux	sand.

ANALYSIS OF RAW MATERIAL.

Wilbur Ore:			Charcoal:	
SiO_2	6.20%		Moisture	14.06%
Fe_2O_3	55.42%	Fe=56.69%	Volatile matter	28.08%
FeO	23.04%		Fixed carbon	55.90%
Al_2O_3	2.56%		Ash	2.54%
CaO	2.00%			
MgO	6.84%			100.58%
P_2O_5	0.023%	P=0.01%	Sulphur	0.058%
S	0.01%			
CO_2 & undet	3.907%			
	100.000			

The sand used was common furnace sand, of which no analysis was made.

COMPOSITION OF CHARGE.

Ore	400 lbs.
Charcoal	125 "
Sand	27 "

ANALYSIS OF IRON PRODUCED.

	Cast No. 49. Grey Iron.	Cast No. 53. Grey Iron.
Total carbon	5.18%	4.65%
Si	1.30%	1.41%
S	0.020%	0 012%
P	0.029%	0.024%

ANALYSIS OF SLAG PRODUCED.

SiO_2	35.84%
Al_2O_3	31.80%
CaO	14.39%
MgO	16.22%
S	0.26%
Fe	0.35%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{4195}{12858} = 0{,}326$$

Length of run	61 hours, 25 min.
Mean volts on furnace	35.75
Mean amperes	5000
Power factor	0.919
Pig iron produced	12858 lbs
Watts = 35.75 × 5000 × 0.919	164271

Electrical horse power $= \frac{164271}{746} =$ 220.2

Output of pig iron per 1,000 El. horse power days=

$$\frac{12858 \times 24 \times 1000}{61.4 \times 220.2 \times 2000} = 11.41 \text{ tons.}$$

El. horse power year per ton of pig = 0.2399.

RUN No. 14.

Ore treated	Magnetite from Blairton mine.
Reducing agent	Charcoal.
Flux	Limestone. Sand.

ANALYSIS OF RAW MATERIAL.

Blairton Ore:			
	SiO_2	6.60%	
	Fe_2O_3	60.74%	Fe=55.85%
	FeO	17.18%	
	Al_2O_3	1.48%	
	CaO	2.84%	
	MgO	5.50%	
	P_2O_5	0.037%	P=0.016%
	S	0.57%	
	CO_2 & undet	5.053%	
		100.000	

Charcoal and limestone same as in previous run.

COMPOSITION OF CHARGE.

Ore	400 lbs.
Charcoal	125 "
Limestone	25 "
Sand	6 "

ANALYSIS OF IRON PRODUCED.

CAST No. 80. GREY IRON.

Total carbon	3.73%
Si	3.53%
S	0.042%
P	0.034%

ANALYSIS OF SLAG PRODUCED.

SiO_2	33.80%
Al_2O_3	10.20%
CaO	21.78%
MgO	30.50%
S	2.05%
Fe	0.25%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{4892}{11989} = 0.41$$

Length of run	65 hours, 30 min
Mean volts on furnace	36.03
Mean amperes	4987
Power factor	0.919
Pig iron produced	11989 lbs.
Watts = 36.03 × 4987 × 0.919	165125

$$\text{Electrical horse power} = \frac{165125}{746} = \ldots\ 221.34$$

Output of pig iron per 1000 El. horse power days=

$$\frac{11989 \times 24 \times 1000}{65.5 \times 221.34 \times 2000} = 9.92 \text{ tons}$$

El. horse power year per ton of pig = 0.276.

RUN No. 15.

Ore treated	Magnetite from Calabogie.*
Reducing agent	Charcoal and charcoal braise.
Flux	Limestone.

ANALYSIS OF RAW MATERIAL.

CALABOGIE ORE:	SiO_2	3.80%	
	Fe_2O_3	56.24%	Fe=59.38%
	FeO	25.76%	

* Calabogie Mining Company.

Al_2O_3	3.73%
CaO	2.00%
MgO	3.42%
P_2O_5	0.85% P = 0.371%
S	0.20%
CO_2 & undet	4.00%
	100.00

Limestone and charcoal the same as in previous runs. The charcoal braise used was of poor quality, being wet, high in ash and mostly fines.

