BRITISH COLUMBIA
DEPARTMENT OF MINES

HON. WM. SLOAN, Minister.
R. F. TOLMIE, Deputy Minister. W. FLEET ROBERTSON, Provincial Mineralogist.
GEO. WILKINSON, Chief Inspector of Mines.

BULLETIN NO. 2, 1919

THE COMMERCIAL FEASIBILITY OF THE ELECTRIC SMELTING OF IRON ORES IN B.C.

BY
ALFRED STANSFIELD, D.Sc., A.R.S.M., F.R.S.C.,
Professor of Metallurgy,
McGill University.

PRINTED BY
AUTHORITY OF THE LEGISLATIVE ASSEMBLY.

VICTORIA, B.C.:
Printed by WILLIAM H. CULLIN, Printer to the King's Most Excellent Majesty,
1919.

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LETTER OF TRANSMITTAL.

The Honourable William Sloan,
Minister of Mines of the Province of British Columbia,
Victoria, B.C.

SIR,—After preliminary correspondence in January and February of the present year, I received a letter from Mr. Wm. Fleet Robertson, dated May 18th, in which he asked whether I could make an investigation of the feasibility of smelting your magnetite ores in electric furnaces, provided that certain information, such as the quantity, quality, and cost of the iron ores available, were furnished to me. I replied by telegram and letter of May 26th, offering to undertake the investigation, and received a telegram from Mr. Robertson, dated May 30th, instructing me to proceed with the investigation.

Mr. Robertson's telegram was confirmed by a letter dated June 20th from the Provincial Secretary, informing me that I had been appointed by His Honour the Lieutenant-Governor in Council to carry out the investigation; my appointment dating from June 5th.

I left Montreal on June 5th, reaching Victoria on June 10th, and devoted myself to the inquiry from that date until July 13th, when I left Vancouver for Montreal. This time was spent mostly in Victoria and Vancouver, but fourteen days were occupied in a visit to San Francisco and Heroult, California, for the purpose of ascertaining the progress that had been made in the electric smelting in that locality. I also visited Nanaimo, at your request, to inspect a process for the production of charcoal.

A supply of cheap electric power is an essential condition for the electric smelting of iron ores, and I made careful inquiries with regard to this. The power companies in Vancouver were unable, during my visit, to give me definite information on this point, but I understood that power could probably be provided at about $15 per electrical horse-power year; a price at which it seemed possible that electric smelting could be undertaken commercially.

On this understanding I made a thorough investigation of the other elements of cost and of the most efficient methods for smelting iron ores under the conditions existing in British Columbia, and came to the conclusion that electric smelting would be possible under these conditions.

On September 19th, when my report was nearing completion, I received a letter informing me that the charges for electric power would be nearly twice the figure I had assumed in my calculations. This change not only alters very greatly the cost of pig-iron obtained by electric smelting, but has caused a radical alteration of the character of my report. Under this changed condition the electric smelting of iron ores by existing methods is scarcely possible, and the only remaining opening, unless cheaper power can be obtained, is by developing a new process, which has lately come to my notice, and which appears to be more economical than the usual methods of electric smelting. The possibility of the electric smelting of iron ores in British Columbia, using power from the present sources of supply, would seem to depend on the successful development of this new process.

I beg to submit herewith the report of my investigation.

I have the honour to be,
Sir,
Your obedient servant,
ALFRED STANSFIELD.

McGill University, Montreal, November 11th, 1918.

INTRODUCTORY.

EXTRACTS FROM CORRESPONDENCE RELATIVE TO THE INVESTIGATION.

DEPARTMENT OF MINES,
OFFICE OF PROVINCIAL MINERALOGIST,
VICTORIA, B.C., May 18th, 1918.

Dr. Alfred Stansfield,
McGill University, Montreal, P.Q.

DEAR DR. STANSFIELD,—I am instructed by the Honourable the Minister of Mines, the Hon. William Sloan, to say that at last matters have come round so that he can see his way to go ahead with the investigation of the commercial feasibility of the smelting of our magnetites in an electrical furnace, and he has asked me to find out if you are still open to engagement for such purpose this summer.

His idea is that we can provide you with all requisite data as to quantity and quality of ores available, costs of delivering same at any given point, all analyses of ores and fluxes, cost of labour by day, etc., fuel, quality, and costs.

On this data, so provided you, you could base your calculations and conclusions, and your responsibility would not extend back of the data so provided.

You would further not be required to go into the question of market. It seems to me that this would greatly lessen the work expected of you and your responsibility, taking much less time.

If you are still open to make investigation, I would be obliged if you would telegraph the Minister or myself to that effect. . . . It would, of course, be very desirable that you came out here and looked over the ground for yourself and indicated to us in advance just the data you would require to be provided with.

I am,
Yours very truly,
(Signed.) WM. FLEET ROBERTSON,
Provincial Mineralogist.

DEPARTMENT OF METALLURGY,
MCGILL UNIVERSITY, May 26th, 1918.

William Fleet Robertson, Esq.,
Provincial Mineralogist, Victoria, B.C.

DEAR MR. ROBERTSON,—I am much obliged for your letter of the 18th, which reached me on Saturday morning, the 25th. . . . . I consider that on the basis outlined in your letter I could make a satisfactory report to the Government on the feasibility of smelting the British Columbia magnetites in electrical furnaces. . . .

I expect to be in New York on June 1st, but I could leave Montreal for the West on the 3rd, and suppose that I should go in the first place to Victoria to confer with yourself and others having information bearing on the subject, to collect all the information available at that point and perhaps to visit some probable location for the smelter.

