

(March 12th, 1906.)

## Electrical Smelting.

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Mr. President and Gentlemen,—The iron and steel industry is the foundation of our modern civilization. To enable us to appreciate our dependence upon steel and iron we need only ask ourselves what would be the state of affairs in the civilized world if that remarkable material which we name iron, and from which steel is produced, were swept from the face of the earth. Transportation, such as we know it, by land and sea would cease. The hum of the machinery of a thousand industries would be hushed. We would be deprived of the comforts and elegancies of life we now enjoy, and the civilization of the population in cities would become impossible. Indeed we could do better without either gold or silver than without this precious, though comparatively cheap, material, iron.

I think you will admit that the commercial status of a nation depends, to a very large extent, on the development of its iron and steel industries. I well recollect that the possession of an English-made jack-knife by a German school boy some fifty years ago rendered him an object of envy. To-day cutlery of all sorts, labelled "made in Germany," can be found in any hardware store in Canada, and Germany owes its prestige, so does the United States, to the remarkable development of its iron and steel industries, not to speak of England, which in this matter has been the pioneer.

Such names as Bessemer, Siemens, Thomas, Krupp and Carnegie will always be regarded as the chief agents in the commercial advancement of their respective nations. A country which requires to import its iron, the raw material of all industrial progress, you will readily grant is severely handicapped in the race for commercial pre-eminence. It is only when a country is able to manufacture commodities beyond its need that exportation and expansion of trade becomes possible. During the year 1903-1904 Canada imported pig iron in the crude and manufactured state to the amount of over \$43,000,000. These figures show to what extent we are at present dependent upon outside sources for a material which is necessary for every industry.

As regards Canada, which in these later days is being regarded as the Eldorado to absorb the overflow of the teeming populations of Europe, the need for iron will, in the near future, be enormously increased to provide the influx of settlers with tools and agricultural machinery, to furnish the material for our new railroads, the struc-

tural steel required in modern architecture and bridge building and the material necessary for the modification of established and the inauguration of new industries.

To stimulate and encourage the production of iron and steel from our abundant sources of raw material, the Government has offered generous bounties on pig iron produced in Canada and placed an export duty on articles manufactured from iron and steel.

Regarding the distribution of the raw material for the production of pig iron, the conditions of the country are, however, such that the necessary coking coal for blast furnace work is found only at the extreme east and west, while the large stretch of country intervening, occupied by the Provinces of Quebec, Ontario, Manitoba, Saskatchewan and Alberta, is without coal deposits capable of furnishing metallurgical coke, although extensive iron ore deposits occur in some of these Provinces, notably in Ontario and Quebec. If these deposits are to be utilized in the production of pig iron by the present methods of smelting, either coke must be brought to blast furnaces erected in the vicinity of these deposits, or the ore of these Provinces must be transported to blast furnaces erected near an abundant coal supply. In either case the transportation costs render such a course uneconomic.

When I assumed the duties of my present position this disability under which the last named Provinces were placed as regards the up-building of an iron and steel industry to furnish sufficient product for home consumption made a deep impression on me. It became evident to me that some other method of smelting in which some other source of energy than that resulting from the combustion of carbon in blast furnaces was needed to solve the problem, for unless such a new process could be proven to be practicable, the extensive ore deposits of these Provinces must remain to a large extent undeveloped and the regions which otherwise might be made to teem with an industrial population remain waste areas for many years to come.

Fortunately the necessity of profitably employing the electric plants erected in different parts on the continent, especially in France, for the production of carbide, which had to be closed down as unprofitable, furnished the incentive to invent methods for applying electric energy: first, to the production of the different ferros, and subsequently to the production of pig iron and steel.

In the solution of the problem of applying electric energy to the extraction of metals from their ores Captain Stassano in Italy and Heroult and Keller in France have rendered conspicuous service. The description of the experiments made by them and the results obtained attracted wide attention and were eagerly discussed in the scientific press, for it was at once seen that if by the electric process pig iron could be economically produced, such countries as Brazil, Chile, Sweden, Norway, Finland and Canada, all rich in iron ore deposits and the neces-

sary fluxes and possessing extensive water powers, but lacking coal, would be able to render themselves independent of outside sources by employing the electro-thermic processes for the manufacture of their iron and steel.

It was with a view of ascertaining the practicability of introducing electric smelting into Canada that the Honourable Mr. Sifton, then Minister of the Interior, appointed a commission to investigate this subject, results of which have been laid down in a special report.

