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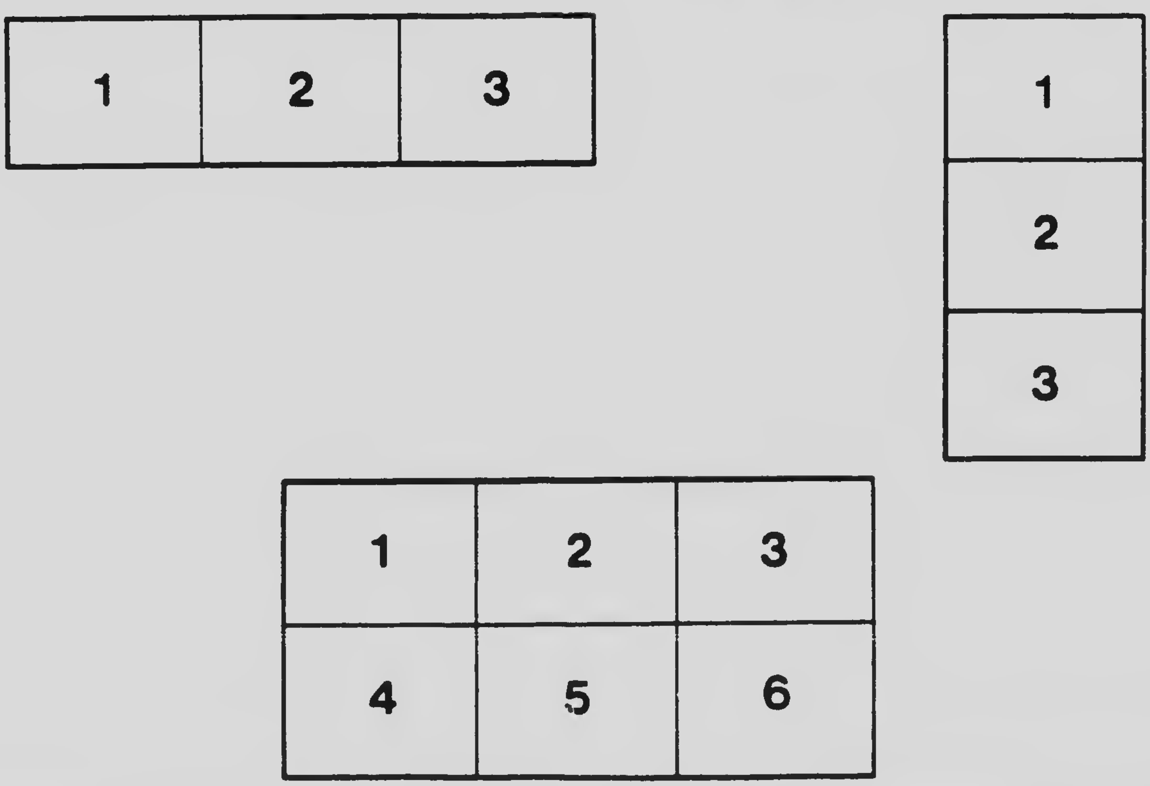
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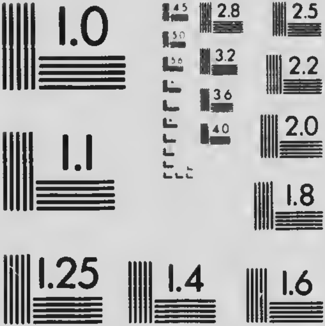

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HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

REPORT

ON THE

INVESTIGATION

OF AN

ELECTRIC SHAFT FURNACE

DOMNARFVET, SWEDEN

ETC.

BY

EUGENE HAANEL, Ph.D.,
Director of Mines

OTTAWA
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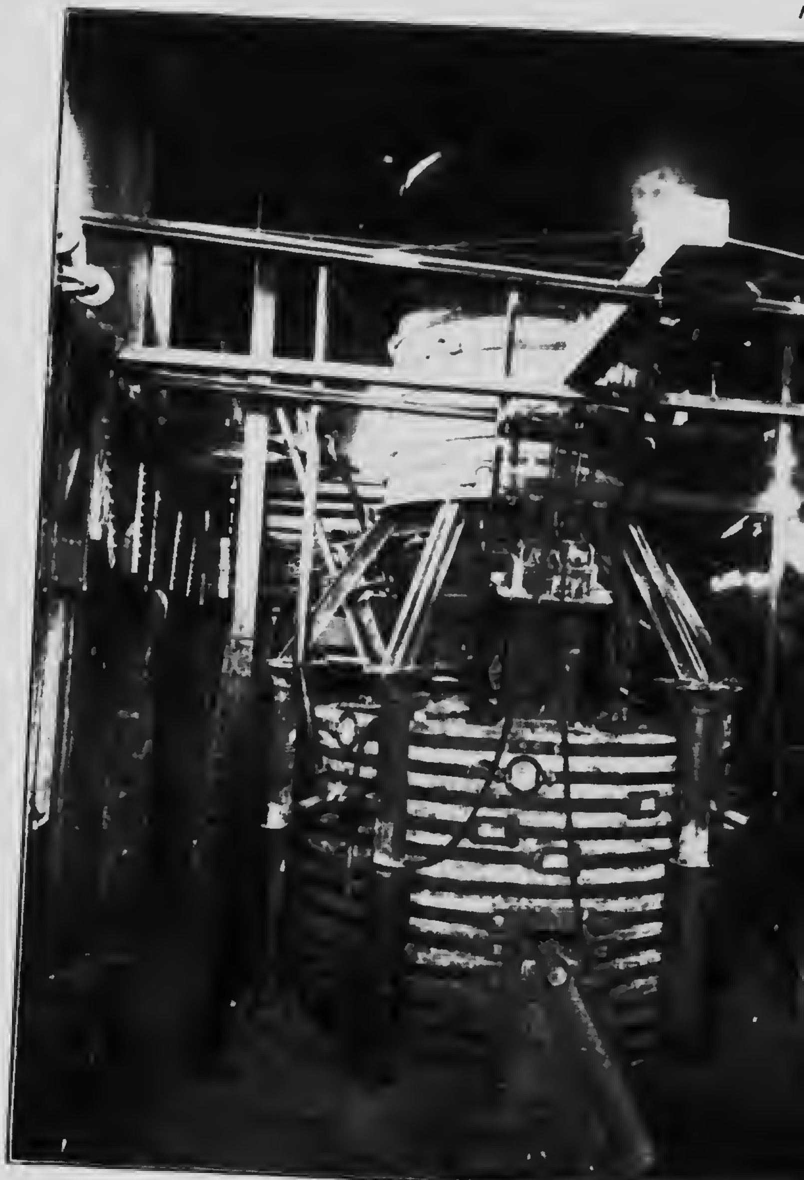

Electric Shaft Furnace, Domnarfvet, Sweden, December, 1908.

Frontispiece.

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ERRATA.

Folder containing Figs. 4 and 5, instead of being placed opposite page 14—as indicated in the Table of Contents—has been transferred to the end of the Report; for the greater convenience of readers.

"Fig. 3," page 10, line 6 from bottom: *read* Fig. 2.

Director of Mines

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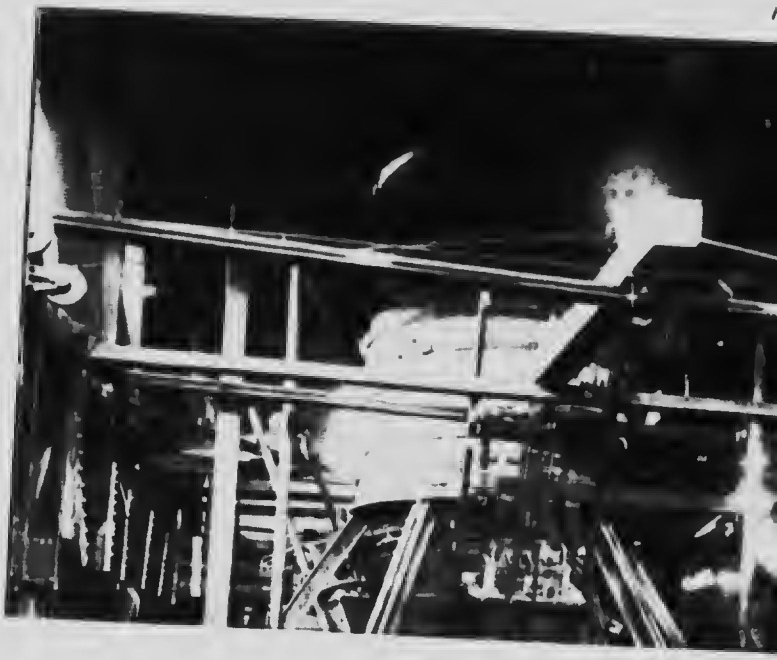

Electric Shaft Furnace, Domnarfvet, Sweden, December, 1908.

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LETTER OF TRANSMITTAL.

To the Hon. WILLIAM TEMPLEMAN, M.P.,
Minister of Mines.

SIR,—I have the honour to submit herewith, a report on my investigation of the Electric Shaft Furnace designed and erected by the Aktiebolaget Electrometall at Domnarfvet, Sweden; and since electrodes and charcoal are necessary materials for the electric smelting of iron ores, chapters have been added, descriptive of the manufacture of electrodes, and of the latest types of charcoal furnaces; together with appendices on the progress of electric smelting in Norway and Sweden.

I have the honour to be, sir,
Your obedient servant,

(Signed) EUGENE HAANEL,
Director of Mines.

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REPORT

ON THE

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ELECTRIC SHAFT FURNACE

DOMNARFVET, SWEDEN

ETC.

BY

EUGENE HAANEL, Ph.D.,

Director of Mines.

PART I.

Introduction.

In the winter of 1905-6, a series of experiments in electric smelting were conducted at Sault Ste. Marie, Ontario, under the auspices of the Dominion government; with the object of establishing the feasibility of economically smelting Canadian magnetic iron ores comparatively high in sulphur, but free from manganese; and using charcoal as the reducing agent.

As a result of these experiments, the electro-metallurgy of the reduction of refractory iron ores without the use of coal or coke fuel was established; and—as far as could be expected from a small, experimental furnace—the output of pig iron per electrical horse-power year, determined. Moreover, based upon the experience thus gained, certain fundamental changes and improvements, necessary in the construction of an economic electric furnace in the future, were suggested;[1] in order to render it suitable for the production of pig iron on a commercial scale.

Although the Canadian experiments of 1905-6, proved entirely successful—as regards the special objects aimed at; and while considerable interest in the reduction of iron ores by the electro-thermic process was manifested at the time, no additional experimentation of any significance has been undertaken in Canada, along the lines suggested in the Mines Branch report; to ensure the commercial success of electric smelting. In Sweden, however, where the conditions governing the economical use of the raw materials necessary for an iron industry are very similar to, and in many respects identical with, those existing in several of the provinces of the Dominion of Canada, the importance of an

[1] Report on Electric Smelting Experiments at Sault Ste. Marie, Ont., 1907, p. 92.

economic, commercial, electric smelting process was fully realized by thre young Swedish engineers some two years ago. These engineers: viz., Assa Grönwall, Axel Lindblad, and Otto Stalhane—stimulated by the successfu results of the work done at Sault Ste. Marie—undertook to solve the problem o designing and constructing a commercial electric furnace.

Inasmuch as the electro-metallurgy of the reduction of iron ores had beei established by the Canadian experiments, these Swedish inventors concentratec their entire efforts in an attempt to solve the practical, commercial problem along the lines suggested in the official report[1] (p. 92). In carrying out thei plans to a successful issue, they were ably assisted by the ironmasters of Sweden who manifested great interest in this question. Special assistance was renderec by the able, and far-sighted director—E. J. Ljungberg, and the vice-director— Lars Yngström, of the largest and most influential industrial company in Sweden: the "Stora Kopparbergs Bergslags Aktiebolag." The inventors made an agreement with this company, and the "Trafikaktiebolaget Grangesberg—Oxelösund" (owners of the largest iron ore deposits in Sweden), to carry on smelting experiments on a large scale at the Domnarfvet iron works.

In order to concentrate their undivided attention on this problem, the inventors formed a company called the "Aktiebolaget Electrometall," to which the patent rights were assigned.

Evolution of the Electric Shaft Furnace.

The construction of the specially designed electrical machinery, and the preliminary work necessary for the construction of the furnace were commenced April, 1906; and towards the end of that year—when the installation of the electrical machinery and high tension cables, etc., was completed—the construction of the first electric shaft furnace was begun.

This furnace was put in operation April, 1907, and from that time experiments were continuously carried on and improvements made: the daily experience thus gained being utilized in successive changes in design and reconstruction towards perfection. All experimentation was conducted along scientific lines, and has yielded a rich fund of useable knowledge and instructive data as follows: (1) on the construction and operation of electric furnaces; (2) on the conductivity and other characteristics exhibited by materials when subjected to high temperature; (3) on the qualities of the refractory lining materials, and (4) on the most suitable manner of designing and constructing the masonry of the furnaces. In addition to this, different methods of supplying the current, and various contact devices, etc., were tried and tested. In these initial steps, the experimenters did not confine their entire attention to the practical side of electric smelting; but carried on laborious researches and investigations concerning the solution of purely theoretical problems; and the determinations made and data gathered, will doubtless form an important contribution to the electro-metallurgy of iron and steel.

Taking into consideration the fact that, the inventors have signified their intention of writing a detailed account of all the experiments conducted by

[1] Report on Electric Smelting Experiments at Sault Ste. Marie, Ont., 1907, p. 92.

them during the past three years, it will be unnecessary for me to enter into minute details; but to set forth only such facts as have a direct bearing on the experimental trials witnessed at Domnarfvet.