The composition of the charge, when using charcoal, was:

Ore	400 lbs.
Charcoal	125 "
Limestone	30 "

When using charcoal braise, the composition of the charge was:

Ore	400 lbs.
Charcoal braise	145 "
Limestone	40 "

During this run the alternator had to be stopped on account of repair of motor. The furnace was then considerably cooled and some time was consumed before it was again in working condition.

1st. PART OF RUN.

ANALYSIS OF IRON PRODUCED.

	Cast No. 89. Grey Iron.	Cast No. 90. Grey Iron.
Total carbon	3.53 %	3.43 %
Si	0.95 %	1.17 %
S	0.024%	0.016%
P	0.554%	0.457%

ANALYSIS OF SLAG PRODUCED.

SiO_2	24.30%
Al_2O_3	27.16%
CaO	36.06%
MgO	10.74%
S	1.67%
Fe	0.25%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{1335}{4520} = 0.29$$

Length of run	23 hours, 50 min.
Mean volts on furnace	36.16
Mean amperes	5,000
Power factor	0.919
Pig Iron produced	4520 lbs.
Watts = 36.16 × 5000 × 0.919	166155

$$\text{Electrical horse power} = \frac{166155}{746} = \ldots\ldots\ldots\ldots \quad 222.72$$

Output of pig iron per 1000 El. horse power days=

$$\frac{4520 \times 24 \times 1000}{23.83 \times 222.72 \times 2000} = 10.21 \text{ tons.}$$

El. horse power year per ton of pig = 0.268.

2ND. PART OF RUN.

ANALYSIS OF IRON PRODUCED.

	Cast No. 92. Grey Iron.	Cast No. 95. Grey Iron.
Si	0.73 %	0 95 %
S	0.011%	0.012%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{892}{2722} = 0.33$$

Length of run	16 hours, 15 min.
Mean volts on furnace	35.85
Mean amperes	5000
Power factor	0.919
Pig iron produced	2722 lbs.
Watts = 35.85 × 5000 × 0.919	164730

$$\text{Electrical horse power} = \frac{164730}{746} = \ldots\ldots\ldots \quad 220.81$$

Output of pig iron per 1000 El. horse power days=

$$\frac{2722 \times 24 \times 1000}{16.25 \times 220.81 \times 2000} = 9.10 \text{ tons.}$$

El. horse power year per ton of pig = 0.301.

RUN No. 16.

Ore treated	Magnetite from Calabogie *
Reducing agent	Charcoal.
Flux	Limestone. Quartz.

ANALYSIS OF RAW MATERIAL.

Calabogie Ore:				Charcoal:	
	SiO_2	6.06%		Moisture	2.20%
	Fe_2O_3	58.00%	Fe = 59.85%	Volatile matter	20.60%
	FeO	24.78%		Fixed carbon	74.40%
	Al_2O_3	1.00%		Ash	2.80%
	CaO	0.40%			
	MgO	6.00%			
	P_2O_5	0.046%	P = 0.020%		
	S	0.17%			
	CO_2 & undet.	3.544%			
		100.000			

* Calabogie Mining Co., Shaft No. 4.

Limestone same as in previous runs.

COMPOSITION OF CHARGE.

Ore	400 lbs.
Charcoal	125 "
Limestone	45 "
Quartz	5 "

ANALYSIS OF IRON PRODUCED.

CAST No. 102. GREY IRON.

Total carbon	4.20%
Si	1.75%
S	0.005%
P	0.047%

ANALYSIS OF SLAG PRODUCED.

SiO_2	30.90%
Al_2O_3	12.30%
CaO	40.09%
MgO	12.91%
S	1.48%
Fe	0 56%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{2556}{7150} = 0.36$$

Length of run	38 hours, 20 min.
Mean volts on furnace	36.5
Mean amperes	4993
Power factor	0.919
Pig iron produced	7150 lbs.
Watts = 36.5 × 4993 × 0.919	167483

$$\text{Electrical horse power} = \frac{167483}{746} = 22[illegible].50$$

Output of pig iron per 1000 El. horse power days =

$$\frac{7150 \times 24 \times 1000}{38.33 \times 224.50 \times 2000} = 9.97 \text{ tons.}$$

RUN No. 17.