I have been making inquiries with regard to the progress of the electric smelting of iron ores by the Noble Electric Steel Company at Heroult, California, and learn that this has been given up and that the plant is now used for the production of ferro alloys. I am informed that the smelting of iron ores in California has never been commercially successful, due to unsatisfactory commercial conditions. In view of this, it appears to me that most valuable information could be gained if the Government could obtain permission for me to visit and inspect the plant, and to discuss with the management the reasons which led to their want of success. . . .

In a general way I can state in advance:—

(1.) It is unlikely that the electric furnace can be operated in British Columbia, under normal conditions, in competition with the blast-furnace for the production of tonnage iron.

(2.) Conditionally on there being available a sufficient amount of cheap electric power, pure iron ore and charcoal, a moderate output of high-grade iron could probably be made at a profit under normal conditions.

(3.) Under present prices it is possible that ordinary grades of iron could be made at a profit.

It may therefore be that a plant could be started to produce the various grades of iron needed at present, and that later, when the price of iron comes down again, the whole production could be put into special-quality iron.

I may add that I have learned recently of a new process which may have an important effect on the electric smelting of iron ores. . . .

I remain,

Yours very truly,

(Signed.) ALFRED STANSFIELD.

AN ACCOUNT OF THE INVESTIGATION.

On my arrival in Victoria on June 10th, I was met by Mr. Wm. Fleet Robertson, and on the following day I had an interview with yourself with regard to the scope of the investigation.

While in Victoria Mr. Robertson and Mr. William Brewer furnished me with information for my report, chiefly with regard to the amount and nature of the available deposits of iron ore, and the probable cost of mining these ores and shipping them to a point at which a smelter could be located. Mr. Robertson also obtained for me a memorandum from the Department of Labour with regard to the supply, nature, and cost of labour in British Columbia. I have consulted Mr. Robertson with regard to the greater part of the investigation, and he has assisted me throughout in obtaining the information needed for my report.

With respect to the supply of electrical power, I had interviews with Mr. J. F. Halls, Mr. Eastman, and other officials of the British Columbia Electric Railway Company in Victoria, and later, in Vancouver, with Mr. George Kidd, General Manager of this company, and Mr. R. F. Hayward, General Manager of the Western Electric Power Company of Canada. I also met Mr. J. M. Savage and Mr. Thomas Graham, of the Canadian Collieries, Limited, with regard to electric power at Comox. Before leaving the Coast I consulted Mr. William Young, Comptroller of Water Rights, and Mr. H. K. Dutcher, of Vancouver, with regard to undeveloped water-powers of British Columbia and the cost of obtaining from them a supply of electric power for smelting.

In Vancouver I met Mr. Giles, General Manager of the Vancouver Engineering Works, and discussed with him the requirements of the district in respect of pig-iron and steel. I attended a meeting of the Vancouver Metal Trades Association, and met Mr. A. B. Weeks, General Manager of the Canadian North-west Steel Company, Mr. G. G. Bushby, and Mr. J. Hart, the Secretary of the Metal Trades Association. I called upon and corresponded with Mr. Nichol Thompson with regard to the supply of iron ores and coal and the local markets for pig-iron and steel. I had an interview with Mr. Murray, of Messrs. Evans, Coleman & Evans, in regard to the consumption and price of pig-iron and steel in Vancouver and district.

I met Mr. R. H. Tudhope, Mr. G. R. Grant, and Mr. Renton, of the Turnbull & Tudhope Engineering Syndicate, and visited their plant at Port Moody, where pig-iron was being made from steel scrap in an electric furnace. I obtained from these gentlemen valuable information in regard to the operation of electric furnaces in the district, and have also corresponded with Mr. Turnbull on this subject.

With a view to obtaining a supply of charcoal, I had interviews with Dr. J. R. Davidson, of the University of British Columbia, and visited with him a Vancouver sawmill and the charcoal plant of the Electric Turpentine Syndicate. I also interviewed Mr. Walter Thomas and his partner in Vancouver in regard to his processes for making charcoal, and visited, with Mr. Thomas and Mr. Brewer, the experimental plant at Nanaimo, where Mr. Thomas's process for coking coals has been tested. I also consulted Mr. Tudhope, Mr. Grant, and Mr. Herbert Carmichael in regard to the production of charcoal. While in Victoria I called on Mr. L. B. Beale, of the Forestry Department, with reference to the supply of timber for charcoal-making, and since returning to Montreal I have obtained information and other assistance from Dr. Bates, Superintendent of the Forest Products Laboratories, and have myself prepared some charcoal from a sample of Douglas fir.

I visited San Francisco in order to meet the Noble Electric Steel Company. I saw Mr. H. H. Noble, the President, and also Mr. W. H. French, the Vice-President, with whom I visited the company's plant at Heroult, in Shasta County. While in San Francisco I met Mr. J. W. Beckman and Mr. H. E. Linden, of the Beckman & Linden Engineering Corporation, and visited an electric-smelting plant at Bay Point, California, which has been erected and operated by that corporation for the Pacific Electro Metals Company. Messrs. Beckman and Linden have supplied me with an estimate of the cost of constructing and operating a similar plant arranged for the electric smelting of iron ores.

The B. L. Thane Construction Company, of San Francisco, have made a very extensive investigation of the supplies of iron ore and coking-coal on the Pacific Coast with a view to the establishment of a large iron and steel plant. Mr. Thane and Mr. F. B. Hyder very generously put at my disposal a large amount of information on this subject. I am also indebted to Mr. T. A. Rickard, Editor of the *Mining and Scientific Press*, and to Dr. L. H. Duschak, of the United States Bureau of Mines, whom I met in Berkeley, California, and to Mr. W. van Winkle, of San Francisco, for important help in my inquiry. While at Heroult I met Dr. Trood and Mr. W. A. Darrah and learned of their work on the reduction of iron ores.