With a view of elucidating a number of disputed technical points involved in the smelting process itself, initial experiments were conducted at Ludvika during the summer of 1907, with a small furnace of 300 horse-power capacity. During these preliminary experiments many difficulties were encountered which had to be overcome; and it was not until the summer of 1908 that they succeeded in designing and constructing a furnace which, in their opinion, could be economically used in practice. Towards the end of the summer a number of experiments were made with this furnace, which demonstrated that the type evolved was durable, and that a good output could be obtained therefrom; notwithstanding the fact that the furnace was constructed with a relatively low shaft in order to reduce the building expense. On account of this low shaft, which was open at the top—as in the case of the furnace employed at Sault Ste. Marie--the consumption of charcoal was large: viz., 460 kilograms per metric ton of pig iron produced. A considerable portion of this charcoal was consumed at the top of the open shaft, and the gas escaping from the furnace consisted almost wholly of carbon monoxide. Hence, notwithstanding the excellent results obtained with this furnace, the inventors conceived that by utilizing the waste gases, even more economic results could be attained, consequently decided to construct a new one of larger capacity, with a higher and more rationally designed shaft.

This new furnace was completed early in December, 1908, and the intention was to at once begin an extended trial run; but owing to a severe drought—such as had not been known in Sweden for generations—this extended trial had to be postponed. Some time previous to the completion of this furnace, the inventors tendered the writer an invitation to witness a short trial test to take place early in December. Although little rain had fallen up to this time, hopes were entertained that by the middle of December there would be sufficient water to carry on the contemplated experimental trials.

Soon after receiving the invitation, I received official instructions to proceed to Sweden to investigate and report upon this new electric shaft furnace, and immediately made preparations for the trip, and sailed for Europe, via New York, on November 25, 1908. Just as the steamer was about to start, I received a cablegram from Sweden announcing the impossibility of running the furnace, on account of low water in the adjacent river. It was then too late, however, to cancel my passage, hence I decided to continue my journey and obtain as much information as possible concerning the furnace.

Immediately on my arrival in Stockholm, where I met Mr. Grönwall—one of the inventors of the furnace—it was arranged that we should go to Falun for the purpose of placing before Mr. Ljungberg, the general director of Stora Kopperbergs Bergslags Aktiebolaget—at whose works the furnace was erected—the great importance to Sweden, as well as other countries, of making, if possible, the contemplated special trials. As a result of this conference, he very generously allowed the use of power to operate the furnace for twelve days. This concession, which entailed considerable inconvenience in the general operations of the steel plant, shows the great importance attached to the solution of this metallurgical problem by men competent to judge.

The inventors informed me, however, that they did not expect entirely satisfactory results as regards the output of pig iron per electrical horse-power year, since a furnace of this size could not possibly arrive at its normal working condition in the short time allowed for the test; inasmuch as the walls are so thick that it takes a comparatively long time to heat them entirely through; and acceleration of the heating could only be accomplished at the risk of damaging the furnace walls. In addition to this, the shaft should not be filled to the top until after several days' working.

In concluding this preface, it may be mentioned that, the experimental trials witnessed were not conducted for the purpose of determining the output of pig iron per electrical horse-power year—this had been satisfactorily determined by the experiments at Sault Ste. Marie; as well as by the Swedish inventors in their experiments with the furnace preceding the one investigated at Domnarfvet—but to demonstrate the commercial feasibility of the furnace, and to prove whether uniform working without disturbance could be expected.

DESCRIPTION OF THE PLANT.

The experimental plant (Fig. 1) was installed in an old building adjoining the basic Bessemer converter house.

The machinery, which was specially designed and constructed for the experimental trials, consists of a three-phase synchronous motor of about 900 horse-power, supplied with a current of 7,000 volts, and 60 periods, from a three-phase cable line in the iron works. This motor is directly coupled to a three-phase generator, which supplies current of 25 periods, adjustable to between 300 and 1,200 volts, through small intervals to the transformers erected in the immediate vicinity of the furnace.

By means of this extensive regulation it is possible to determine the most suitable voltage to be employed with furnaces of different construction, and operating under various conditions.

The fields of both the synchronous motor and the generator are fed with current at a tension of 220 volts, from a direct current generator, 20 kw. capacity, directly coupled to the system. For starting the system a three-phase synchronous motor, directly coupled, is employed. This is fed with a current stepped down to 500 volts. In Plate II is shown a photograph of this machinery. The arrangement for controlling the machines may be seen from the coupling scheme shown in Fig. 3.

From the switchboard the current is conducted, through copper bars, laid in cement channels, to the three-phase transformers. The capacity of these transformers is 1,500 K.V.A., and their ratio of transformation, 14:1. By regulating the tension of the generator, the low tension sides of the transformers can be altered through small intervals, from 20 to 85 volts. The ratio of

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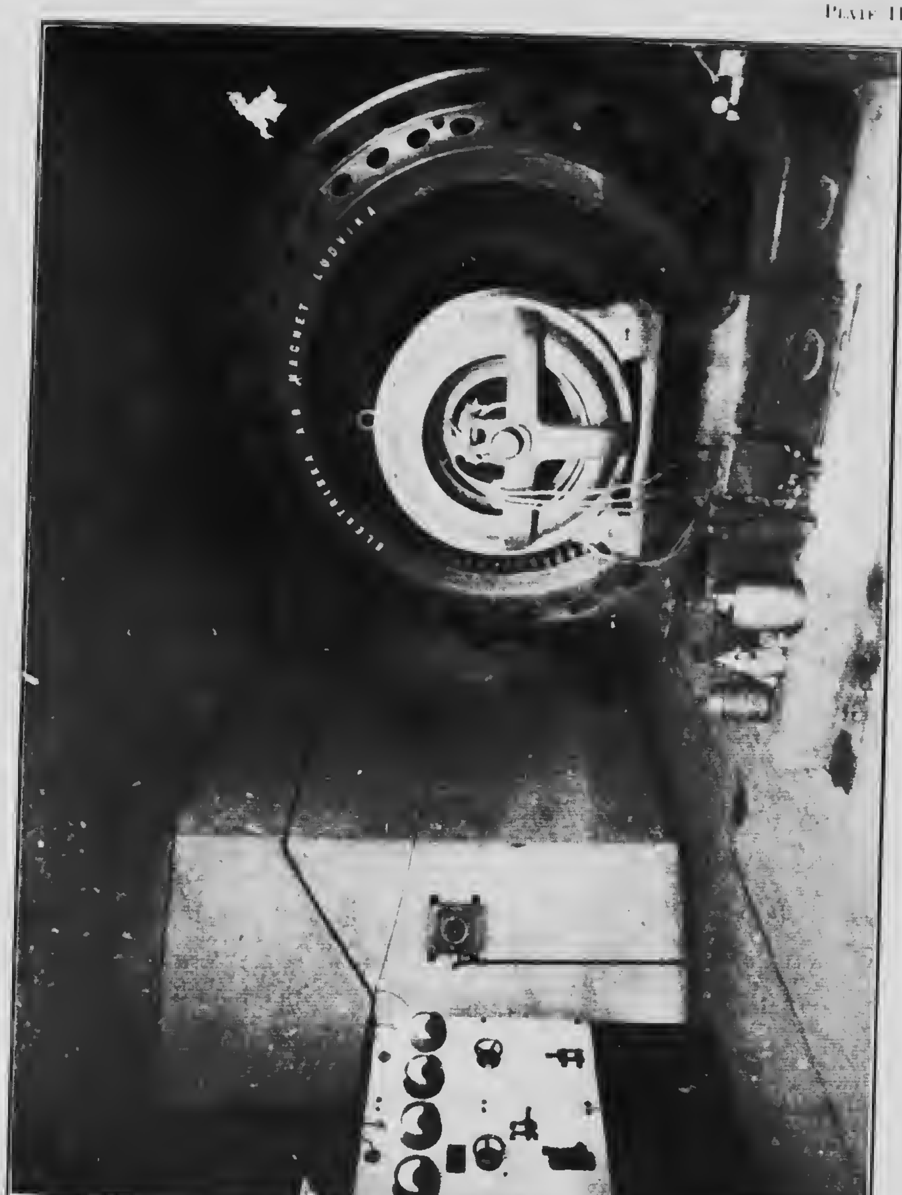

GENERATING MACHINERY

transformation can be altered to 7:1 by means of certain easily performed changes of coupling in the transformers; in which case the low tension can be varied between 40 and 170 volts. The transformers are cooled with air supplied under pressure by two electric blowers.

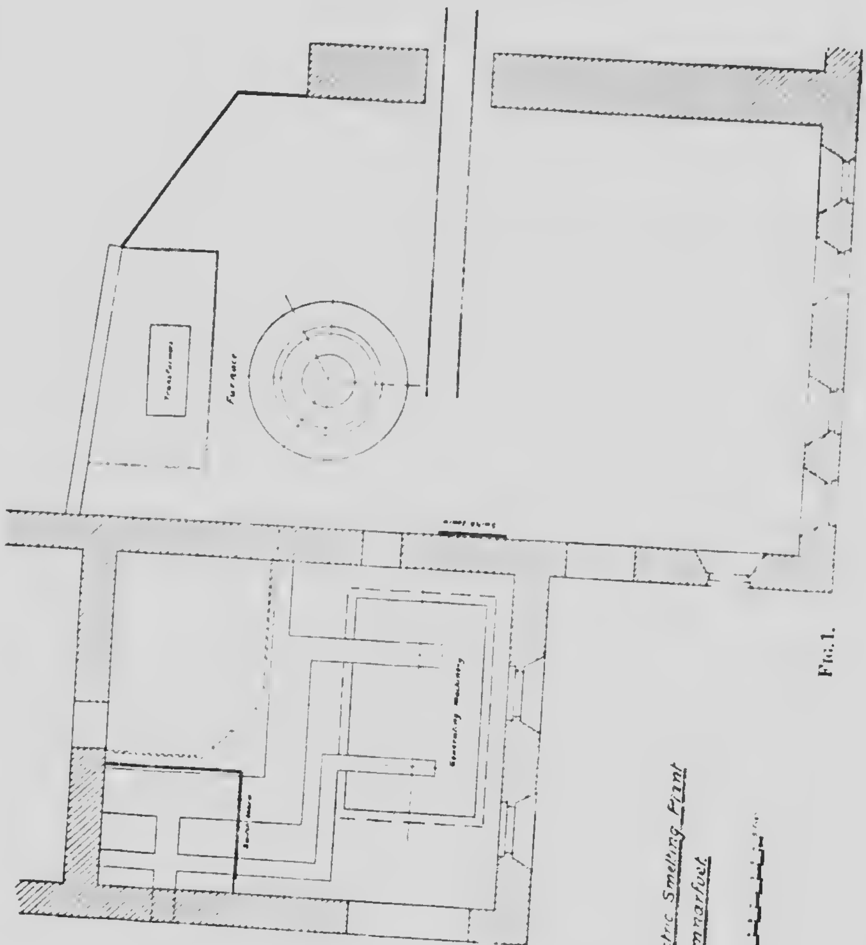

Fig. 1.

Plan of Electric Smelting Plant at Domnarfvet

A switchboard is situated conveniently near the furnace for controlling its operation: on which are mounted the following instruments: 1 three-phase precision wattmeter for differently loaded phases; 3 ampere meters—one for each phase, and 1 voltmeter.

The ampere meters, and the wattmeter, are connected to the current syste
by means of transformers. The voltmeter and tension terminals of the wat
meter are directly connected to two of the conducting bars.

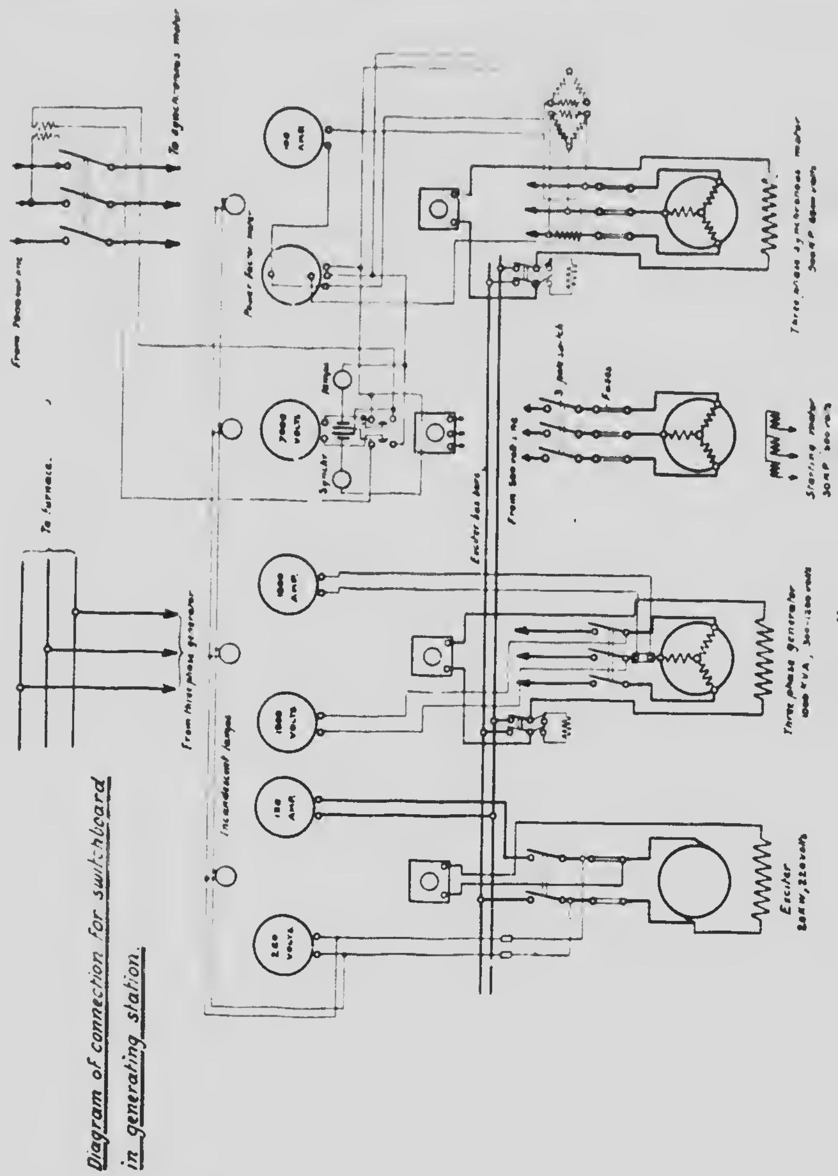

Diagram of connection for switchboard in generating station.