Ore treated	Magnetite from Calabogie mine*
Reducing agent	Charcoal.
Flux	Limestone. Quartz.

---

* T. B. Caldwell, Esq.

ANALYSIS OF RAW MATERIAL.

CALABOGIE ORE:	SiO_2	4.00%	
	Fe_2O_3	55.31%	Fe=58.29%
	FeO	25.20%	
	Al_2O_3	2.24%	
	CaO	2.40%	
	MgO	4.00%	
	P_2O_5	0.95	P = 0.415%
	S	0.45%	
	CO_2. & undet	5.45%	
		100.00	

Charcoal same as in Run No. 15. Limestone same as in previous runs.

COMPOSITION OF CHARGE.

Ore	400 lbs.
Charcoal	125 "
Limestone	20 "

Occasionally small quantities of sand were added.

ANALYSIS OF IRON PRODUCED.

	CAST No. 111. GREY IRON.	CAST No. 113. GREY IRON.
Si	1.49 %	1.55 %
S	0.016%	0.015%
P	0.500%	0.520%

ANALYSIS OF SLAG PRODUCED.

SiO_2	26.96%
Al_2O_3	20.64%
CaO	27.40%
MgO	15.50%
S	1 41%
Fe	0.21%

$$\frac{\text{Slag}}{\text{Iron}} = \frac{3263}{8303} = 0.39$$

Length of run	43 hours, 5 min.
Mean volts on furnace	36.79
Mean amperes	5000
Power factor	0.919
Pig iron produced	8303 lbs.
Watts = 36.79 × 5000 × 0.919	169050
Electrical horse power = $\frac{169050}{746}$ =	226.6

Output of pig iron per 1,000 El. horse power days =

$$\frac{8303 \times 24 \times 1000}{43.08 \times 226.6 \times 2000} = 10.20 \text{ tons.}$$

El. horse power year per ton of pig = 0.268.

RUN No. 18.

Ore treated	Roasted Pyrrhotite.
Reducing agent	Charcoal.
Flux	Limestone.

ANALYSIS OF RAW MATERIAL.

Roasted Pyrrhotite:	SiO_2	10.96 %
	Al_2O_3	3.31 %
	Fe_2O_3	65.43 %
	CaO	3.92 %
	MgO	3.53 %
	S	1.56 %
	P	0.016%
	Cu	0.41 %
	Ni	2.23 %
	Metallic iron	45.80 %

Charcoal and limestone same as in previous run.

The limestone in the charge was decreased from 120 lbs. when starting to 50 lbs. The composition then being:

Ore	400 lbs.
Charcoal	110
Limestone	50 "

ANALYSIS OF IRON PRODUCED.

	Cast No. 125.	Cast No. 130.	Cast No. 133.
Total carbon	3.23 %	3.38 %	2.50%
Si	4.90*%	4.50%*	6.32%*
S	0.007%	0.006%	0.007%
P	0.062%	0.037%	0.042%
Cu	0.86 %	0.87 %	0.71 %
Ni	3.70 %	4.12 %	4.00 %

ANALYSIS OF SLAG PRODUCED.

SiO_2	16.44%
Al_2O_3	13.86%
CaO	53.25%
MgO	8.80%
S	5.28%
Fe	0.65%
Cu	trace.
Ni	trace.

$$\frac{\text{Slag}}{\text{Iron}} = \frac{5060}{7336} = 0.69$$

Length of run	56 hours, 20 min.
Mean volts on furnace	36.05

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* By increasing the limestone of the charge the silicon content of the ferro-nickel pig recently produced has been depressed to 2%.

Mean amperes	5,000
Power factor	0.919
Pig iron produced (ferro-nickel)	7336 lbs.
Watts = 36.05 × 5000 × 0.919	165649

$$\text{Electrical horse power} = \frac{165649}{746} \ldots\ldots 222.05$$

Output of pig iron (ferro-nickel) per 1000 El. horse power days =

$$\frac{7336 \times 24 \times 1000}{56.33 \times 222.05 \times 2000} = 7.038 \text{ tons.}$$

El. horse power year per ton of pig = 0.389.

RUN No. 19

Ore treated	Titaniferous iron ore.
Reducing agent	Charcoal.
Flux	Limestone. Fluorspar.