Mr. R. H. Stewart, of Vancouver, helped me in regard to the engineering aspects of the report and furnished me with certain cost data in respect to the construction of an electric smelting plant in British Columbia. I am indebted to Professor E. T. Hodge, of the University of British Columbia, and to Mr. E. A. Haggan, Editor of the *Engineering and Mining Record*, for assistance in my inquiry.

In San Francisco I met Mr. Davis and Mr. M. H. Schnapp, of the General Electric Company. In Vancouver I met Mr. H. Pim, Manager of the Vancouver office of the Canadian General Electric Company, and I have corresponded with their head office in regard to electrical equipment.

I wish to express my indebtedness to all the gentlemen named above as well as to some others who have helped me in obtaining the very varied lines of information that are essential for the preparation of even a preliminary report on so complex and difficult a subject.

After concluding my investigation on the Coast, I left Vancouver on July 13th, arriving in Montreal on the 18th. Since that time I have been occupied with the preparation of my report.

While in British Columbia I endeavoured to obtain from the power companies some definite assurance with regard to the price at which power could be supplied to an electric-smelting plant. It was not, however, until September 19th, when my report was nearing completion, that I received a letter containing the terms on which power could be obtained.

INTRODUCTION TO THE REPORT.

The object of this investigation and report is to determine the commercial feasibility of smelting electrically the magnetite ores of British Columbia.

For this purpose I obtained information with regard to the supply of iron ores, electrical power, charcoal, labour, and other necessaries.

Early in the investigation it appeared that electric power might be obtained at such a price that electric smelting by the methods now in use would be commercially possible. I therefore investigated and discussed carefully the type of furnace and design of plant that would best suit the local requirements, and prepared estimates for the cost of such a plant and of making pig-iron on a scale determined by the present requirements of the Province. It now appears that electric power cannot, at present, be obtained at prices that will permit of the use of the usual electric smelting methods; but I am presenting the results of my investigation along these lines because they are needed to show that the process described would be too costly with power at this higher price, and because it is possible that, in the future, power may be available at a lower price, which would then permit of operations being undertaken.

In view of the very high price asked for electric power, I have paid special attention to a new process for producing electric furnace iron which offers possibilities of a decided economy as compared with standard methods. I have presented the available information and made estimates of the cost at which iron may possibly be smelted by these means.

The whole investigation is necessarily very extensive, and it is a matter of some difficulty even to present the results in a clear and simple manner, especially as each conclusion arrived at is dependent on a number of factors which cannot be stated in a few words, and many of which are liable to change. The information obtained is set forth and discussed in detail in a number of Appendices; while the conclusions arrived at are presented as concisely as possible in the following report.

ELECTRIC SMELTING OF IRON ORE.

This has passed the experimental stage and is in operation commercially on a large scale in Sweden and elsewhere. The product of this operation is a special quality of high-grade iron which commands a higher price than ordinary blast-furnace iron, and the cost of production is in general too high to allow of competition at equal prices with the blast-furnace product. Carbonaceous material is needed, even in electric furnaces, for reducing the iron ore to metal, and for this purpose charcoal is preferable and is generally used. The electric furnace that has been adopted for the commercial smelting of pig-iron is that of Messrs. Electro-Metals, Limited, of Sweden, which may be regarded as the standard. The pig-iron normally produced from this furnace, although unusually pure and commanding a high price, is a white or low-silicon iron, unsuitable for use in the iron-foundry. The officials of the Swedish company consider that a foundry iron can be made by these furnaces, though at a somewhat higher cost, but I have no evidence that this has been accomplished in regular commercial practice, and the Noble Electric Steel Company, which smelted iron ores electrically for several years at Heroult, in California, was obliged to adopt a different type of furnace for the production of foundry iron. I consider, however, that the Electro-Metals furnace could be used for this purpose because any low-silicon iron could be made suitable for foundry use by additions of ferro-silicon; but considerations which will determine the best type of furnace for use in British Columbia are given later in the report.

FACILITIES FOR ELECTRIC SMELTING IN BRITISH COLUMBIA.

The essential conditions for the electric smelting of iron ores on a commercial scale are: A supply of high-grade ores at a reasonable price, an ample supply of cheap electric power, a supply of charcoal or other fuel at a moderate price, a supply of labour at a moderate price, a suitable location for the smelting plant, and a sufficient market for the resulting iron at a rather high price. The situation in British Columbia may be considered under these separate heads as follows:—

Iron Ores.

The information furnished to me by your officials shows that the iron-ore deposits of the Province have not been opened up to any extent, but that it is safe to assume that adequate supplies of ore of reasonable richness and purity can be obtained at easily accessible points. These ores are chiefly magnetites, and on this account are undesirable for use in the blast-furnace except in admixture with other ores; magnetites are, however, quite suitable for treatment in the electric furnace. It appears that the ores are not of very high grade, but that a supply may be expected to contain from 50 to 55 per cent. of iron. The ores are practically free from phosphorus and titanium, and the proportion of sulphur can probably be kept as low as 0.1 per cent. The ores under consideration are also practically free from copper. Your officials estimate that a supply of 50,000 tons per annum of ore of this grade can be delivered at a suitable smelter-site at a cost, under present conditions, of about $4 per net ton, which would be made up as follows:—

Mining	$1.50 to $2.00
Loading or tramming	.15 to .25
Freight (by water)	1.00 to 1.50
Unloading	25 cents
Royalty to owner*	50 cents
Total cost at smelter	$3.96 to $4.10

From the information at my disposal, I feel satisfied that these ores can be smelted electrically for the production of a high-grade pig-iron. For the production of one long ton†

* Using a royalty in this estimate removes the need of considering the purchase of an iron-mine.