The only experiments which the commission was able to witness in the electric smelting of iron ores were those made by Dr. Heroult at La Praz, France, and Mr. Keller, of Keller, Leleux and Company, at Livet. The first was a mere trial, the latter more extensive experiments continued for a number of days, but were made in furnaces not designed for the production of pig iron, but in furnaces which had been constructed for the production of ferro-silicon. The ore used in the Livet experiments had been imported for that purpose from Spain and was an excellent hematite, very porous, free from sulphur and containing a considerable percentage of manganese, consequently an ore easily treated in regard to sulphur and also easily reduced.

The output of pig iron per 1,000 electric horse power days was for one set of experiments equal to 5.76 tons, for the second set of experiments it was equal to 12.12 tons, but the iron made in this last experiment was mainly white iron. Mr. Harbord, the metallurgist of the commission, adopted as the probable output of 1,000 electric horse power days the mean of the two experiments, namely, 7.82 tons.

Not alone was this discrepancy between the two experiments very unsatisfactory regarding the absorption of electric energy required per ton of pig produced, but a number of points requiring determination for our Canadian ores, such as the successful smelting of magnetite, the utilization of iron ore of high sulphur content and the substitution of charcoal for coke required to be demonstrated.

As a matter of fact an experiment was made at Livet with the substitution of charcoal for coke, which proved an absolute failure, and it was assumed by Mr. Harbord and Mr. Keller that charcoal could be used only if it was first briquetted with the ore and the briquette broken up the size of one inch cubes.

Regarding the electric smelting of iron ores of high sulphur content Mr. Harbord states that the experiments cannot be said to have demonstrated that low sulphur pig iron can be obtained without manganese in the ore mixture and before this can be considered experimentally proved, it will be necessary to have a series of experiments made with non-manganiferous ores.

For the successful introduction of electric smelting of Canadian ores the following points which could not be settled by the European experiments required demonstration:

Can magnetite, which is our chief ore and which to some extent is a conductor of electricity, be successfully smelted?

Can iron ores with considerable sulphur content be made into pig iron of marketable composition?

Can charcoal, which can be made from mill refuse and other available sources of wood useless for other purposes, be substituted for coke which must be imported?

And lastly, what is the exact amount of electric energy required per ton of pig iron produced?

With a view of ascertaining these important facts experimentally, I prepared a memorandum to the Honourable Mr. Oliver, Minister of the Interior, recommending an appropriation for the investigation of the whole subject.

It was fortunate that Dr. Heroult, of La Praz, who had been the first to experiment on the subject of electric smelting of iron ores, happened at that time to be on a visit in Ottawa. He signified his consent, if the appropriation were made, to undertake the designing of a furnace of about 250 h.p. capacity and the investigation of the factors entering into the economic production of pig iron from Canadian ores by the electro-thermic process.

The Lake Superior Power Company, of Sault Ste. Marie, offered a building in which to erect the plant and the use of one of their alternators of 300 electric horse power capacity, free of expense for four months. It was decided to accept this offer and the plant was ordered to be erected in the building provided for this purpose.

The necessary transformer to transform the current down from 2,200 volts to about 40, such as was required for our experiments, and the necessary measuring instruments to determine the power consumed were ordered from the Westinghouse Company and electrodes 6 feet long and 16 inches square section were ordered from Sweden. The construction of bins, overhead work of the furnace, construction and erection of furnace and experimentation to adjust the capacity of the crucible of the furnace to the power available consumed the greater part of the fall and winter.

The experimentation on Canadian ores began in earnest about the middle of February, 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. For the first experiments the ores employed were hematite, such as used by the Algoma Steel Company in their blast furnaces; for the remainder of the experiments different classes of Canadian magnetite from different sources, all of high sulphur content, with the exception of the Wilbur magnetite, which was low in sulphur, were employed.

From theoretical grounds much difficulty was expected to be encountered in the smelting of magnetite. This can be best understood

by describing to you the construction of the furnace which, you will perceive, is exceedingly simple.

Imagine this glass to be the cylinder in which we boil the iron. It is lined with fire brick, the lower part being the carbon, to which is attached the cable. The centre prism is carbon and the charge surrounds the carbon. The current in passing through, thus, meets with the resistance and is turned into heat. The charcoal is the reducing material and the iron is melted to the bottom of the crucible. The regulation temperature is maintained by a man who looks after the instrument and moves the electrode, but this is only in the experimental stage. When it is put to commercial utility this regulation will be automatic.