ANALYSIS OF RAW MATERIAL.

Titaniferous Iron Ore:

SiO_2	7.12%	
Fe_2O_3	30.30%	Fe=43.59%
FeO	28.78%	
Al_2O_3	7.00%	
CaO	1.00%	
MgO	4.14%	
P_2O_5	0.064%	P=0.028%
S	0.04%	
TiO_2	17.82%	
Cr_2O_3	2.50%	Cr=1.42%
	99.684	

Charcoal and limestone same as in previous run.

COMPOSITION OF CHARGE.

Ore	400 lbs.
Charcoal	100 "
Limestone	50 "
Fluorspar	50 "

ANALYSIS OF PIG IRON PRODUCED.

	Cast No. 136.	Cast No. 137.
Total carbon	%	3.50 %
Si	4.50 %	2.80 %
S	0.007%	0.091%
P	0.143%	0.060%
Ti (approx.)	1.00 %	1.30 %

ANALYSIS OF SLAG PRODUCED.

SiO_2	7.00%
Al_2O_3	28.50%
CaO	14.23%
MgO	2.93%
TiO_2	38.92%
Fe	1.13%
S	0.90%

On account of the furnace being in a very bad condition, the lining being eaten away by the limey slag used in the previous run, the run had to be stopped and no figures as to output could be obtained.

The slag was very fluid and likely the fluorspar in the charge could have been reduced considerably or omitted altogether.

The iron obtained in cast No. 136 was probably mixed with some iron from the previous charge, when ore with high phosphorus content was used.

THE SMELTING OF MAGNETITE.

It was expected that considerable difficulty would be experienced in the smelting of magnetite on account of its conductivity. It was thought that with the furnace in use, in which the electrode was immersed in the charge, the current would disseminate itself laterally from the sides of the electrode through the charge, preventing the current at the reducing and fusion zone from attaining such density as would be required for the high temperature necessary for reduction and fusion. With charcoal as a reducing agent no difficulty was experienced in this respect nor was the inductance of the furnace increased by the presence of magnetite.

THE USE OF CHARCOAL AS A REDUCING AGENT.

Since charcoal and peat-coke can be produced in the Provinces of Ontario and Quebec while metallurgical coke requires to be imported, it was of great importance to ascertain whether charcoal, without being briquetted with the ore, could be used instead of coal-coke. No difficulty whatever was experienced, in fact so admirably adapted was charcoal, when crushed to pass a ¾ inch ring, as a reducing agent in the electric furnace that coke and briquettes of coke with clay were abandoned and all the experiments with magnetite and roasted pyrrhotite described were made with charcoal. Some of the charcoal available was of very poor quality, some of it being little better than charred wood containing only about 56% of fixed carbon.

This and the fact that a considerable quantity of the charcoal was consumed on top of the furnace account for the large quantity of charcoal used per ton of product. A modification of the furnace, protecting the upper layer of the charge from the atmosphere, and the use of charcoal properly carbonized would decrease considerably the amount of charcoal which was actually used in the experiments and consequently reduce the cost of production as given.

CONSUMPTION OF ELECTRODE.

For the production of 42,711 lbs. of pig iron 384 lbs. of electrode were consumed, the same electrode having been in commission for 13 days.

Consumption of electrode per ton of pig iron:

$$\frac{384 \times 2000}{42711} = 17.98 \text{ lbs.}$$

During the time this electrode was in commission the material in the furnace was melted down several times, exposing the red hot electrode to the oxidizing atmosphere. The consumption of electrode was found to be greater for white iron than for grey iron and since the 42,711 lbs. of pig iron produced included several casts of white iron, the consumption of electrode was also on that account greater than it would have been had only grey iron been produced.

POWER FACTOR.

The power factor of the furnace was determined by Mr. Chas. Darrall of the Canadian Westinghouse Company, of Hamilton, Ont., and was found to be 0.9[illegible]9. This high power factor is due to the construction of the furnace casing, which prevents the closing of the magnetic lines of force.