† *Long and Short Tons.*—Pig-iron is sold by the long or gross ton of 2,240 lb. not only in England and Canada, but in the United States, and I have conformed with this custom in my report. The supplies needed for smelting, such as iron ore, charcoal, coal, and coke, are sold in British Columbia by the short or net ton of 2,000 lb., and the use of this dual system has necessarily complicated the calculations in this report. The situation is further complicated because, in Government reports, pig-iron is estimated by the short ton, and in regard to pig--iron quotations in British Columbia it is sometimes difficult to say which ton is intended. In sweden a more consistent system is followed, as the pig-iron and all the necessary supplies are measured by the metric ton of 1,000 kilograms, or 2,204 lb. This ton, which may be assumed in all statements of the Electro-Metals Company of that country, can be taken without serious error to be the same as the long ton.

of pig-iron about 2 net tons of 55-per-cent. ore would be needed, so that the ore would cost $8 per long ton of pig-iron. In view of the somewhat low grade of the ore, the cost of smelting per ton of product will be rather higher than is usual with the Swedish ores, but this may perhaps be remedied by the use of magnetic concentration.

ELECTRIC POWER.

British Columbia is well provided with water-powers, and many of these can be developed cheaply for the use of electric-smelting and similar industries. Competent engineers have assured me that some of these powers in accessible locations can be developed at such a cost as to yield a continuous electrical horse-power for smelting at a cost of $10 per annum. This figure is not much higher than obtains in Sweden, and if a dependable supply of power can be secured at this rate it seems almost certain that an electric-smelting industry can be undertaken profitably. The consumption of power, under conditions obtaining in British Columbia, would be between 0.4 and 0.5 of a horse-power year per ton of iron produced; so that the cost for power should be between $4 and $5 per long ton of pig-iron. Some 8,000 or 9,000 horse-power would be needed for a daily production of 50 tons of pig-iron.

In view of the desirability of producing pig-iron at the earliest possible time, and of the difficulty and expense attending the development of water-powers under present conditions, it is highly desirable, if not imperative, that an electric-smelting industry shall be supplied, in the first place, from powers that are already developed. The British Columbia Electric Railway Company has surplus power which might be employed for this purpose, and I gathered from the officials of this company that they could possibly supply such power at $15 per horse-power year, a charge which appeared to me to be the highest that the industry could support. Under these conditions the cost for power per ton of pig-iron would be between $6 and $7.50.

Since returning to Montreal I have received a letter, dated September 12th, from the general manager of this company, informing me that conditions have changed since my visit, and that they would now have to charge higher rates. They would be willing to make short-term contracts for from 2,000 kw. to 10,000 kw. of electric power in Vancouver District for restricted service during the peak-load periods at a rate of 0.5 cent per kilowatt-hour. This charge would amount in effect to at least $27.80 per horse-power year and would represent a charge of from $11 to $14 per ton of iron. They would also offer 2,000 kw. of power on Vancouver Island at $15 per horse-power year for a short term and subject to peak-load restriction. The proposed charge in Vancouver is, I believe, altogether too high to allow of the commercial production of pig-iron by present methods, except perhaps on a small scale as a temporary operation to take advantage of the present high price of pig-iron. The supply on Vancouver Island, besides its uncertainty, is too small to permit of profitable operation.

CHARCOAL AND COKE FOR REDUCTION.

For the electric smelting of iron ores a supply of carbonaceous material is needed for reducing the iron ore to metal. For this purpose charcoal is generally used, although coke is employed to some extent. Charcoal is preferable to coke on account of its greater purity, as a higher grade of pig-iron can be obtained by its use. The use of charcoal is more satisfactory also from an operating point of view, and the consumption of power is greater when coke is employed; a proportion of coke can, however, be used without difficulty in admixture with charcoal. The consumption of charcoal varies with the grade of iron required, and the type of furnace employed, from about 0.4 to 0.5 net tons of charcoal per long ton of pig-iron, so that 20 or 25 tons of charcoal would be needed daily for an output of 50 tons of pig.

In the Coast districts of British Columbia there is an abundant supply of timber from which charcoal can be made suitable for use in electric smelting. At present there is no considerable charcoal industry, and the small quantities now obtainable cost as much as $30 per ton, a figure which would be prohibitive for the electric smelting of iron ores. In view, however, of the large amount of waste wood produced at some of the large sawmills, it appears reasonable to suppose that a well-designed charring plant can be erected that would utilize this waste material and deliver charcoal to the smelter at a cost of from $6 to $8 per net ton; estimated on the following basis:—

2½ cords of Douglas fir mill-waste	$2 50
Cost of charring, less returns for by-products	2 50
Carriage of charcoal to smelter	1 00
Total	$6 00

The charge per ton of iron would thus be between $2.40 and $4.

With regard to the method to be employed, it may be stated briefly that the Douglas fir, which would probably constitute the staple supply for charcoal-making, does not furnish by-products of suitable quality and quantity to warrant the use of elaborate methods for their recovery. Charcoal should therefore be made in large kilns, or in some appliance which might be devised to char the wood-waste with the minimum amount of hand-labour; in either case a partial recovery of by-products could be made at a moderate expense.