To protect these instruments from heat when tapping, an iron curtair
which may be lowered or raised, is placed in front of the switchboard. Th

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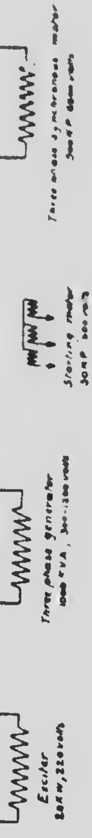

Fig. 2

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Plate III

Wheels and Instruments for Controlling Electrodes.

connexion of the instruments is shown by the connexion-diagram—Fig. 3; while the external appearance of the arrangement is shown by the photograph—Plate III. It will be seen that the wheels—by which the electrodes are adjusted—

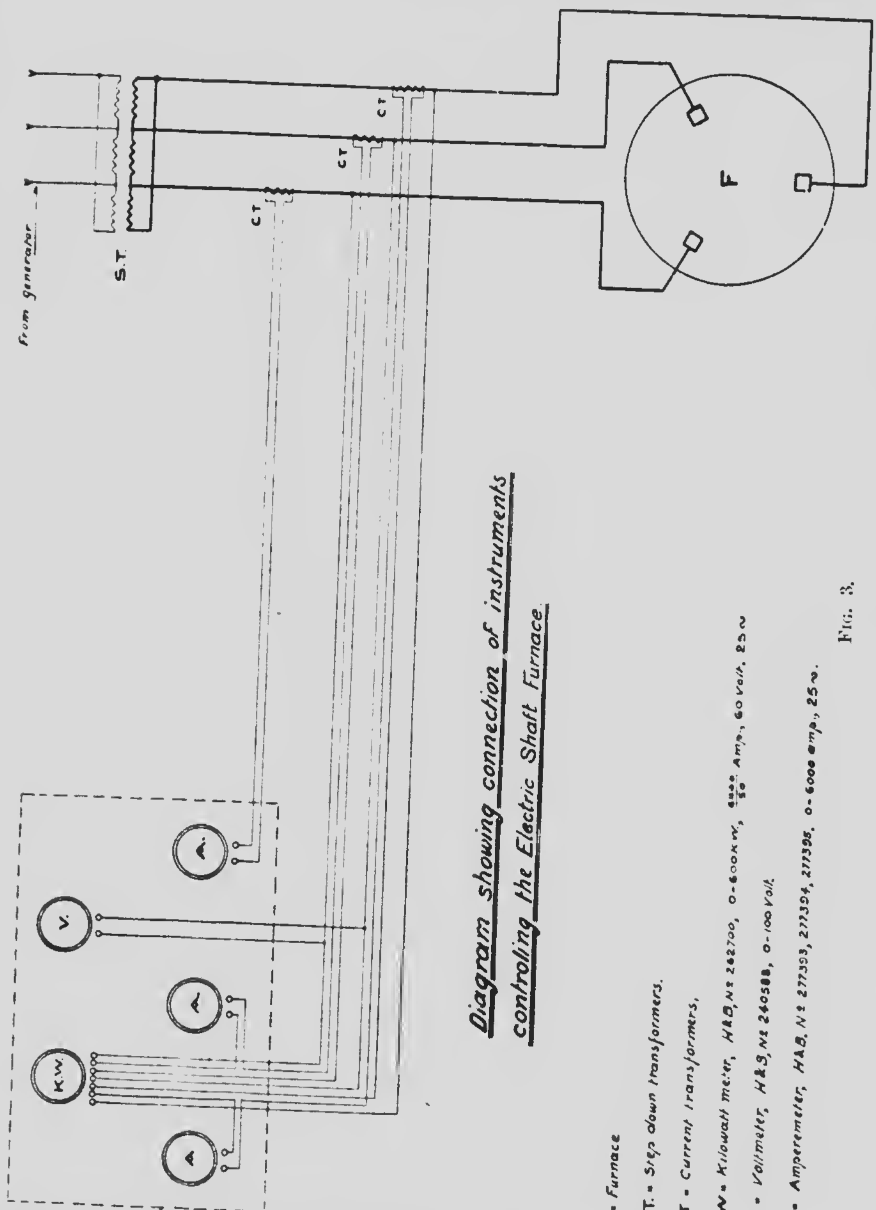


Fig. 3.

are placed under the instruments in such a manner that, the wheel and ampere meter opposite each other, belong to the same phase.

DESCRIPTION OF ELECTRIC SHAFT FURNACE.

In general appearance this electric shaft furnace is unlike any hitherto constructed; being very similar in design to an ordinary blast furnace in which the tuyères are replaced by electrodes.

A vertical section of the furnace is represented by Fig. 4; and Fig. 5 shows a top view with the shaft and electrodes removed.

The height of the furnace above ground level is about 25 feet. The melting chamber or crucible containing the electrodes is about 7 feet high, and is of greater diameter than any other part. The shaft is about 18 feet high, the lower end of which—for about 4 feet—has the form of a truncated cone; for the purpose of directing the charge into the crucible in such a manner that the electrodes, lining, and descending charge, could not come in contact. This special feature in the design was introduced by the inventors after repeated experiments: which demonstrated that the upper surface of the column formed by the materials charged into the furnace assumes a definite angle: viz., 50° to 55° to the vertical, when the materials—crushed to normal size, and at the same temperature as that existing in the melting chamber—are allowed to fall through a circular aperture into a free space. In Fig. 4 the slope is indicated by dotted lines.

It is this isolation of the descending charge from the lining at the point where the electrode enters the furnace that constitutes the particular economic advantage of the construction; since it prevents the destruction of the lining: which occurred in all previous furnaces where the electrode came directly in contact with the melting charge and the lining; for the temperature of the brickwork in close proximity to the electrodes becomes so great that the most refractory lining materials are rapidly destroyed—even when the electrodes are cooled by water jackets.

The contracted neck of the shaft immediately over the central opening into the melting chamber, is not supported by the arched roof, but the entire weight of the shaft is carried by six cast-iron columns arranged symmetrically around the furnace hearth.

The melting chamber is made in the form of a crucible, and is covered with an arched roof provided with openings for the reception of the electrodes and descending charge. The roof and walls of the crucible are lined with magnesite.

For the purpose of cooling the brickwork composing the lining of the roof of the melting chamber, and thereby increasing its life, three tuyères are introduced into the crucible—just above the melting zone—through which the comparatively cool, tunnel-head gases[1] are forced against the lining of the roof

[1] During the run of the furnace now in progress (July 7) an examination of the tunnel-head gases was made, resulting as under:—

The escaping gazes were kept (by regulating the circulation) at a temperature of 200° to 300°; and the following is an analysis when using—

Hematite		Magnetite:—	
CO_2	40%	CO_2	25%
CO	50%	CO	65%
H	10%	H	10%

into the free spaces. This gas absorbs heat from the exposed lining of the roof and walls, and the free surface of the spreading charge; thus effectively lowering the temperature of the roof and exposed walls.

With the exception, however, of radiation from the tuyères, no heat is lost by this method of cooling, or lowering of temperature; since the heat given up by the lining of roof and wall to the comparatively cool gas introduced through the tuyères, is imparted in passing upward through the shaft to the cooler portions of the descending charge. This effects not only a better utilization of the reducing power of the CO; but in addition, produces a better distribution of heat throughout the charge in the shaft than in any electric furnaces previously constructed.

The tuyères are provided with sight holes, covered with mica, through which the interior surface of the arched roof can be observed. By means of this device, it is possible to determine approximately the necessary quantity of gas required to effectively cool the roof lining at the mouth of the melting chamber.

Each electrode was built up from two carbons 11″ square × 63″ long, making the total cross section of the built up electrode 11″ × 22″. The electrode holder is made of a strong steel frame, forming a support for the wedges; by means of which the copper plates conducting the current from the copper cables are pressed against the faces of the electrode.

The electrode is clamped in the steel frame mentioned above, and slides on two guides; which serve the two-fold purpose of keeping the angle of inclination to the vertical, constant, and relieving the arched roof of any undue strain which would arise from the weight of the electrode—if insufficiently supported. A steel cable, secured to the top of the electrode holder and passing over a system of guide wheels or pulleys to the drum operated by the hand wheel on the switchboard, serves to lower and raise the electrode, by winding or unwinding the drum.

In order to protect the parts of the electrodes outside the furnace from the oxidizing action of the air, a suitable covering is provided.

The water-cooled stuffing boxes, through which the electrodes enter the melting chamber, are provided with special devices (not shown on the drawing) for preventing the gas under pressure within the melting chamber from leaking out around the electrodes.

The shaft—as previously mentioned—is supported by an iron plate, resting on six cast-iron pillars arranged symmetrically around the furnace hearth. To prevent the pillars from being cut off in the event of the molten iron accidentally finding its way to them, the lower parts are protected by sand enclosed in a sheet-iron casing.

This mode of construction enables the operator to repair or replace—without removing the shaft—those parts of the furnace needing the most frequent repairs, viz., the lower part of the shaft, and the melting chamber.

In order to collect the waste gases at the throat of the furnace—with the object of utilizing them economically for the purposes specified on pages 14 and 15, and at the same time to protect the charcoal fuel from premature combustion—the top of the shaft is closed by an iron cover, fitted with a charging bell and hopper, covered in by means of a specially constructed sheet iron hood; designed to prevent gas explosions caused by the intrusion of atmospheric air into the shaft when a charge is being introduced.

The collected gases at the throat of the furnace are discharged into a down-comer pipe, provided with a dustcatcher, from which the gases—largely denuded of dust—are drawn by means of a fan, and forced down into the melting chamber through the three tuyères.

With a view of preventing excessive pressure in the interior of the furnace, an uptake pipe—provided with loaded, self-closing valve—is placed at the junction of outlet pipe and top of downcomer, for conducting the gases generated in the furnace (when the pressure reaches a certain point) to apparatus designed for the utilization of the waste gases, or, to the atmosphere.

RAW MATERIALS USED.

The iron ore placed at the disposal of the inventors for the trial run was magnetite from Grängesberg, and had the following composition:—

	Per Cent.
Fe_3O_4	66·46
Fe_2O_3	21·21
MnO	0·30
MgO	0·98
CaO	3·84
Al_2O_3	1·07
SiO_2	3·16
P_2O_5	2·34
S	undetermined
Metallic iron	62·96

During the first part of the trial run, coke containing 85% C and 0.55% S was used. This, however, had been exposed for a long time to the open air and rain, which made its percentage of moisture unusually high. Lime was used as a flux.

The raw material—crushed to pieces of about 1″ diameter—was conveyed to the charging floor of the furnace, where it was weighed, and charged by hand. The instruments were read every half hour, the product of each tapping carefully weighed, and samples of both the iron and slag taken for analysis. The iron and slag were tapped through the same hole; but no difficulty was encountered in separating the iron from the slag after cooling.

The men operating the furnace were divided into two shifts: each shift being of twelve hours duration, and consisting of four labourers and a foreman.

HEATING OF THE FURNACE.

Notwithstanding the fact that the furnace was new in every respect, only one week was allowed for heating from the time the first coke fire was lighted in the melting chamber to the time of the first tapping. Experience with blast furnaces has proved that at least three weeks should be devoted to the drying of the linings in furnaces of this size, prior to charging; otherwise, the heat energy which should be utilized in the reduction and dissociation of the ores will be expended in converting the moisture in the brickwork into steam: resulting in the chilling of the iron, and consequent reduction of the output. The unavoidable neglect of this precaution in the present instance, interfered materially with the normal thermal working condition of the furnace throughout the entire trial—especially at the beginning—as the output tables clearly show.

POWER SUPPLIED TO THE FURNACE.

Although the furnace was designed for a much larger capacity, the power available at this time was only 400 to 450 kw. The tension was kept at between 40 and 50 volts, and the power factor—which, with the lower tension during the first part of the run was 0·85—rose to 0·90 with the higher tension.

A point in the construction of this furnace deserving of special mention is, the almost complete absence of fluctuation in the instruments for recording the current and tension delivered. This, in former electric furnaces, occasioned a serious difficulty, and necessitated either the installation of automatic electrode regulators, or the constant presence of a man at the switchboard for adjustment and regulation. In this case, however, the only regulation required is that corresponding to the consumption of the electrodes, which requires to be done once a day, and sometimes for slightly longer periods. The cost of the electric installation for this furnace, compared with that of other types, is, therefore, cheaper; inasmuch as the costly apparatus for controlling the electrodes is dispensed with. Since the fluctuation of power is almost negligible, and current shocks do not have to be taken into consideration, this type of electric furnace constitutes an ideal load for a power station.

THE TRIAL RUN.

The trial run was started at 6.30 a.m., December 27, when the readings of the different measuring instruments were taken and recorded every half hour. Samples of the pig iron and slag were taken for analysis; and the iron—after the slag had been entirely removed—carefully weighed.

During the first part of the trial the composition of the charge was:—

Ore.	209·0 lbs.
Coke.	48·4 "
Lime.	11·0 "

The coke used in this charge corresponds to a consumption of about 810 lbs. per long ton pig iron. During tapping, however, carbon was observed to escape through the tap-hole with the slag, which, in addition, contained a considerable amount of carbide. This indicated an excess of carbon. The charge was, therefore, altered the next morning to the following composition:—

Ore..	209·0 lbs.
Coke..	42·0 "
Lime..	4·4 "

corresponding to a consumption of carbon of about 704 lbs. per long ton of pig iron.