But even the very first experiments with magnetite proved that our fears had been groundless and that magnetite could be smelted with as much facility as hematite and with an output equal to that of the best experiment made with hematite. Moreover, since it was important to substitute, if possible, charcoal, which can be cheaply produced in Canada, for coke, which is dear and which must be imported, the charges were made with charcoal. No difficulty was experienced whatsoever, the furnace working quietly and regularly, requiring little attention to the regulation of the electrode.

Analysis of the iron produced soon proved that although the slag was not particularly basic the sulphur could be caused to pass into the slag, resulting in a pig iron containing a few thousandths of a per cent. of sulphur.

In every instance the output was far greater—in several instances one-third greater than the figure adopted by Mr. Harbord in the report of the commission on electric smelting.

Upon the attainment of these remarkable results and the desulphurization due to the higher temperature available in the electric furnace over that of the blast furnace it was decided to experiment with the roasted and briquetted nickeliferous pyrrhotite, of which there were several thousand tons in stock in the yards. An analysis of these briquettes showed that they contained about 1.6 per cent. of sulphur. The experiments were entirely successful, furnishing a ferro-nickel pig containing  $4\frac{1}{2}$  per cent. of nickel and virtually free from sulphur, that is, containing only about six-thousandths of a per cent. The estimated value of this product is from \$40 to \$44 per ton. So successful have these experiments proven that the Lake Superior Power Corporation have decided to acquire the Government plant for the purpose of converting their stock of briquetted ore into marketable ferro-nickel pig.

One of the most important points in the investigation, which could not be successfully settled by the experiments at Livet, was the consumption of the electrodes and it was found that the consumption was beyond expectation small and that an electrode which had been in use for three weeks and during that time had been exposed to free air in

an incandescent state for many hours and had been used for melting down charges, which is always attended by waste of electrode without corresponding output in metal, that even with this severe test the consumption per ton of pig iron produced was between 15 and 20 pounds. Dr. Heroult states that by his process of manufacturing electrodes one pound would cost about one and a half cents, so that thirty cents would be a maximum outlay per ton of pig for electrode consumed, instead of seventy-seven cents as given in the commission's report.

The far-reaching consequences of the gratifying results achieved by these experiments will at once be apparent. Many of our magnetites are too high in sulphur to be handled by the blast furnace and consequently have so far been of no commercial value. But the very best of pig iron, as has been proven, can be made from ores which contain as high as seven per cent. of sulphur. A blast furnace will not usually handle an ore which contains more than one-tenth per cent. of sulphur and requires, therefore, an ore which cannot be got at a low figure. The Algoma Steel Works pays, I understand, \$4.50 for the hematite which they use in their blast furnaces. A pig iron equal in value and lower in sulphur content can be made by the electric process from sulphurous ores, which could be bought for \$1.25.

Regarding the water power required for the application of this process it may be stated that many water powers exist in Ontario surrounded by iron ore fields in localities ill-adapted for the application of electric energy for any other purpose and could be developed to furnish an electric horse power year from \$4.50 to \$6.00.

With such a price for the energy required, the small consumption of electrode, the cheapness of the ore employed and the peculiar excellence of the pig iron produced, electric smelting of iron ores in Canada, using charcoal or peat coke made from our peat bogs of enormous extent, may be pronounced a commercial success. Under the prevailing conditions in Canada it now only remains for the engineer to design a plant on a commercial scale, say of 100-150 tons daily output, with all the necessary labor saving appliances. Just as in the case of the blast furnace so likewise with the electric furnace, experience gained will result in further economy and the day may not be far distant when the carbon monoxide, product of the reaction taking place in the electric furnace is allowed to escape without utilization, will be employed for increasing the output by at least  $\frac{1}{3}$  if not  $\frac{1}{2}$ . If that should take place, the blast furnace could not compete with the electric furnace, even under condition where coke might be cheaper than at present quoted in Ontario and Quebec.