It does not appear that coke can be produced from British Columbia coals at a price that would be as low as that of charcoal; and unless the coke was decidedly the cheaper per ton it would be more economical to use charcoal. Coke breeze, however, can probably be obtained for a very nominal charge, and can be used in admixture with charcoal in cases where extreme purity of the pig-iron is not desired.

Labour.

The Department of Labour has furnished me with a statement of the supply, nature, and cost of labour in British Columbia, from which it appears that labourers are fairly plentiful and receive nearly $4 a day, and that most skilled men are scarce at about $6 a day. The cost of labour per ton of product will depend very largely on the size and output of the plant and the nature of its equipment; but it appears that in a fully equipped plant making about 50 tons of pig-iron daily, besides steel and ferro-alloys, the cost of labour might be from $4 to $5 per ton of iron; although in the initial stages the labour cost would certainly be higher, perhaps in the order of $7 per ton of iron. The manner in which these figures are arrived at is stated in the Appendices.

Location for Smelting Plant.

A plant for the electric smelting of iron ores should be conveniently situated with respect to the supplies of ore, charcoal, and other requirements; it should also permit of cheap delivery of the iron and other products to market. The plant must be placed as close as is convenient to the source of electric power, so as to lessen the cost of transmission. When a satisfactory supply of power has been secured, it will doubtless be possible to obtain a smelter-site within a reasonable distance of the power-station and located on tide-water, so as to provide for cheap delivery of supplies and products. A plant located near a centre of population, such as Vancouver, would have advantages with respect to labour and general supplies and nearness to markets, but the provision of an adequate and cheap supply of electric power, iron ore, and charcoal should be the determining consideration.

Market for Pig-iron.

For the purpose of this report I have limited my investigation to the market in British Columbia itself, though a moderate export market may be developed later. The present consumption of pig-iron is only about 10 tons daily, but it appears that the consumption has been seriously limited by the extremely high prices now ruling, and that if a supply of iron becomes available at a moderate price a consumption of 20 or 30 tons may be expected. This amount is too small to permit of economical operation, and I would therefore recommend, if a suitable supply of electric power can be obtained, that a plant be constructed to produce, say, 25 tons daily of foundry iron for sale and a further 25 or 30 tons of low-silicon iron for conversion into steel. I have not investigated the market for steel in any detail, but apparently a sufficient market for this product could be found.

The prices of foundry iron in Vancouver have varied recently from about $60 to $80 per long ton. Before the war the price was around $25. It seems unlikely that the price for good foundry iron will fall much below $35 a long ton during the next few years. In most localities electric smelting depends for its commercial possibility on obtaining for its product a higher price than that of ordinary foundry iron. I find that at present there is scarcely any demand

in British Columbia for such special grades of iron, but there can be no doubt that they will be needed in the future, as the iron and steel industry develops.

FOREIGN COMPETITION.

The market prices already mentioned as obtaining in British Columbia are based on the present sources of supply from Eastern points in Canada and the United States. It is possible that an iron blast-furnace plant may be established on the Pacific Coast of the United States, and the effect of this on the market in British Columbia must be considered. It appears that pig-iron could be made in such a plant at a cost of about $25 per long ton under present conditions. The duty on pig-iron entering Canada from the States is $2.80 per long ton plus 7½ per cent. *ad valorem*, which at a sale price of $30 per ton would amount to $2.25 per long ton, or a total charge of about $5. This duty, together with the freight charge and the Canadian bounty, would place the electric-furnace iron, if made with $15 power, on an equality with imported blast-furnace iron. This would not hold, however, in the case of iron imported for war-work, as this is duty free, and after the war the duty of 7½ per cent. *ad valorem* will no doubt be removed. In this connection it may be added that a large iron and steel plant can scarcely be built until some years after the war, so that an electric-furnace plant, if constructed promptly, would command the market for a number of years. Ultimately, blast-furnace iron may be expected to take a part at least of the market for common grades of iron, but the electric furnace should always be able to command a small market for its higher grade of iron.

ARRANGEMENT WITH THE DOMINION GOVERNMENT.

A deputation from British Columbia went to Ottawa early in the present year, seeking for aid to develop an iron industry in British Columbia. In answer to their request, the Dominion Government undertook for a period of years to purchase, if necessary, at market prices, the whole output of a plant making pig-iron in British Columbia. Your Department was unable at the time of my visit to give me the exact text and meaning of the arrangement, but was to obtain further information from Ottawa. This agreement will no doubt apply equally to electric-furnace iron, but it does not appear to me that it is likely to help matters materially, for the following reasons:—

(1.) The offer is obviously of no use if the price referred to is that obtaining in Eastern Canada, as iron could not be made at that price.

(2.) If the price intended is the local price in British Columbia, we are met with the difficulty that the Government's ability to carry out the undertaking would be limited to the local demand for iron, as it would be impossible for it to buy expensive iron in British Columbia and ship it to lower-priced markets elsewhere. We are thus limited to the natural market for iron and steel in British Columbia and to possibilities for exportation on a small scale.

BOUNTIES AND TAXES.

The Provincial Government has offered a bounty of $3 per net ton of pig-iron made in British Columbia from local ores, and, on the other hand, imposes a tax of 37½ cents per net ton of iron ore mined. The combined effect of these measures will be a payment of about $2.60 per gross ton of pig-iron; a source of income which will be of some importance, and may sometimes make the difference between operating at a loss and at a profit.

TYPE OF FURNACE TO USE FOR ELECTRIC IRON-SMELTING.