Since the true electric power is the apparent electric power multiplied by the power factor, it is evident that any error made in the determination of the power factor which tends to decrease its value will appear to decrease the consumption of energy per ton of product. The large output of 12.12 tons per 1000 electric horse power days, i. e. the small amount of electric horse power absorbed per ton of product in the second Livet experiments, was obtained in a furnace with the abnormally low power factor 0.564. Whatever doubt may be engendered as to the correctness of the figure obtained for the absorption of electric energy on account of this low power factor of the Keller furnace, such doubt cannot arise regarding the figures obtained with the Heroult furnace for the absorption of electric energy in the Government experiments on account of its remarkably high power factor 0.919.

Moreover, since the cost of alternate current generators increases with increase of capacity, furnaces with high power factors (which can utilize a high percentage of the capacity of the generators) will be more economical as regards the first cost of the electrical installation of an electric smelting plant than furnaces with low power factors.

MODIFICATION OF EXPERIMENTAL FURNACE FOR COMMERCIAL PRODUCTION OF PIG IRON.

Probably the largest unit which can at present be constructed on the model of the experimental furnace will not exceed 1,500 H. P. The construction of the experimental furnace to fit it for the production of pig iron on a commercial scale will require to be modified in the following important particulars:—

(1). The top of the furnace requires to be modified to permit of the application of labor-saving machinery for charging.

(2). Provision requires to be made for the collection and utilization of the carbon monoxide produced by the reduction of the ore; this involves also the protection of the charcoal of the charge from combustion on top of the furnace.

The greater capacity insuring less loss of heat by radiation and the modification of the furnace to permit of the utilization of the carbon monoxide will materially increase the output beyond that ascertained by the experimental furnace. The experiments indicated that under *normal* conditions about 11.5 tons were produced by an expenditure of 1,000 E. H. P. days. (See runs Nos. 8 and 13). It is, therefore, not unreasonable to assume that under similar conditions with a properly constructed plant the output per 1,000 E. H. P. days would certainly reach 12 tons. This figure has been adopted in calculating cost of production per ton of pig.

The protection of the charcoal of the charge from combustion on top of the furnace will materially decrease the amount of charcoal necessary for reduction and consequently lessen the cost of this item. This saving has, however, not been taken into account in the estimate of cost.

On account of the value of the product, the smelting of roasted nickeliferous pyrrhotite by the electro-thermic process, as carried out with the

Government experimental plant, admits of immediate commercial application without other modification of the furnace than increase of its capacity.

ESTIMATE FOR A 10,000 H. P. PLANT* PRODUCING 120 TONS OF PIG IRON PER DAY OF 24 HOURS.

Furnaces, contacts, overhead work	$ 24,500
Bins, chutes, elevators	14,000
Crushers	4,000
Hoists and regulators	10,500
Instruments	1,400
Cables for conductors	8,400
Building	10 500
Mixer and casting machine	10,000
Travelling crane and tracks	5,000
Ladles	1,500
Slag trucks	3,000
Ore bins	3,000
Repair shop	5,000
	$100,800
Charcoal plant	50,000
Power plant (assuming cost of developing 1 El. horse power = $50.00)	500,000
	$650,800
Electrode plant	6,000
Unforeseen expenditure	43,200
	$700,000

Amortization 5%
Depreciation 5% } 15% on $700,000 = $105,000.
Interest 5%

On a production of 43.200 tons per year of 360 days per ton of pig iron $2.43

COST OF PRODUCTION PER TON PIG IRON.

Ore (55% metallic iron) at $1.50 per ton	$2.70
Charcoal, ½ ton at $6.00 per ton	3.00
Electric energy, amortization, etc	2.43
Labor	1.00
Limestone	0.20
18 lbs. of electrode at 2 cents. per lb.	0.36
General expenses	1.09
Total	$10.69

GENERAL REMARKS.

The ores treated, with the exception of the hematite and the roasted pyrrhotite, contained a high percentage of magnesia, producing a very

* This estimate is given on the authority of Dr. P. Heroult.

infusible slag. When the furnace had been running for some time this infusible material formed a scale around the crucible, the electric energy available not being sufficient to keep it in a molten condition. The crucible and lower part of the furnace were, therefore, partially filled up, preventing easy access of the charge to the reducing and melting zone. This slower feeding left the charcoal on top of the furnace exposed to the air a longer time, thus increasing the amount of charcoal required and decreasing the output. With a greater current than was available and consequent higher temperature, the formation of the scale would have been prevented and the output correspondingly increased.