On the evening of the same day the charge was again changed to:—

Ore..	220·0 lbs.
Coke..	41·8 "
Lime..	4·4 "

which corresponds to a consumption of carbon of about 671 lbs. per long ton of pig iron.

The coke used up to this time was very wet, having been exposed to rain and snow. As, however, dry coke, which consequently contained a higher percentage of carbon per unit weight, was now available, the charge was again changed to:—

Ore..	220·0 lbs.
Coke..	37·4 "
Lime..	4·4 "

which corresponds to a consumption of coke of about 605 lbs. per ton of pig iron. This might be further reduced when the furnace is working normally, and the gases circulated as previously described. However, this consumption of carbon must be considered as extremely satisfactory.

Analyses of the pig iron from six different tappings, and of the slag from tapping No. 4, are given below. From an inspection of these analyses it will be seen that the sulphur content, especially in the last one, is exceedingly low. During the last tapping the temperature of the furnace was higher than in the former tappings, which accounts for the low sulphur content.

ANALYSES OF PIG IRON PRODUCED.

Cast No.	C	Si	Mn	P	S
2	3·20	0·056	0·32	1·80	0·015
3	3·20	0·103	0·37	1·50	[1]........
4	3·40	0·065	0·34	1·64	0·015
5	3·20	0·075	0·32	1·80	[1]........
9	3·20	0·075	0·39	1·90	0·015
13	3·15	0·070	0·24	2·06	0·005

[1] Undetermined.

ANALYSIS OF SLAG FROM CAST NO. 4.

SiO_2	26·54
CaO	54·48
S	0·78
Fe	0·35

The readings of the volts and amperes, and the consumption of energy, are given in the following tables. As previously explained, *these figures cannot serve as a criterion for judging the process commercially*,[1] *and are only inserted here as they may be of some interest from a technical point of view.*

ELECTRICAL MEASUREMENTS.

Date.	Time.	Amperes. I.	Amperes. II.	Amperes. III.	Volts.	Kilo-watts.	Remarks.
Dec. 27	6 30 a.m.	6,800	6,800	6,800	41	400	
"	7.00 "	6,800	6,800	7,000	42	415	
"	7.30 "	7,000	7,000	7,000	40	400	
"	8.00 "	7,000	7,000	7,000	41	405	
"	8 30 "	6,800	7,000	6,800	42	415	
"	9.00 "	7,000	7,000	7,000	40	400	
"	9 30 "	6,800	7,000	7,000	40	395	2,860 lbs. of pig iron cast.
"	10 00 "	6,800	6,800	6,800	40	385	
"	10 30 "	7,000	7,000	7,000	40	400	
"	11 00 "	7,200	7,000	7,000	38	380	
"	11 30 "	7,200	7,000	7,200	38	375	
"	12.00 "	7,200	7,200	7,400	33	325	
"	12 30 p.m.	7,200	7,200	7,400	39	390	
"	1 00 "	7,200	7,200	7,400	38	380	
"	1 30 "	7,200	7,600	7,200	36	360	
"	2 00 "	7,400	7,400	7,200	36	360	1,067 lbs. of pig iron cast.
"	2 30 "	7,400	7,200	7,400	38	385	
"	3 00 "	7,200	7,200	7,200	40	400	
"	3 30 "	7,400	7,200	7,400	39	395	
"	4.00 "	7,400	7,400	7,600	40	415	
"	4 30 "	7,200	7,200	7,400	38	380	
"	5.00 "	7,200	7,200	7,400	40	405	
"	5.30 "	....	....	....	....	....	Power off, due to change on switchboard wiring.
"	6.00 "	....	....	....	....	....	
"	6 30 "	....	....	....	....	....	
"	7 00 "	6,200	6,400	6,600	42	380	
"	7 30 "	6,600	6,800	7,000	40	380	
"	8.00 "	6,800	7,000	7,000	40	385	
"	8 30 "	7,200	7,200	7,000	36	350	1,441 lbs. of pig iron cast
"	9.00 "	7,200	7,200	7,000	36	350	
"	9 30 "	7,400	7,400	7,400	36	[illegible]	
"	10 00 "	7,400	7,400	7,400	36	365	
"	10 30 "	7,400	7,400	7,200	37	370	
"	11 00 "	7,200	7,400	7,200	36	355	
"	11 30 "	7,200	7,400	7,000	36	350	
"	12.00 "	7,200	7,400	7,000	36	350	
Dec. 28	12 30 a.m.	7,000	7,400	6,800	40	395	
"	1 00 "	7,000	7,400	7,000	40	400	
"	1.30 "	7,000	7,400	7,000	40	400	
"	2 00 "	7,000	7,400	6,800	40	395	1,650 lbs. of pig iron ca
"	2.30 "	7,000	7,400	7,000	40	400	
"	3.00 "	7,000	7,200	7,000	38	375	
"	3.30 "	6,800	7,400	7,000	39	385	
"	4 00 "	6,800	7,200	6,800	39	375	

[1] For reasons, see paragraph headed "Heating of the Furnace," page 17.

ELECTRICAL MEASUREMENTS—*Continued.*

Date.	Time.	Amperes. I.	Amperes. II.	Amperes. III.	Volts.	Kilo-watts.	Remarks.
Dec. 28..	4 30 a.m...	7,000	7,100	7,200	36	375	
" ..	5 00 " ..	7,200	7,100	7,200	36	355	
" ..	5 30 " ..	7,400	7,400	7,600	37	380	
"	6 00 " ..	7,200	7,200	7,400	36	360	
"	6 30 " ..	7,200	7,100	7,400	38	385	
"	7 00 " ..	7,200	7,400	7,100	38	385	
" .	7 30 " ..	7,100	7,600	7,600	36	370	
" .	8 00 " ..	7,400	7,100	7,600	36	365	4,870 lbs. of pig iron cast
"	8 30 " ..	7,400	7,400	7,100	38	385	
" ..	9 00 " ..	7,200	7,200	7,400	38	380	
" ..	9 30 " ..	7,400	7,400	7,400	36	365	
"	10 00 " ..	7,200	7,200	7,200	38	375	
"	10 30 "	7,200	7,400	7,400	38	385	
" .	11 00 "	7,400	7,400	7,400	36	365	
" ..	11 30 " ..	7,100	7,100	7,600	38	390	
"	12 00 " ..	7,400	7,600	7,800	38	400	
"	12 30 p.m...	7,600	7,800	7,600	40	430	
" .	1 00 " ..	7,600	7,600	7,800	38	400	
" .	1 30 " ..	7,600	7,100	7,600	38	395	
"	2 00 " ..	7,600	7,400	7,600	38	395	
"	2 30 " ..	7,600	7,600	7,400	40	425	
" .	3 00 " ..	7,200	7,400	7,600	36	365	
" ..	3 30 " ..	7,200	7,600	7,400	38	385	
" .	4 00 " ..	7,200	7,200	7,400	40	405	
" ..	4 30 " ..	7,400	7,400	7,800	38	395	
" .	5 00 " ..	7,400	7,400	7,800	40	425	
" .	5 30 " ..	7,400	7,400	7,600	40	415	1,430 lbs. of pig iron cast
"	6 00 " ..	7,400	7,100	7,600	42	440	
" .	6 30 " ..	7,200	7,200	7,600	40	410	
" ..	7 00 " ..	7,200	7,200	7,400	40	405	
" ..	7 30 " ..	7,200	7,100	7,100	40	400	
" .	8 00 " ..	7,200	7,100	7,200	38	380	
"	8 30 " ..	7,400	7,400	7,600	38	390	
" ..	9 00 " ..	7,200	7,200	7,600	38	385	
" ..	9 30 " ..	7,000	7,400	7,400	38	380	
"	10 00 " ..	7,200	7,200	7,600	37	370	
" ..	10 30 " ..	7,400	7,100	7,400	38	380	
" ..	11 00 " ..	7,200	7,600	7,600	38	390	2,343 lbs. of pig iron cast
" ..	11 30 " ..	7,200	7,600	7,400	38	385	
" ..	12 00 " ..	7,400	7,200	7,400	39	395	
Dec. 29..	12 30 a.m. .	7,400	7,200	7,600	39	400	
" .	1.00 " ..	7,600	7,400	7,800	39	410	
" ..	1.30 " ..	7,400	7,400	7,600	39	405	
" .	2 00 " ..	7,400	7,400	7,600	38	390	
" ..	2 30 " ..	7,600	7,400	7,600	38	395	
" ..	3.00 " ..	7,400	7,400	7,600	38	390	
" ..	3 30 " ..	7,600	7,200	7,600	37	380	
" ..	4.00 " ..	7,800	7,800	8,000	37	400	
" .	4 30 " ..	7,800	7,600	7,800	36	380	
" ..	5 00 " ..	7,800	7,600	7,800	36	380	1,562 lbs. of pig iron cast
" ..	5 30 " ..	7,800	7,400	7,800	36	375	
" .	6 00 " ..	7,800	7,100	7,800	35	365	

It may be pointed out that the output continued to steadily rise as the furnace more nearly approached its normal working condition—even with the inadequate power supplied—until an unfortunate accident occurred to one of the water-cooled stuffing boxes, necessitating the removal of one electrode.

Towards the end of the run, one of the cast-iron, water-cooled stuffing boxes developed a bad crack, which allowed large quantities of water to escape into the furnace. This would not have occurred had sufficient time been allowed for the thorough testing of all the castings, and cannot happen in the future; since the design of these water-cooled stuffing boxes has been changed. But even while running with only two electrodes, the output again began to rise when the heat lost by the water escaping into the furnace was partially restored to the walls of the furnace, and to the wet charge in the shaft.

The time limit set by the director of the company for the delivery of power to the furnace, was January 1, 1909; it was necessary, therefore, that the latest charge in the furnace should be all melted down, and tapped out, prior to that date. This was accordingly anticipated, and the official trial run was discontinued at 6 a.m., December 29, 1908.

In the following table is given the number of tons of pig iron produced per electrical horse-power year, in casts Nos. 2 to 10, inclusive:—

Cast No.	Tons of pig iron per E.H.P. year.
2	0·744
3	1·870
4	2·180
5	2·360
6	2·410
7	1·120[1]
8	3·160
9	1·950
10	1·030

* Electrode holder began to leak badly.

From the foregoing tables it will be seen that the output before the leakage of water into the furnace became serious, was 2·44 metric tons per electrical horse-power year. This figure—considering the disadvantages[1] under which the trial run was made—may be deemed very satisfactory.

Owing to the short duration of the trial, it was impossible to determine the consumption of electrodes per ton of pig iron produced. According to former tests, however, this may be placed at about 5 Kgs per metric ton (2,204 lbs.) of pig iron produced.

TECHNICAL OBJECTIVE OF TRIAL RUN.

The trial run was intended to elucidate the following points:—

(1) Whether undisturbed and uniform working without troublesome regulation of the electrodes could be obtained.

(2) Whether great variations in the consumption of energy would occur.

[1] Water leaked into the furnace in small quantities from the beginning of the trial, but was not so noticeable until after the seventh cast.

(3) Whether the free spaces within the melting chamber would be maintained with a shaft considerably higher than in the furnaces of earlier design and construction.

(4) Whether the contraction of the shaft would prevent the charge from sinking uniformly, or cause hanging.

(5) The durability of the arched roof, and the possibility of cooling it by means of the circulating gas.

DEDUCTIONS FROM OBSERVATIONS.

The following is a summarized statement of practical deductions drawn from observations made during the trial run: having regard to the objective points specified above:—

(*a*) It was observed that the furnace operated uniformly and without trouble of any kind, and that the electrodes required absolutely no regulation, in one case, for five consecutive days. In any case, the only regulation required is that corresponding to the consumption of the electrodes, and is necessary only once a day, and sometimes not for much longer periods. On account of this, expensive regulation can be dispensed with.

(*b*) During the short trial, even though the furnace did not approach its normal working condition until towards the end, it was observed that the consumption of energy was remarkably uniform. This can readily be seen from an inspection of the readings of the different instruments.

(*c*) Free spaces were maintained between the linings of the roof and walls, and the electrodes and charge at the openings where the electrodes enter the melting chamber.

(*d*) It was found that the charge did not jam in the lower contracted neck of the shaft, as had been feared, but moved with regularity into the melting chamber.

(*e*) Although the gases generated by the reduction of the ore were not circulated through the cooling tuyères until near the end of the trial run, it was demonstrated that the lining of the roof of the melting chamber was effectively cooled by this means.

COMPARISON OF THE COST OF PRODUCTION OF PIG IRON IN THE CHARCOAL BLAST FURNACE WITH THAT PRODUCED IN THE ELECTRIC SHAFT FURNACE.[1]

BY

PROFESSOR VON ODELSTIERNA, STOCKHOLM, SWEDEN.

If we take as a basis for our comparative study, an ordinary charcoal blast furnace, and the electric shaft furnace erected at Domnarfvet: and suppose the iron ore used in these furnaces to contain 60% metallic iron, and the charcoal 83% carbon, then it should be possible to make a reliable comparison. It should be pointed out, however, that in this comparison no account is taken of the fact that, the gases produced in the electric shaft furnace contain a higher percentage of CO—probably 60% more—than the ordinary blast furnace gases.

In regard to the labour charges and general expenses, I make the supposition that these charges are the same for both the electric shaft furnace and the charcoal blast furnace, if the contrasted furnaces are of such capacity as to produce the same quantity of pig iron per year. A charcoal blast furnace of medium capacity produces in Sweden about 8,000 to 10,000 short tons of pig iron per annum—a quantity which I believe can also be produced in a properly constructed electric shaft furnace of the type of Aktiebolaget Electrometall..

COST OF PIG IRON PER SHORT TON IN DOLLARS.