A point of considerable importance to this investigation is the determination of the most suitable type of electric furnace. This is important not only for the guidance of those who may undertake the establishment of an electric-smelting plant in British Columbia, but also in order to arrive at reasonably accurate figures for the cost of the plant and the cost per ton of the products. In outline the situation is substantially as follows:—

(1.) In Sweden the firm of Electro-Metals (of Ludvika and London) has developed a type of electric-smelting furnace which has proved very satisfactory for the production of low-silicon pig-iron from the Swedish ores. There are now seventeen of these furnaces at work in Sweden, ranging in size from 2,000 kw. to 5,000 kw., and a few in Norway, Switzerland, and Japan. This is, as far as I am aware, the only type of electric furnace that has ever attained commercial success in the production of pig-iron from iron ores.

The furnace is circular in plan and is provided with a tall stack, in which the ore is preheated and partially reduced before it enters the smelting-chamber. This reduction of the ore is aided by a mechanical circulation of the furnace gases, which are withdrawn from the top of the shaft, freed from dust, and then blown through tuyeres into the smelting-chamber above the ore. The gases become heated at this point, and passing up the shaft they heat and reduce the ore. The circulation of the gases also serves to cool and protect the arch of the smelting-chamber, but, on the other hand, it increases slightly the consumption of the electrodes.

On account of these special features the Electro-Metals furnace uses somewhat less charcoal than a simpler type of furnace, a difference of, say, one-tenth ton per ton of pig-iron, and it is believed to use less power. The saving in charcoal is probably more than offset by the need of a better quality of charcoal, which is rendered necessary by the use of a tall shaft. It must be noted, however, that the usual product of the Electro-Metals furnace is a white pig-iron suitable for chilled castings or for steel-making, while the need in British Columbia would be largely for a foundry iron. There does not appear to be any evidence that the Swedish furnaces have been used regularly for the production of foundry iron, and there seems to be some doubt regarding their suitability for this purpose.

(2.) An independent development of electric iron-smelting took place at Heroult, Shasta County, California, where a deposit of very pure magnetite has been smelted electrically by the Noble Electric Steel Company for the production of foundry iron. Operations were started in 1907 by the late Dr. Heroult, who built a simple rectangular furnace having an arched roof, and ore-chutes in which the charge could be preheated. As this furnace did not prove satisfactory, a shaft-furnace of the Swedish type was tried. This was also unsatisfactory, and the management reverted to the rectangular type with arched roof and with charging-chutes, in which, however, the ore was not preheated. It was claimed at the time (1913) that success had been obtained with this furnace, but nothing further was published about it, and I find that its use was discontinued about four years ago. The plant is at present employed solely for the production of ferro-alloys, because the price now charged for electric power, the cost of charcoal, and the cost of transportation are all so high as to render impossible the commercial production of pig-iron. I am of the opinion that we cannot accept the work at Heroult as an argument for or against the type of furnace that was used there.

(3.) Another furnace of the closed rectangular type was devised by Helfenstein for the production of calcium carbide and ferro-silicon. A Helfenstein furnace for smelting iron ores was being tried at Domnarfvet, in Sweden, at the time of my visit in 1914. At that time the management was unwilling to give any information about its operation. An account published a year or two later stated that this furnace was working satisfactorily, but Messrs. Electro-Metals now inform me that "the furnace was found quite useless and has been pulled out."

(4.) For the production of ferro-silicon, ferro-manganese, and calcium carbide a simple rectangular open-topped furnace has been developed, and is in use at many places. In this furnace no attempt is made to preheat the ore, and the gases produced in the furnace escape and are lost, besides creating a nuisance by burning above the furnace. On the other hand, the furnace is easy to build, simple to operate, and is probably not far inferior to the Swedish furnace in commercial efficiency. I am not aware that this furnace has been used commercially for making pig iron, but there can be no doubt that pig iron of any desired variety could be made in it. The Beckman and Linden Engineering Corporation of San Francisco, who are using it for ferro-manganese, consider that it would be preferable to the Swedish furnace for making pig iron, and that it would be little if any inferior in point of economy.

Conclusions.—(1.) If a permanent smelting plant were being erected, the Swedish type of furnace would be selected, because it is more economical than any other at present in use, and is the only one that has been employed commercially.

(2.) If a temporary plant is contemplated, it may be better to install the open-pit furnace, on account of its smaller first cost and the ease with which it could be converted to other uses.

(3.) Information should be obtained with regard to the iron-ore reduction process of Trood and Darrah, as this may prove superior to any direct smelting process. If this process is likely to be available, it will be best in the meantime to use a simple pit-furnace rather than to install the more elaborate Swedish furnace.

Further particulars in regard to the two types of furnace will be found in Appendix VIII.

COST OF PRODUCTION.

In order to arrive at an approximate estimate of the cost of smelting iron ores, it is necessary, in the first place, to decide upon the scale of operation. In view of the local market and other considerations, which I discuss elsewhere, I suggest the following equipment as being suitable for an electric-smelting plant in British Columbia, providing that the usual electric-smelting methods are adopted:—

OUTLINE OF PLANT.

One electric-smelting furnace of 3,000 kw., making daily about 25 tons of foundry iron for sale.

One electric-smelting furnace of 3,000 kw., making about 30 tons of low-silicon iron for conversion into steel.

Three electric furnaces of 300 kw. each, making together about 3 tons of ferro-alloys.

Two electric steel furnaces of 1,500 kw. each, making together about 50 tons of steel.

Steel foundry and rolling-mill using 50 tons of steel daily.