The electric installation at our disposal was far from ideal for electric smelting experiments. Aside from the drop of voltage due to the frequent slipping of the belt connecting motor and generator, it was impossible to increase the current beyond 5,000 amperes at from 35 to 40 volts.

This inelasticity of the system prevented the determination of the most suitable current and voltage for a given charge in the furnace.

SUMMARY OF THE RESULTS OF THE EXPERIMENTS.

1st: Magnetite can be as economically smelted by the electro-thermic process as Hematite.

2nd: Ores of high sulphur content not containing manganese can be made into pig iron containing only a few thousandths of a per cent. of sulphur.

3rd: The silicon content can be varied as required for the class of pig to be produced.

4th: Charcoal which can be cheaply produced from mill refuse or wood which could not otherwise be utilized can be substituted for coke as a reducing agent, without being briquetted with the ore.

5th: A ferro-nickel pig can be produced practically free from sulphur and of fine quality from roasted nickeliferous pyrrhotite.

6th: The experiment made with a titaniferous iron ore containing 17.82% of titanic acid permits the conclusion that titaniferous iron ores up to perhaps 5% titanic acid can be successfully treated by the electric process.

PLATE 1.

ELECTRIC FURNACE JUST AFTER METAL HAS BEEN TAPPED.

I:

PLATE 2.

ELECTRIC FURNACE, SHOWING MEASURING INSTRUMENTS IN PLACE
AND METHOD OF REGULATING ELECTRODE

PLATE 3.