Charcoal blast furnace.		*Electric shaft furnace.*	
Charcoal, 0 95 ton at $8 per ton	$ 7 60	0·27 ton	$ 2 16
Electrical energy	0 00	0 3 E.H.P. year at $12	3 60
Labour	1 00		1 00
Electrodes	0 00	10 lbs. at 3c. per lb.	0 30
Repairs and general expenses	1 50		1 50
	$10 10		$ 8 56

In this calculation the price of ore and limestone, and the royalty are not given, as the former varies with the locality and the character of the ore, and the latter has not yet been determined.

From this calculation it is apparent that in Sweden, under the above-mentioned circumstances, a saving of $1.55 should be effected in the production of pig iron by the electro-thermic process.

[1] Based upon conditions in Sweden.

PART II.

Electric Steel Furnace.

The inventors of the electric shaft furnace for the reduction of iron ores— just described, have also obtained patents for an electric steel furnace, possessing some novel features.

Either a two, or three-phase current can be used with this furnace, which has but two adjustable electrodes; the bottom of the hearth—composed of magnesite, intermixed with a small amount of graphite—forming the third.

By the special distribution of the electrodes, the bath is caused to rotate in a vertical plane, thus continually bringing new material in contact with the slag for purification. The time required for refining is by this means considerably shortened.

Since the majority of power plants are designed for multi-phase currents, and multi-phase generators are cheaper to construct than single-phase generators, the advantage which such a furnace has over one using single-phase current is manifest.

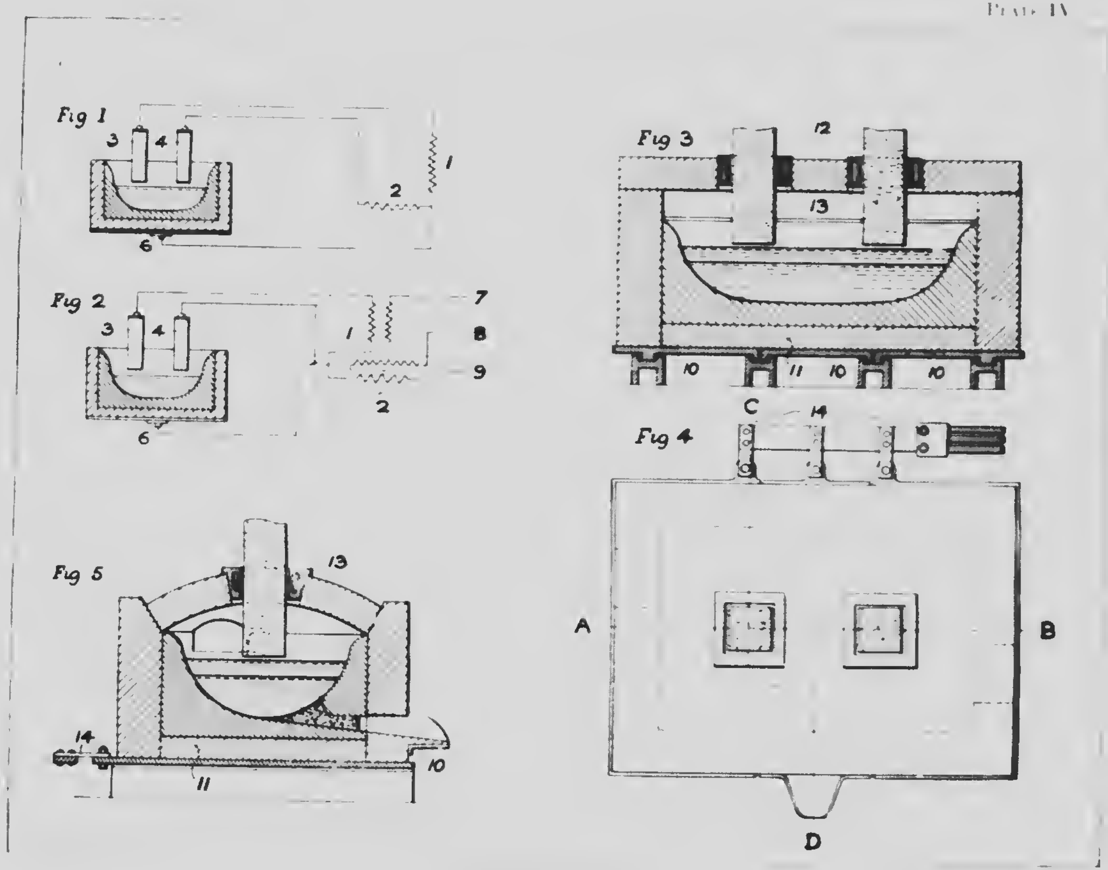
If the current to be supplied is two-phase, an ordinary twosphase transformer can be used with the furnace; but if the supply is three-phase, two single-phase transformers with Scott's connexion can be used.

ABSTRACT OF SWEDISH PATENT SPECIFICATIONS.

Improvements in Methods of Electric Production of Iron and Steel and other Metals, and Furnaces for carrying out the same.

In the electric melting and refining of metals, such, for example, as iron and steel, the following well known method is employed: The current flowing through an electrode inserted in the furnace passes in the form of an electric arc into the molten bath, composed of the materials to be refined, or to the layer of slag floating thereon, and then from the molten bath it flows back to the source of current by means of a bottom contact, or else in the form of an electric arc to a second electrode inserted into the furnace, and from this electrode back to the source of current, in which latter case the tension must be doubled, since the two electrodes are coupled in series. Both the above methods, however, presuppose the utilization of a single-phase alternating current. A multi-phase alternating current, however, offers important advantages, both in generation and in transmission to the place where it is to be used.

For these reasons it is very desirable to use multi-phase currents direct in the electric steel furnace, and many suggestions to accomplish this have been made. In all these suggestions the assumption has been made, that the number of adjustable electrodes used should be as great as the number of terminals of the poles in the current system, i.e. in three-phase currents three electrodes, in



Electric Steel Furnace

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[illegible]

two-phase four electrodes, etc. This large number of adjustable electrodes has, especially in the case of a small furnace, occasioned difficulties which precluded their employment.

The present invention relates to a method and furnace which permits the use of multi-phase currents without increasing the number of adjustable electrodes beyond that employed in furnaces for single-phase currents.

The salient feature of this invention is the method for supplying a two-phase current in such a manner that the terminals of one pole of the two phases are each electrically connected with one of the two adjustable electrodes of the furnace, while the terminals of the other pole of the two phases are electrically connected with the lining of the furnace, which is conductive, or else with any other electrode which is in direct contact with the current, that passes to the molten bath in the form of an electric arc.

In the accompanying drawings, Plate IV, Fig. 1 illustrates the connexion; while Fig. 2 shows in like manner a modified form of this connexion.

In Plate IV, Figs. 1 and 2 represent the two phases of a two-phase system: where two ends of the phases are electrically connected to each other. The current system is thus interlinked. Each of the two phases is connected with a corresponding electrode, (3) and (4) respectively, from which the current passes in the form of an electric arc to the bath. From the bath the two phases unite and pass through the conducting lining to the contact (6), and from thence to the source of the current. Since the difference of phase between the two circuits, relatively to each other, is 90°, it is evident that the resultant current, which passes through the bath and contact (6), will be $\sqrt{2}$ times greater than the current which flows through each of the electrodes, (3) and (4); and also the tension between the electrodes should be $\sqrt{2}$ times that tension which is consumed in each arc. It is also evident, without further explanation, that as almost the entire tension is absorbed in the arcs, the current system will be balanced, and the two phases equally loaded.

If a three-phase current is used, it can be transformed to two-phase by means of the well known Scott's connexion in the transformer belonging to the furnace. The diagram in that case is shown in Fig. 2, where (7), (8) and (9) are the three conducting wires from a three-phase system; the other numerals in this figure indicate the same parts as in Fig. 1.

A furnace suitable for carrying out this process is shown in Figs. 3, 4 and 5. In Fig. 4 is shown a top view of the furnace; while Fig. 3 represents a vertical section along line A—B, and Fig. 5 a vertical section along the line C—D, shown on the top view.

The furnace is built on iron plates (10), which also serve as conductors for the resultant current of the phases; for this purpose they are connected with the conductors (14). The walls are constructed in the usual manner. When soft iron or steel is to be produced, the lining is made of magnesite, dolomite, or quartz. Since these substances are conductors of the second class, and consequently must be at a rather high temperature in order to conduct electricity well, a layer (11) of graphite, for example, would be rammed in on the plates

(10). This material, when cold, is an excellent conductor of electricity, and serves the purpose of conducting the current until the lining attains the proper temperature to become itself a conductor. Where the lining is composed of magnesite or dolomite, with tar, pitch, or the like, as an adhesive, it is usually a sufficiently good conductor; on account of the carbon introduced in this manner, even when in a cold condition. Under these conditions, the conducting layer (11) can then, if desired, be omitted. The two electrodes (12) Fig. 3, are connected to the free ends of the phases. These electrodes penetrate into the cupola of the furnace and are adjustable. For the purpose of protecting the brickwork of the cupola the electrodes pass through water-cooled stuffing boxes (13). The electrodes are so adjusted that there is formed between them and the bath or layer of slag floating thereon, an arc of suitable length.

It is, moreover, plain that the constructive details of the furnace can be carried out in many different ways and can be arranged to suit circumstances.

With this furnace all processes occurring in the production of iron and steel, such as puddling, desulphurization, dephosphorization, etc., can be carried out.

PART III.

Manufacture of Carbon Electrodes.

Great development has taken place during recent years in the manufacture of electrodes for electric furnaces. The equipment of an up-to-date factory is very different to the simple devices and appli ces which were in use a decade ago.

A modern factory is divided into four main parts, viz.:—

(1) Storing and sorting
(2) Crushing and mixing
(3) Moulding of the electrodes
(4) Drying process.

The raw material used for electrodes varies somewhat for different purposes. The simplest and cheapest electrodes consist of anthracite, retort coal, and tar. For electrodes of higher quality, graphite is added to the above.

The raw material is collected in big bunkers or silos; which are so constructed that the raw material flows freely and easily out of the bottom. In most cases the anthracite must be picked so that its full purity is ensured.

The anthracite and retort coal is crushed and ground independently: first in ordinary crushers, and then in edge-runners. It is not good practice to grind the whole of the raw material to the same fineness; on the contrary it is very important that a special mixture should be obtained, consisting of many different sizes of grain; varying from a few cubic millimetres to the fineness of powder. When the mixture is ready, tar is added, and the whole is then treated, first in ordinary mixers, and afterwards in edge-runners.

The above process—as now adopted in modern factories—is almost entirely automatic, thus requiring but few workmen.

The mixture is allowed to settle for some days, after which it is ready for use in the electrode press. It has been found that for big electrodes where no special shaped heads are required, a special kind of extrusion press is the most suitable. This press operates with a very heavy pressure, and the electrodes thus obtained have absolutely smooth faces, and a hardness which ensures them against losing their shape.

After leaving the press, the electrodes are dried in the air for about a week, and then passed through the kiln. In the modern factories a special type of "ring" kiln is used, of somewhat elaborate construction. These kilns are very similar to those used for burning firebricks at high temperature. The kiln used for carbon electrode factories is an improvement on the Mendheim kiln.

The electrodes should be burnt at a temperature of about Cone 13 or 14. The kilns are heated by generator gas, and very convenient arrangements permit the operation of the different chambers separately.

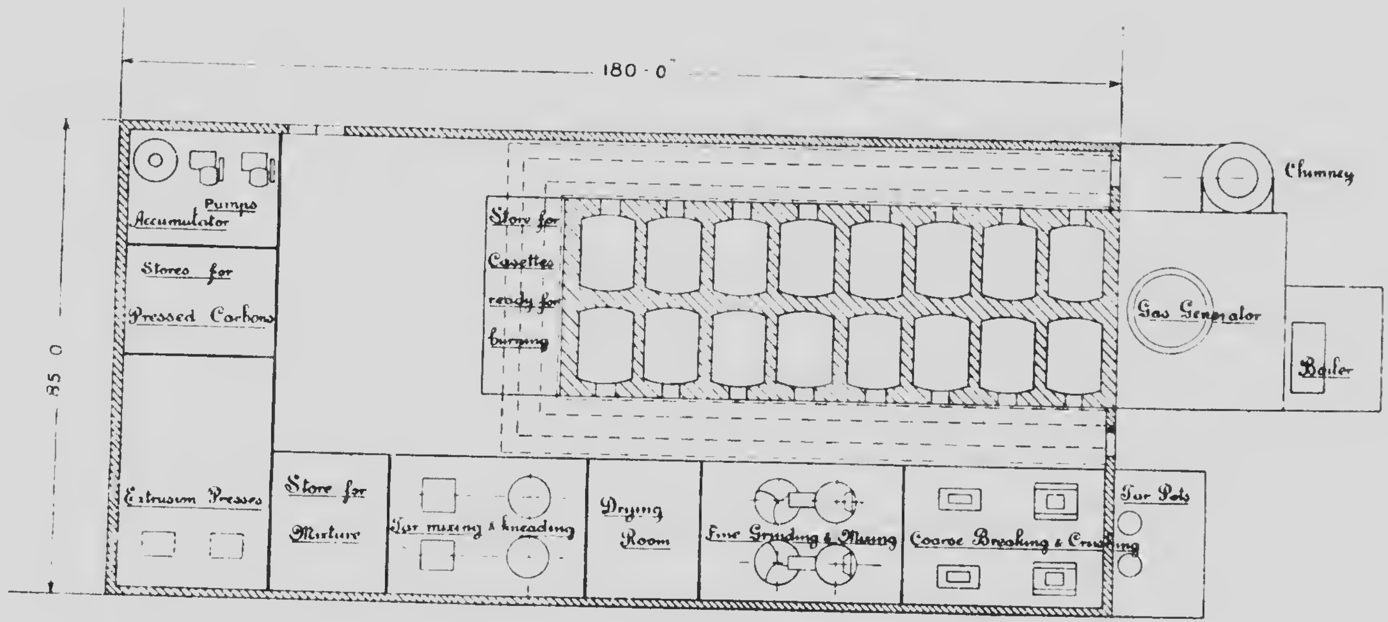

FIG. 6. ELECTRODE FACTORY.