COST OF PLANT.

The design and cost of such a plant is discussed in the Appendix. As, however, it would be very difficult to use so complicated a plant as a basis for estimating cost of making pig-iron, I shall consider for this purpose a plant of about equal size devoted entirely to the production of foundry iron. In so doing I am making the assumption, which will not be very far wrong, that the cost of making pig-iron in the simple plant will afford a fairly correct idea of the cost of making it in the complex plant, outlined above, which would be suited to the local requirements.

The simple plant, assumed for purposes of calculation only, would consist of three electric-smelting furnaces of 3,000 kw. each, producing altogether about 80 tons of pig-iron daily.

The cost of such a plant and of smelting iron in it will depend on the type of furnace employed. The most economical furnace, as far as my information goes, is that of the Electro-Metals Company, and I give in the first place an estimate based upon its use.

An electric iron-smelting plant of this type, containing three 3,000 kw. furnaces, would cost from $350,000 to $400,000 to erect in British Columbia (details are given in the Appendix), and should have a production of 27,000 long tons of foundry iron per annum.

COST OF ELECTRIC SMELTING.

The cost of making a long ton of foundry pig-iron in such a plant would be estimated as follows, assuming that power can be obtained at $15 per horse-power year:—

Smelting in Swedish Furnace with $15 Power.

Iron ore, 2 net tons at $4	$ 8 00
Electric power, 0.45 horse-power year at $15	6 75
Charcoal, 0.4 net tons at $8	3 20
Electrodes, 15 lb. at 8 cents	1 20
Repairs and maintenance	1 00
Labour	4 50
Management	2 00
Interest, 6 per cent. on total capital, and depreciation, 10 per cent. on cost of plant	2 60
Royalty to Electro-Metals Company	50
Total	$29 75

If power could be obtained at $10 per horse-power year, the charge for this item would be $4.50 and the total cost of a ton of pig-iron would be $27.50.

If power were to cost 0.5 cent per kilowatt-hour, the charge for power would be about $12.50 and the total cost of a ton of pig-iron would be $35.50.

In regard to these figures, it should be stated that the Electro-Metals furnace is a somewhat elaborate appliance, and that a plant with furnaces of this type should not be constructed unless

a permanent supply of cheap power can be assured. This is not so much because of the cost of construction, which may not be much more per ton of yearly product than that of a plant with the simplest type of furnace, but because the furnace, and the building containing it, are entirely specialized, and would be of no use for any other purpose. If for any reason it should be decided to erect a plant with an expensive or a temporary source of power, it would be desirable to arrange for a plant of the type in use for making ferro-alloys, as the furnace, and plant generally, could readily be converted to other purposes if at any time it became inadvisable to make pig-iron. With this simpler type of furnace the cost of making pig-iron would probably be about $5 higher per ton than the above estimates; thus the cost of a ton of pig-iron would be $35 per ton if power costs $15 per horse-power year, and would be more than $40 per ton with power costing 0.5 cent per kilowatt-hour.

The following table will give an idea of the distribution of costs under these conditions:—

Smelting in Simple Furnace with 0.5-cent Power.

Iron ore, 2 tons at $4 per ton	$ 8 00
Electric power, 0.5 horse-power year at $27.80	13 90
Charcoal, 0.5 ton at $6 per ton	3 00
Electrodes, 20 lb. at 8 cents per pound	1 60
Repairs and maintenance	1 00
Labour	6 00
Plant and general office expenses	4 00
Interest and depreciation	3 00
Total	$40 50

The prices obtained for pig-iron in British Columbia during the last year or two have been considerably higher than this, but it does not seem safe to count on a price of more than about $35 a ton during the next few years, so that making iron under these conditions would appear to be out of the question.

MAGNETIC CONCENTRATION OF IRON ORES.

As the cost of smelting iron ore is greater per ton of the product with poor ores than with rich ores, and as the ores in British Columbia are only expected to contain 50 to 55 per cent. of iron, with about 23 to 30 per cent. of gangue, it is worth considering whether it will pay to concentrate the ore preparatory to smelting.

Until adequate samples of the ores have been obtained, analysed, and submitted to magnetic concentration, it is impossible to discuss this subject except in general terms.

(1.) If the ore is of such a nature that after breaking down to a size of about 1 inch the ore can be concentrated magnetically so as to reject a large part of the gangue, it will usually pay to do this before smelting.

(2.) If the ore is so firmly grained that it is necessary to crush it to a sand before magnetic dressing, there will be involved the cost of the fine crushing and also the cost of briquetting or sintering the concentrates to make them suitable for smelting.

(3.) In the case of an ore that does not contain over 50 per cent. of iron, if the ore lends itself readily to magnetic concentration so that very fine grinding is unnecessary and a clean separation can be obtained, the saving in the cost of smelting will probably pay for the cost of crushing, magnetic dressing, and sintering with sawdust on a Dwight-Lloyd machine. The ore will incidentally be improved by the removal of phosphorus and sulphur, and will be left in a condition more favourable for smelting.

(4.) If preliminary reduction of the ore is employed, the ore will have to be crushed to a coarse powder, and magnetic concentration will then form an essential step in the process; being applied either before or after the reducing operation.

AUXILIARY INDUSTRIES.

On account of the limited market for pig-iron in British Columbia, it will be impossible to conduct at a profit a plant producing nothing but pig-iron. By including in the plant the production of steel and ferro-alloys the plant will be more likely to pay.

STEEL.