A further advantage of the electric process should be pointed out, in that the units employed are comparatively small and cheap of construction. A unit of 1,500 H. P. is perhaps the largest that under present circumstances should be constructed. Such a unit would have an output of about 18 tons per day and corresponds in size to about the larger Swedish

charcoal blast furnaces. With the present advance which has been made in the transference of electric energy batteries of electric furnaces could be set up at various iron ore deposits, which could be fed with electric energy from some centrally located water power, thus affecting a saving of the transportation costs of the ore from the mine to the furnace. When a deposit is worked out the furnace may be moved to the next deposit, simply lengthening the wires which carry the high tension current to the transformers of the plant. This method is especially applicable in the case of the many pocketty deposits of magnetite which occur in the Ottawa Valley.

The following is a summary of the results of the experiments which have been made under Government auspices at Sault Ste. Marie:—

1st. Canadian ores chiefly magnetite can be economically smelted by the electro-thermic process.

2nd. Ores of high sulphur content can be made into pig iron containing only a few thousands 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 and peat coke made from peat, of which there are abundant deposits in Ontario and Quebec, can be substituted for coke 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. Pyrite cinders, resulting from the roasting of pyrite in the manufacture of sulphuric acid and which at present constitute a waste product, can be smelted into pig iron by the electric process.

7th. Titaniferous iron ores containing up to five per cent. can be successfully treated by the electro-thermic process. This conclusion is based upon an experiment made with an ore containing 35 per cent. of titaniferous acid, yielding a pig iron of passable quality, judging from its fracture.

The results of the introduction of electric smelting into Canada may be summarized as follows:

1st. The utilization of our extensive water powers, which cannot at present be profitably employed for any other purpose.

2nd. The utilization of the large number of iron ore deposits, which on account of their high sulphur content cannot be treated by blast furnace methods and have so far been valueless. This is of extreme importance, for already the question has arisen, how long the present supply of blast furnace iron ore is likely to last and ores are now accepted by furnace men with a metallic content such as would not have been looked at a few years ago, and when these ores are exhausted and none but sulphurous ores or titaniferous ores are available, the stacks of the numerous blast furnaces, which have rendered such magnificent service to our

present civilization, will be silent and smokeless, having been supplanted by the electric furnace which can successfully treat an ore which the blast furnace cannot handle.

3rd. The utilization of our extensive peat bogs for the production of peat coke, to be used as reducing material for the operation of electric furnaces, and utilization of mill refuse and sawdust, for which there has so far been no practical use.

4th. Rendering Canada independent of fuel import for metallurgical processes.

5th. Enabling Canada to produce her own pig iron from her abundant sources for home consumption and consequently retaining in our own country the money which otherwise would have to be sent abroad to purchase pig iron in the crude and manufactured state.

6th. The development of steel plants and rolling mills using only electric energy.

Already, and it is only a year since the report of the Commission appointed to investigate the different electro-thermic processes for the smelting of iron ores and the making of steel in operation in Europe has been sent out to the public, a steel plant adopting Heroult's system has been erected in Syracuse, N.Y., and will be in operation in about two weeks; another using the Kjellin system has been erected in Sheffield, England, and I have been notified that two of the Kjellin system and one Heroult have been erected in Germany. These furnaces are designed to make the best crucible steel and their introduction means the abandonment of the old crucible process. I see no difficulty in the way of constructing electric furnaces of a capacity equal to that of our open hearth furnaces and the production of structural steel by the electric process is likely to become an accomplished fact in the near future.

I need not picture to you the future which opens a vista of commercial success for Canada by the inauguration of the new metallurgy of iron and steel, on account of the magnificent asset of her abundant supply of water power. I remember having delivered in Faraday Hall, Victoria University, Cobourg, shortly after the invention of the telephone, a lecture in which I tried to picture the results of the discoveries which had been made in the practical application of that wonderful agency we term electricity and while what I said seemed greatly to interest the audience, the outcome of the lecture was the pronouncement that certainly the lecturer possessed a brilliant imagination. But when I look back at what I said, how feebly and inadequately did I describe what might take place and the twenty years that have elapsed have shown a progress such as I could not have imagined, so much greater has been the final outcome than the feeble prophecy ventured by me to the audience on the occasion named. But in the matter of electric smelting we do not draw upon the imagination, but present to you hard facts and well established figures.

But to reap the benefit of the experiments made at Sault Ste. Marie means intelligent enterprise in the expenditure of capital. The Government has furnished you with facts on which to base a sound judgment as to the feasibility of commercially engaging in the manufacture of pig iron by the electric process; with that its duty to the nation is done, it remains for you business men to apply, perfect and profit.

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