The last modern factory has been constructed for the British Aluminium Company at their works at Kinlochleven. This factory has been built and equipped according to the designs and plans of Mr. Jens Orten-Böving, 72 and 74 Victoria street, London, S.W. This plant has a capacity of about 6,000 tons a year. The total cost—including very expensive factory buildings and heavy concrete foundations (which were necessary on account of the poor ground)—amounted to £55,000. This would correspond to a little over £9 for an output of a ton per year; but for a small plant, which would not be so labour-saving and complete, the initial cost might be reduced to between £4 or £5 for one ton output per year. The working cost of a modern plant is not more than about one-third of the cost of the old type of factory.

The following is a description by Jens Orten-Böving, M.I.M.E., of a factory for producing yearly, 3,000 tons of large size carbon electrodes:—

MODERN FACTORY FOR MAKING CARBON ELECTRODES.

General.—The statements and figures given below, are derived from facts and operating results obtained from two large factories, constructed on similar lines.

Messrs. Höganäs-Billesholm, Limited, of Sweden, have a carbon factory of 2,000 tons yearly output, making electrodes for carbide furnaces, steel smelting furnaces, and aluminium works.

The British Aluminium Company, Limited, have a factory at Kinlochleven, Scotland, producing yearly 6,000 tons of electrodes for their own aluminium works.

These electrode factories have been designed and put up by Mr. Jens Orten-Böving, 72-74 Victoria street, London, S.W.

The factory which is dealt with in this description would have an output of 3,000 metric tons (@ 1,000 kilos) yearly.

The cost of raw material and labour should approximately correspond to Canadian conditions. The figures are on the safe side, and can be taken as reliable.

Raw Material.—Many different kinds of coal may be used with advantage, but for Canadian conditions, anthracite, gas-retort carbon, and coal tar, would probably be the most suitable. The percentage of each depends greatly on the quality, and no general figures can be given until analyses of the various materials are known.

The price of gas-retort carbon is lower than anthracite; but there is always a certain amount of the retort carbon which cannot be used, and the cost of the useful part will be about the same as for anthracite, or $10 per metric ton (1,000 kilos).

General Arrangement of Works.—It will be seen later on that only some fifteen men are required for the machinery, and the furnace proper; but a great number of unskilled hands may be required in addition to this; if the works are not properly designed from the beginning, and fitted with labour-saving appliances.

The raw material must be conveyed as short a distance as possible, and be transported automatically as far as possible. The fuel bill for the baking will run very high if the furnaces are not of the very best construction. Hence the general arrangements, while rather expensive, effect a cheap production.

Coarse Crushing Plant.—This consists of stone breakers and ordinary heavy edge-runners. The raw material is conveyed by an elevator to the fine crushing plant.

Fine Crushing Plant.—This is semi-automatic, and consists of a series of edge-runners, roller mills, and assorting sieves.

The raw material is now ready for mixing, which is a process requiring great care, as it is of importance that the right percentage of material ground to different grades of fineness should be obtained.

Tar Heating.—Ordinary coal-tar contains some water, which must be removed by evaporation.

It is also necessary that the tar should be heated so that it is quite liquid before mixing it with the coal.

The Mixing of Coal and Tar.—This is a very important process. It is done in a so-called wet mixer, constructed on much the same lines as a clay-mixer. The raw material is now passed through a kneading process, for which edge-runners are used.

When the carbon mixture is ready, it should be left to settle for some days in the store-room, before it goes to the presses.

Presses and Pumping Plant.—The best results are obtained from extrusion presses working under very high pressure. Electrodes for steel smelting furnaces would require a pressure of 600 tons.

The pumps and the accumulator are of quite normal construction.

When the electrodes have been shaped, they must be left to settle for at least twenty-four hours.

The electrodes are now packed into saggers (casettes) of chamotte. (A special department could be arranged for making the saggers, which would be advisable if there were no fireclay works near enough to obtain the saggers cheap. A special sagger factory is now under construction for the electrode works of the British Aluminium Company, Limited.)

The space between the electrodes and the sagger is filled up with anthracite dust, which is there calcined during the burning of the electrodes. This is a very important feature of the process, and the whole amount of the anthracite used for the manufacture of electrodes should be treated in this manner.

Mendheim's Gas Kiln.—This system has proved to be superior to any other systems, both as regard reliability, easy control, and saving of fuel. The construction is very similar to kilns used for chamotte and firebrick works.

The size required for this factory would require sixteen chambers, each of which can be worked and controlled independently of the others. The system of gas and smoke channels, as well as the valve arrangement, is somewhat elaborate, but the efficiency and practicability are very great.

The electrodes should stay twenty to twenty-two days in the kiln chambers.

The gas is obtained from a generator of the improved Morgan type, with automatic charging arrangement.

The highest temperature in the kilns should be about 1,410° Cent., corresponding to Pyramide No. 14 of the Seger scale.

There must be an ample draft from the smoke channels produced either by a high chimney or by forced draft, if the hot gases should be required for roasting or for similar operations.

There should be plenty of room in the middle of the factory for charging and unpacking the saggers.

ESTIMATE OF NECESSARY EXPENDITURE AND WORKING COSTS.

Electrode machinery—

Coarse crushing plant.	$ 7,000
Fine crushing plant.	10,500
Fine crushing plant, and assorting sieves, mixers. .	10,500
Mixing and kneading plant.	6,750
Tar heating plant.	2,000
Pumps, accumulators, presses.	10,000
Erection of machinery.	1,000
Contingencies.	1,250
	$40,000

Total cost of factory—

Machinery as per the above.	$ 40,000
Factory buildings.	108,000
Mendheim's furnace, with gas generator and forced draft plant.	72,000
Electric motors, and light plant.	3,500
Steam boiler.	900
Water and steam pipes.	1,000
Conveying appliances.	4,500
Transmissions.	1,700
Belting.	900
Contingencies.	17,500
	$250,000

Labour required—

2 men in coarse crushing plant	$ 900
2 men in fine crushing plant	800
1 man in tar heating plant	450
2 men in kneading plant	900
4 men in press room	1,000
1 man for supervision of pumps, presses and general machinery	1,200
1 man in generator and boiler	450
2 men for control of furnaces	1,000
20 men for rough labour	7,200
2 foremen	1,400
	$15,300

Yearly expenses—

Carbon, 3,000 tons (of 1,000 kilos) at $10	$30,000
Tar, 600 tons at $8	4,800
Labour	15,400
180 B.H.P. at $50 a year	9,000
Coal for generator and boiler, 3,000 tons at $5	15,000
Oil and water	1,000
Saggers and firebricks	3,500
Belting and repairs	3,500
Contingencies	7,800
	$90,000

To these costs there should, of course, be added general costs of administration, as well as depreciation of plant; and such interest on original expenditure as would correspond to a fair profit.

PART IV.

Modern Methods for Manufacturing Charcoal.

The different methods employed in foreign countries for the coking of wood in furnaces or ovens and the recovery of by-products have proved less economical in Sweden, where principally soft woods (pine and spruce) are used for coking, than in other countries where hard woods are available. The wood used in Sweden for coking yields a smaller percentage of by-products than the hard woods used in foreign countries. For this reason the coking industry in Sweden

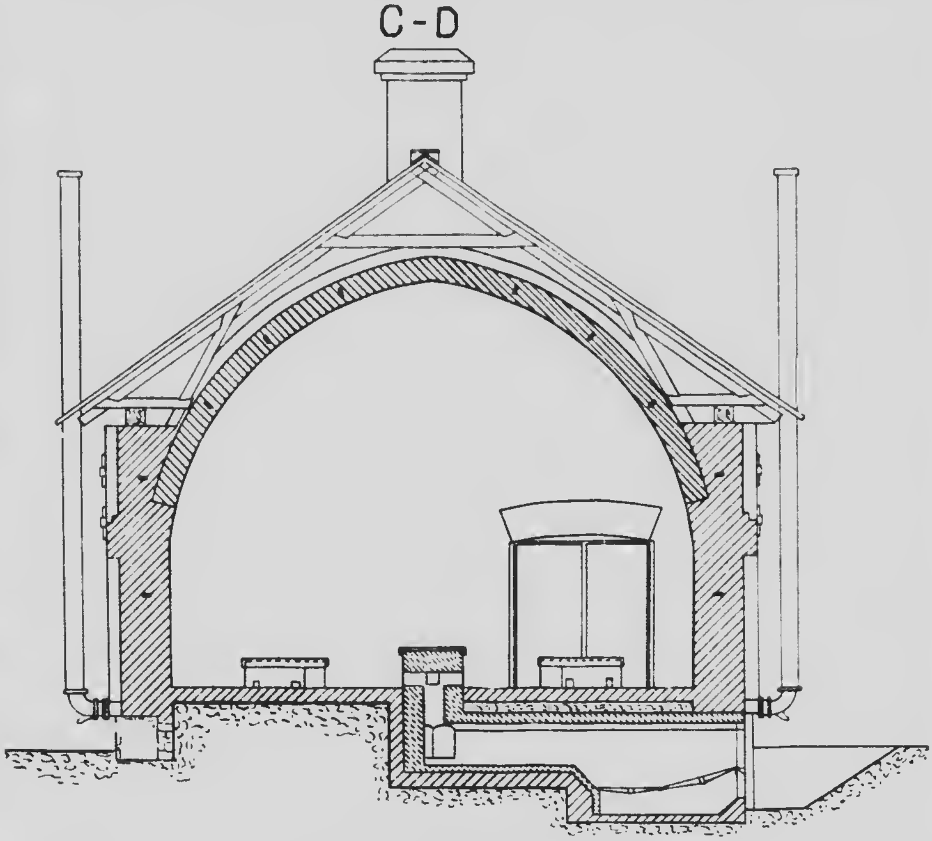

Fig. 7. Kiln for Charcoal Making.

has been forced to utilize to the utmost degree the economical improvements which from time to time have been invented, and at the present time Sweden is in advance of other countries, both in regard to the furnaces or ovens employed and the treatment of the by-products.

The following different types of coking ovens are employed in Sweden:—

(1) *Kilns.*—A number of such ovens (see Fig. 7) are in use, which in principle are very similar. The recovery of by-products is less in these ovens than in retort ovens.

(2) *Tunnel ovens.* In these ovens the coking is done on cars. Different types of such ovens are in use. A few plants are built similar to the common types usually employed in America. This type has, however, now been superseded by brick ovens heated by systems of iron stoves. (See Fig. 8.)

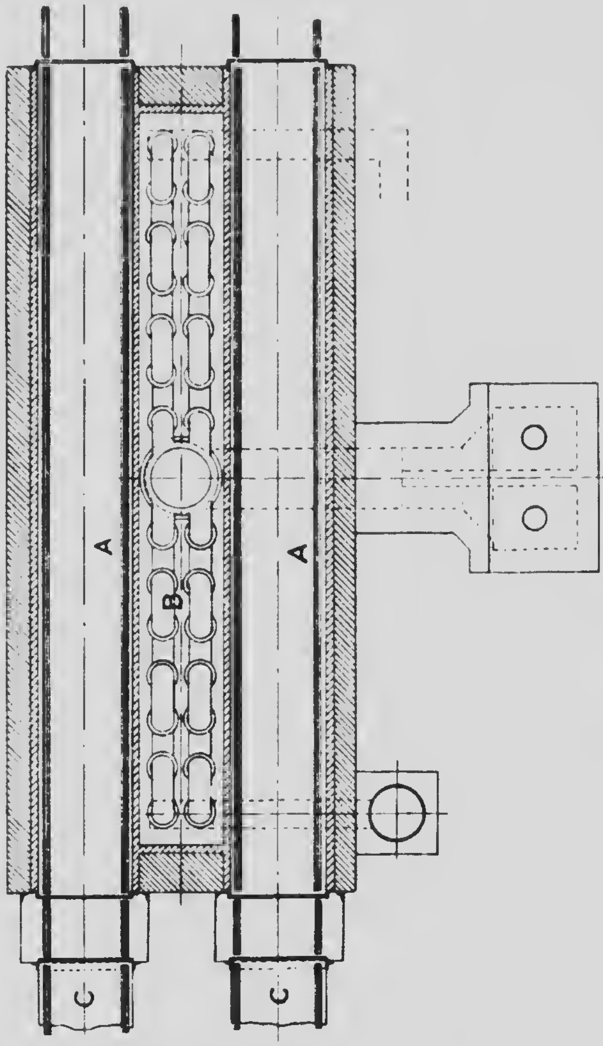

FIG. 8.—TUNNEL OVENS FOR CHARCOAL MAKING.

(3) *Iron retorts.* Holding about 350 cubic metres. (See Fig. 9.)

(4) *Shaft furnaces.*—These furnaces are constructed as shown in Fig. 10, and consist of iron retorts with exterior firing, and hold about 60 cubic metres. The wood, which is cut in lengths of 8", is either charged from the hopper on top of the retort or direct by means of a conveyer.

When the operation of coking is completed, the trap in the bottom of the retort is opened, and the coke falls down into the cooling chamber. The retort is then immediately filled with fresh wood and the process repeated. When the charcoal is sufficiently cool, the trap in the bottom of the cooling chamber is opened, and the charcoal transported to the store-house by means of a conveyer.