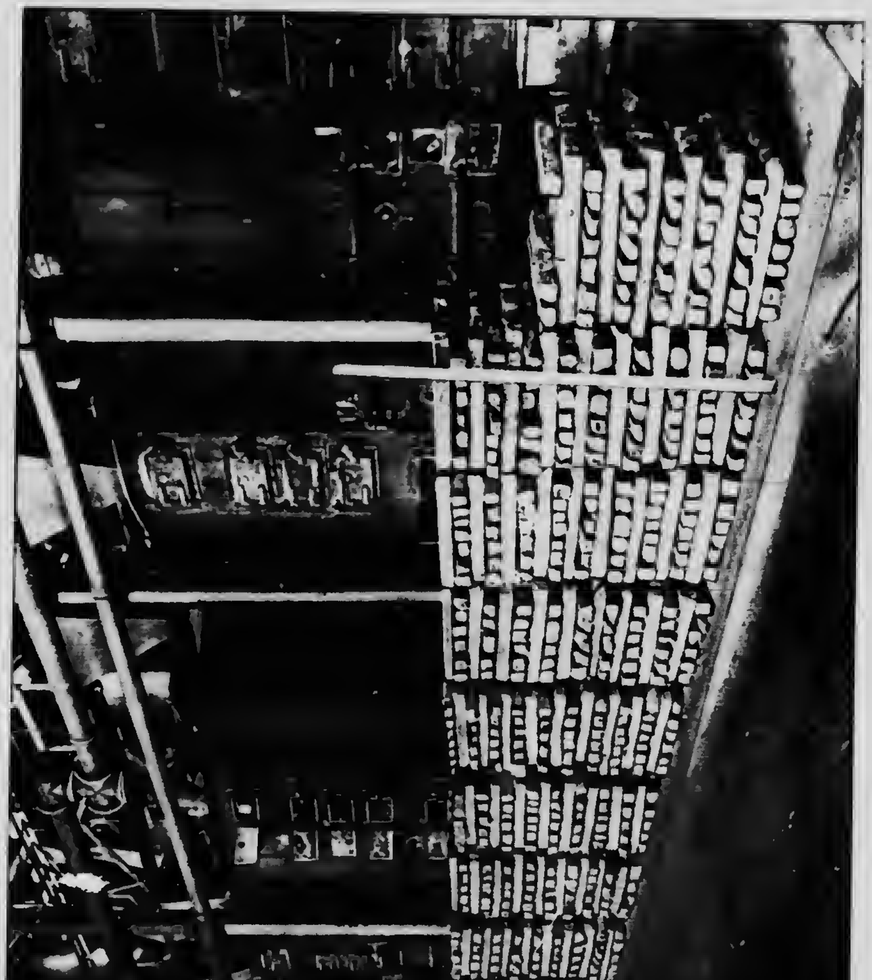
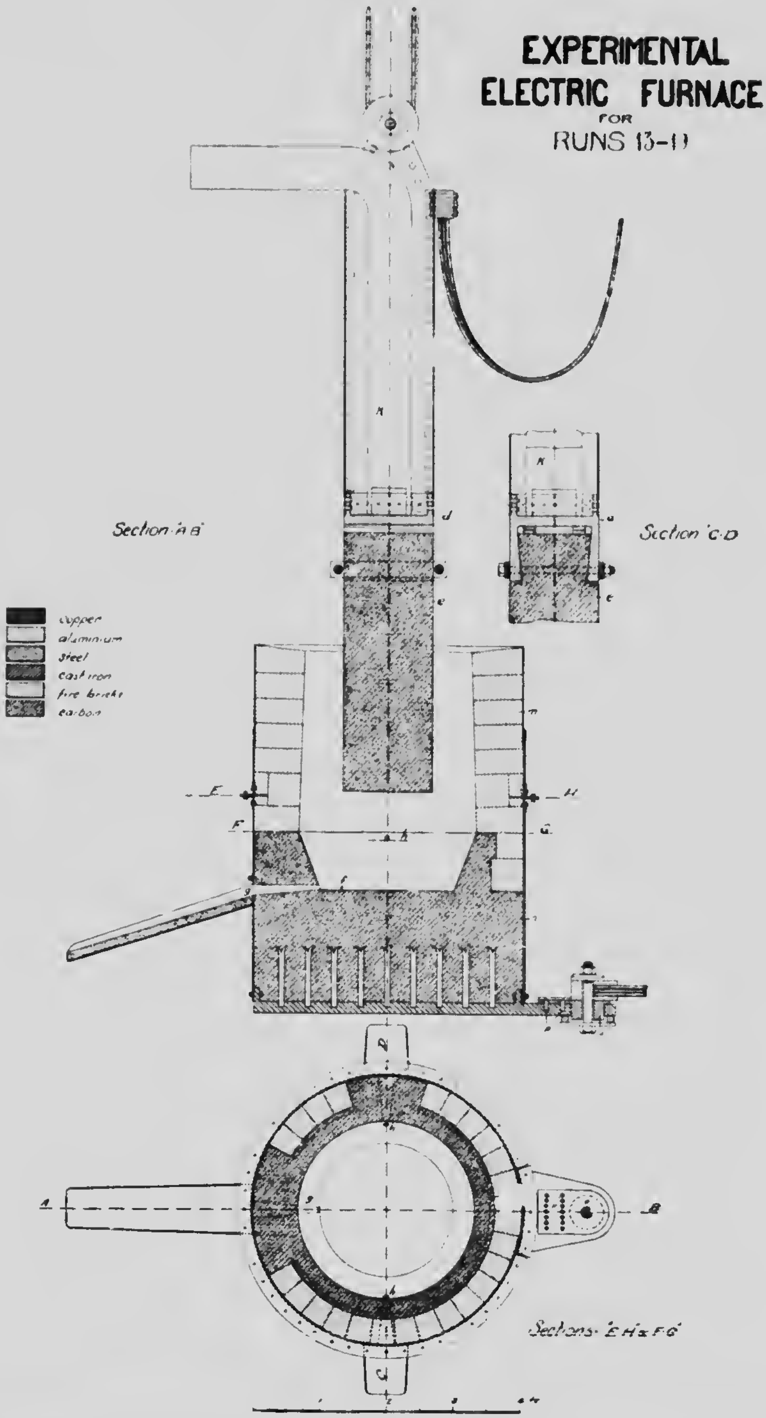


EXHIBIT OF TWO-THIRDS OF THE PIG IRON PRODUCED.

PLATE 4.


EXPERIMENTAL
ELECTRIC FURNACE
FOR
RUNS 13-
Section A-B
Section C-D
copper
aluminium
steel
cast iron
fire bricks
carbon
Sections E-H & F-G