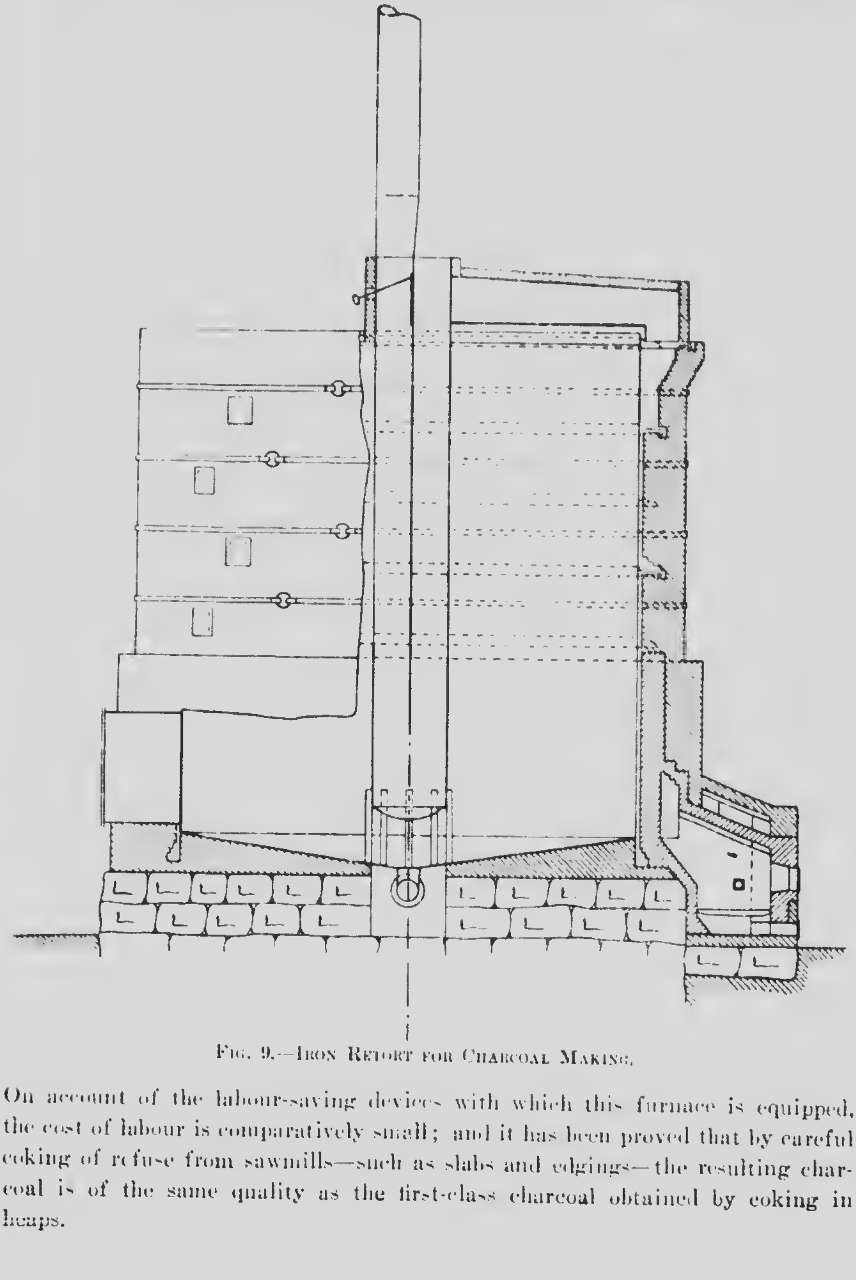

FIG. 9.—IRON RETORT FOR CHARCOAL MAKING.

On account of the labour-saving devices with which this furnace is equipped, the cost of labour is comparatively small; and it has been proved that by careful coking of refuse from sawmills—such as slabs and edgings—the resulting charcoal is of the same quality as the first-class charcoal obtained by coking in heaps.

A plant built in accordance with this system, for the production of 90,000 cubic metres of charcoal per year, costs in Sweden (including only the coking furnace with accessory machinery and apparatus) about 350,000 kronors ($91,500).

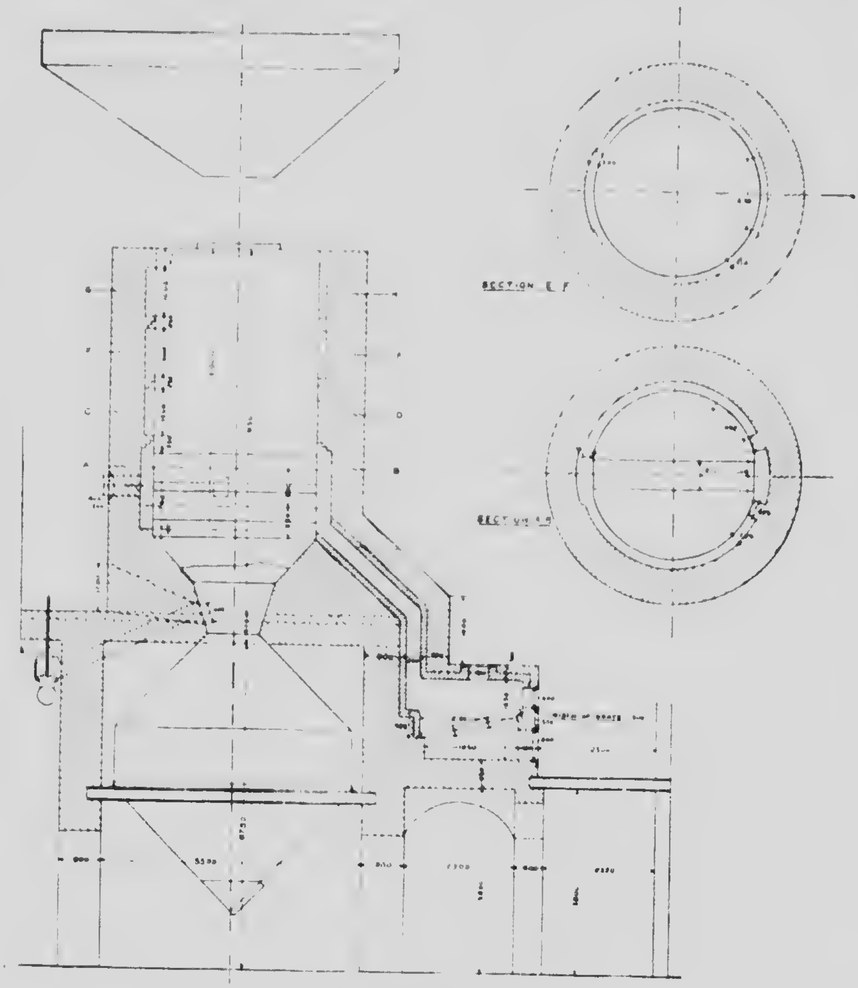

FIG. 10. SHAFT FURNACE FOR CHARCOAL MAKING.

The labour cost per cubic metre of charcoal can be reduced to as low as 0.50 krona (13½ cents), and the fuel consumption 10 to 15% of the coking wood used.

The figures here given refer to air-dried wood.

APPENDIX I.

Progress of Electric Smelting in Norway.

Extract from letter to Dr. Eugene Haanel, Director of Mines, from one of the inventors of the Electric Shaft Furnace, Sweden.

"LUDVIKA, March 9, 1909.

"As I believe it to be of interest to you, I can tell you that we recently made a contract for an electric smelting plant in Norway. The first installation will be built this summer, and includes two shaft furnaces, 2,500 horse-power each, and two steel furnaces, 600 horse power each. All the furnaces are to be supplied with two-phase current. The plant will later be extended with four more shaft furnaces of the same size, and four steel furnaces of larger size.

"At present we are busy with the working out of the drawings and specifications for this plant. Besides the electric smelting plant, the installation will include also a rolling mill for billets and flat iron. We have every reason to suppose that the plant will be erected in a perfectly modern and commercial way, as everything is newly designed.

"As soon as the drawings are ready, we shall be glad to send you an outline drawing of the whole plant, from which you will be able to see the arrangement of the different parts.

"(Signed) OTTO STÅLHANE."

APPENDIX II.

Progress of Electric Smelting in Sweden.

Extract from letter addressed to the Right Honourable Sir Wilfrid Laurier, G.C.M.G., P.C., by Sir Cecil Spring-Rice, British Ambassador, Stockholm, Sweden, June 10, 1909, and transmitted to the Mines Branch of the Department of Mines, June 30, 1909.

"Arrangements have been made with the Trollhatten Water Power Company for the construction and working of three electric furnaces for the production of pig iron. Each furnace is to receive a current of 2,500 horse-power and to produce 7,500 tons per furnace per annum. Two are to be in working, while the third is in reserve. The price of the current per horse-power per annum is 27·60 kronors ($7.45) the first ten years, and 36·80 kronors ($9.93) the next ten.

"The ore is to be brought from Grangesberg, containing from 0·4 to 1·9 per cent phosphorus. Westphalia coke will be used, costing about 21 kronors ($5.67) at Trollhatten. It is calculated that the cost of production will be 51 kronors ($13.77) per ton pig iron. The sale price is 58 kronors ($15.66). With a production of 15,000 tons per year the cost is calculated as follows:—

	kronors.	$
Three furnaces	150,000	40,500
Tools, etc.	15,000	4,050
Crushing apparatus for 35,000 tons ore and 7,000 coke	9,000	2,430
Electric motors, lighting, etc.	6,000	1,620
Transport of ore and coke from harbour	15,000	4,050
Transport of pig iron and slag	12,000	3,240
Houses and shelters	64,000	17,280
Harbour works, levelling, etc.	15,000	4,050
Laboratory, unforeseen, etc. (11%)	20,000	5,400
Licence	34,000	9,180
Working capital	25,000	6,750
Minimum capital	235,000	63,450
	600,000	$162,000"

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3. Investigation of the different electro-thermic processes for the smelting of iron ores, and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904. (Out of print.)
4. Rapport de la Commission nommée pour étudier les divers procédés électrothermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe. (French Edition), 1905. (Out of print.)
5. On the location and examination of magnetic ore deposits by magnetometric measurements. Eugene Haanel, Ph.D., 1904.
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12. Zinc Resources of British Columbia and the Conditions Affecting their Exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, 1905.
16. Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process. Final Report on—by Eugene Haanel, Ph.D., 1907.
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26. The Mineral Production of Canada, 1906. Annual Report on—by John McLeish, B.A.
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28. Summary Report of Mines Branch, 1908.
30. Investigation of the Peat Bogs and Peat Fuel Industry of Canada, 1908. Bulletin No. 1—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.
31. Production of Cement in Canada, 1908. Bulletin on—by John McLeish.
32. Investigation of Electric Shaft Furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

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23. Iron Ore Deposits along the Ottawa (Quebec side) and Gatineau rivers. Report on—by Fritz Cirkel, M.E.
29. Chrome Iron Ore Deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary Section: Experiments with Chromite at McGill University—by Dr. J. B. Porter.)

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Chemical Analyses of Special Economic Importance made in the Laboratories of the Department of Mines, 1906-7-8. Report on—by F. G. Wait, M.A., F.C.S.

MAPS.

6. Magnetometric Survey of Calabogie mine, Bagot township, Renfrew county. Vertical Intensity—by E. Nyström, M.E., 1904.
13. Magnetometric Survey of the Belmont Iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, B.Sc., 1905.
14. Magnetometric Survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, B.Sc., 1905.
15. Magnetometric Survey of Iron Ore Deposits at Austin brook, Bathurst township, Gloucester county, N.B. Vertical Intensity—by E. Lindeman, M.E., 1906.
36. Survey of Mer Bleue Peat Bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

37. Survey of Alfred Peat Bog, Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

38. Survey of Welland Peat Bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

39. Survey of Newington Peat Bog, Osnabrück, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

40. Survey of Perth Peat Bog, Drummond township, Lanark county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

41. Survey of Victoria Road Peat Bog, Bexley and Carden townships, Victoria county, Ontario—by Erik Nyström, M.E., and S. A. Anrep, Peat Expert.

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33. Magnetometric Survey, Vertical Intensity: Lot 1, Concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, M.Sc., 1909.

34. Magnetometric Survey, Vertical Intensity: Lots 2 and 3, Concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, M.Sc., 1909.

35. Magnetometric Survey, Vertical Intensity: Lots 10, 11 and 12, Concession IX, and Lots 11 and 12, Concession VIII, Mayo township, Hastings county, Ontario—by Howells Fréchette, M.Sc., 1909.

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Magnetometric Survey of Huron Mountain mine, Timagami Forest Reserve, Ontario—by B. F. Haanel, B.Sc.

Magnetometric Survey of Lot 7 A, Range 5, Leeds township, Quebec—by B. F. Haanel, B.Sc.

Magnetometric Survey of Some Iron Ore Occurrences in British Columbia—by Einar Lindeman, M.E.

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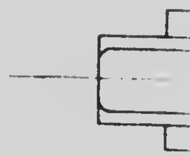

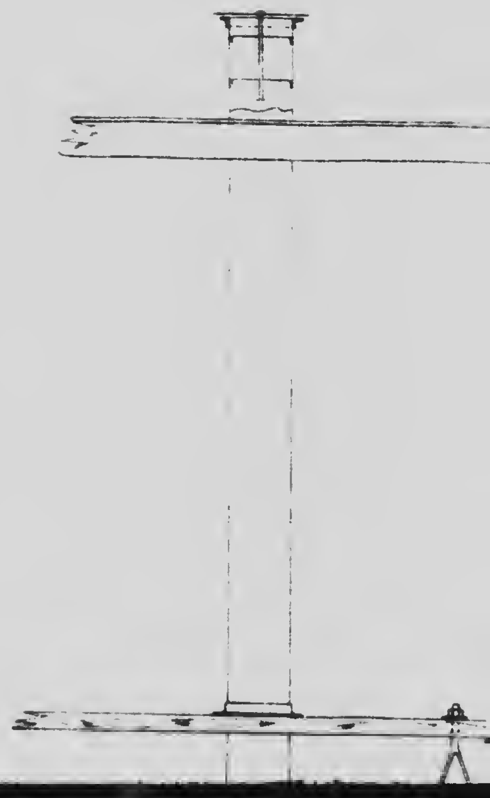

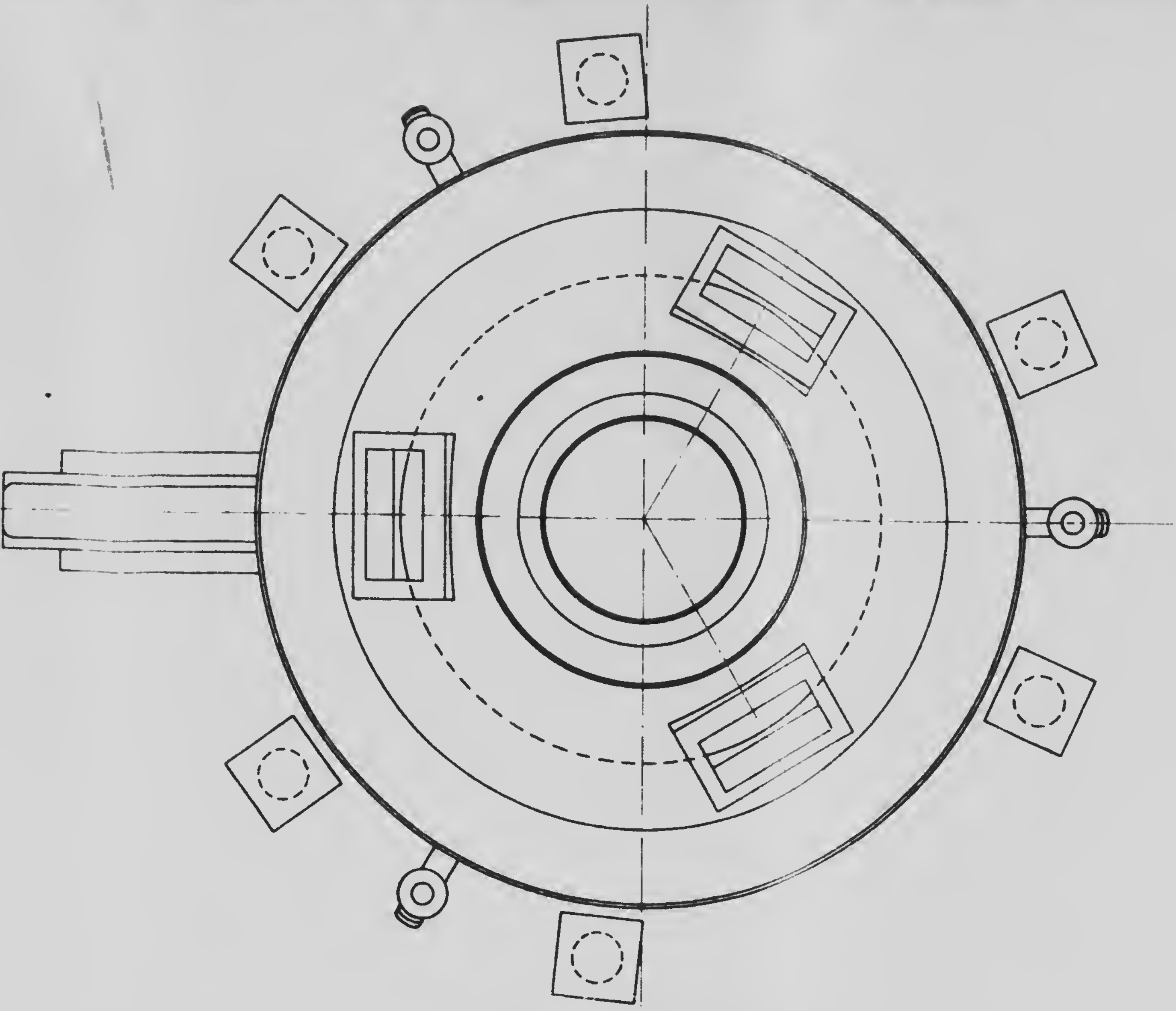

Plan: With Shaft and Electrodes removed

FIG. 5.—ELECTRIC SHAFT FURNACE.

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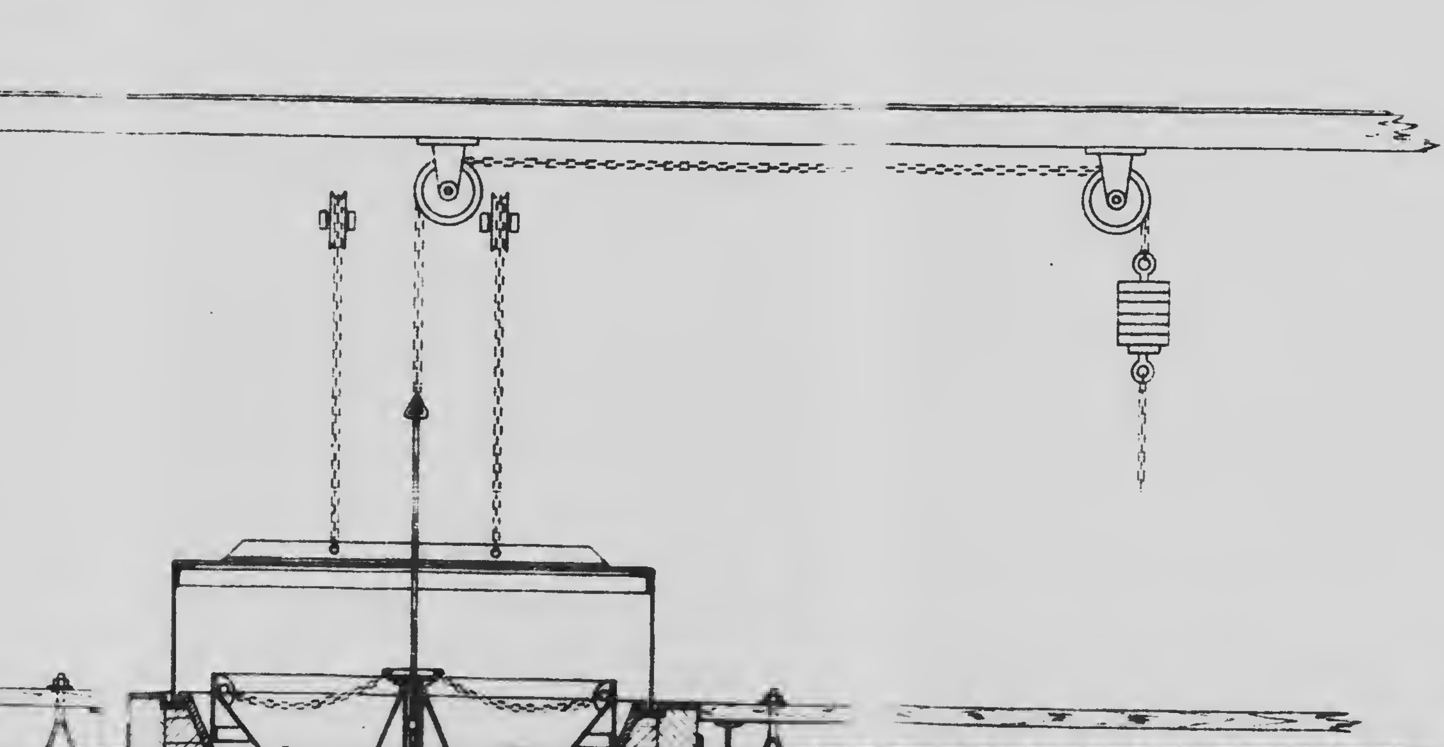
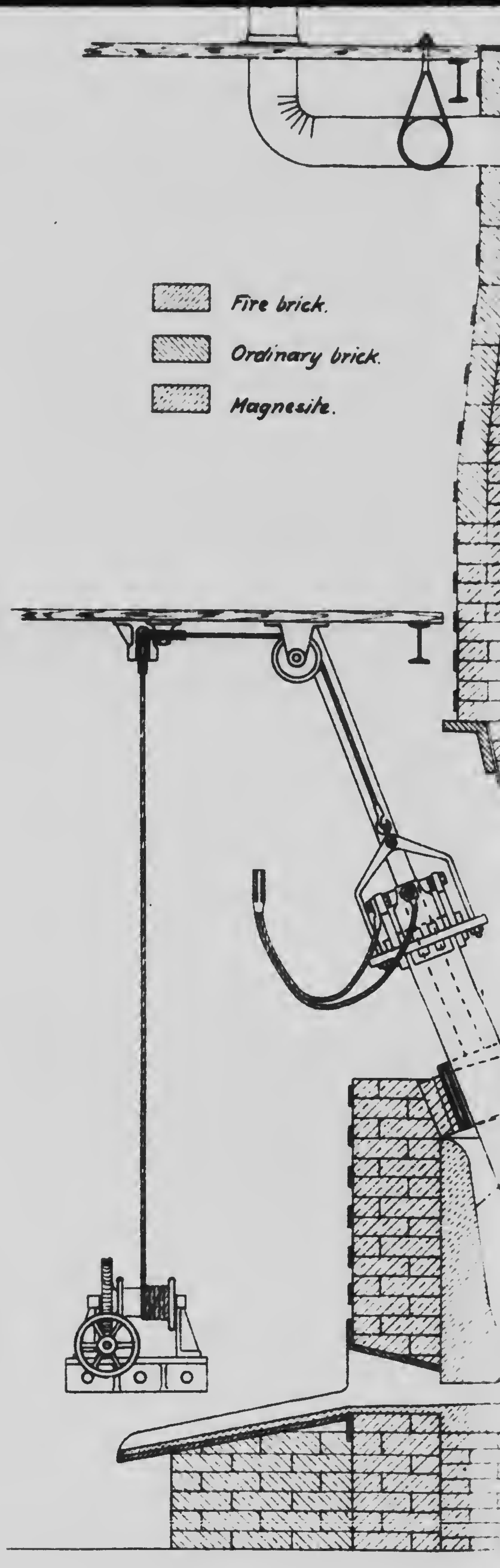
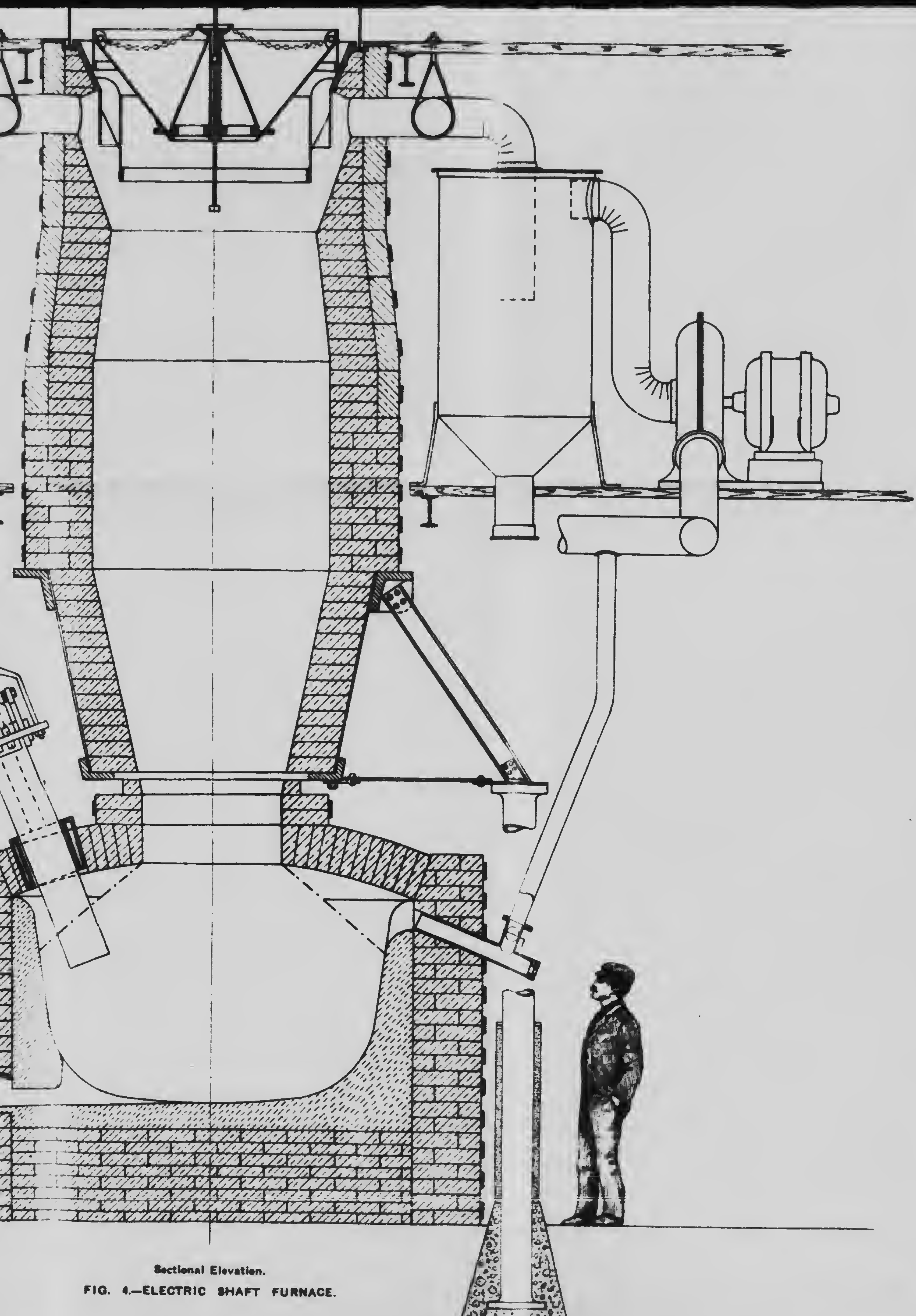



Fire brick.
Ordinary brick.
Magnesite.



Sectional Elevation.

FIG. 4.—ELECTRIC SHAFT FURNACE.