In view of the small size of the industry, it will be out of the question to attempt to roll large plates for ship-building or large structural sections or rails, but small sections and bars of structural steel can be rolled, besides bars of cast steel for drills and similar purposes. Steel will also be needed for the production of steel castings.

The steel can be melted in an open-hearth or an electric steel furnace, using, as stock, steel scrap and white pig-iron from the electric-smelting furnace. If it is desired to charge the pig-iron in the molten state, so as to save the cost of remelting, a "mixer" will be needed to keep the iron molten until it is needed. As the iron ore is low in phosphorus, the iron will be of "Bessemer" quality and an acid-lined furnace will be satisfactory for steel-making. A small rolling-mill and a steel-foundry will form necessary adjuncts of the plant. Further particulars are given in Appendix XIII.

FERRO-ALLOYS.

The production of these alloys would form a simple and profitable part of the work of such a plant. The alloys that would probably be made are ferro-manganese, ferro-chrome, and ferro-silicon. The essential ingredients of these are manganese ore, chrome ore, quartz, scrap-iron or iron ore, and charcoal or coke. All these are available, and these alloys can be made in the small 300-kw. single-phase furnaces mentioned in the design. Information with regard to the supply of manganese and chrome ores and the methods and costs of making ferro-alloys will be found in Appendix XIII.

A NEW METHOD OF PRODUCING ELECTRIC-FURNACE IRON.

It has been pointed out that an electric-smelting industry must depend for the present on electric power furnished by the power companies of British Columbia. It has also been stated that the company best able to supply power has asked so high a price that the commercial production of pig-iron by electric smelting seems to be impossible. Under these conditions it would appear that nothing can be done except to wait for cheaper power or to make a little pig-iron as a part of some more remunerative operation.

There is, however, in view at the present time the possibility of an entirely different method, which may possibly enable iron and steel of electric-furnace quality to be produced at a decidedly lower cost than that of direct smelting in the electric furnace. According to this method, the iron ore would be crushed to a coarse powder, the gangue removed by magnetic concentration, and the nearly pure iron mineral exposed to reducing gases or carbonaceous reducing materials, at moderate furnace temperatures, until the grains of iron ore are converted into grains of metallic iron. This grain metal can then be melted in electric furnaces, with suitable additions, for the production of both pig-iron and steel. The electric power needed for the final melting of the metallic powder would be less than one-third of that required for smelting the iron ore by existing methods, and it seems quite possible that the preliminary reduction of the ore, using waste wood or other cheap fuel, can be effected so cheaply that there will be a substantial saving on the whole process. It will also be noticed that one operation, the conversion of pig-iron into steel, will be avoided by the new process.

This new process was referred to in my letter of May 26th to Mr. W. Fleet Robertson. I had at that time applied to the Advisory Research Council for funds to assist me in investigating the reduction of iron ores, but I have not as yet been able to begin experiments.

During my visit to California I heard of the work of Dr. Trood and Mr. Darrah along similar lines, and I met these gentlemen at Heroult, where I saw in operation a small plant for the reduction of magnetite ore to metallic iron. I am not at liberty to give full particulars of their process, but can state that it consists substantially in heating the coarsely powdered magnetite with charcoal or other carbonaceous reducing material to a temperature of 800° C. for about three hours. In the small plant the heat was supplied electrically, which was more convenient and also permitted of more accurate measurement, but on the large scale it is probable that fuel-heat would be employed. I have received from Dr. Darrah data in regard to the operation, and I have modified these to suit conditions in British Columbia. It will be seen that, even if electrical heat is used for reduction and melting, there should be a decided economy as compared with the direct smelting process.

Cost of One Ton of Reduced Iron (in a Plant making 100 Tons daily).

Ore, 2.2 tons at $4	$ 8 80
Charcoal, ⅓ ton at $6	2 00
Power for heating, 1,380 kilowatt-hours at ½ cent	6 90
Crushing materials, at 50 cents per ton	1 10
Handling materials, at 50 cents per ton	1 10
Labour and supervision	85
Interest and depreciation on an investment of $20,000	25
Total	$21 00

The operation of converting this metallic powder into foundry pig-iron would have to be worked out experimentally, but I believe, with electric power costing ½ cent per unit, and with other supplies at the rates assumed in this respect, that the cost of this operation would be about $10 per ton of pig-iron. The final cost of a ton of iron would therefore be $31, even using high-priced power; and if this figure can be substantiated, it becomes clear that an electric-iron industry can be started in British Columbia under present conditions. I am of the opinion, also, that the electrical power used for reducing the ore can be replaced by ½ ton of coal or similar fuel, or even by waste wood. If this can be done, the charge for heat may be reduced to $2 or $3, and the cost per ton of metallic powder to $16 or $17, so that a ton of foundry pig-iron produced by this process should cost only $26 or $27.

If it is found possible in practice even to approach these estimates, it will be clear that an electric-iron industry can be undertaken immediately in British Columbia and in some other parts of Canada, and that the plants that are now employed for the electric smelting of iron ores may have to be remodelled. I must repeat, however, that although the results indicated appear to me to be very probable, I have not as yet enough information to speak with entire certainty, and further experimental work must be undertaken before it would be safe to proceed to the erection of a plant.

The metallic powder can be made into steel equally easily by melting in electric furnaces, and steel ingots should be produced at a cost only a little higher than that of foundry iron—say, at about $30 per ton. This would render possible a large steel industry in British Columbia.

GENERAL CONSIDERATIONS.

In view of the abnormal prices of products and supplies and the high cost and uncertainty of labour, it is almost impossible at the present time to arrive at any reliable conclusions with regard to the commercial side of a new industry. The high prices obtainable for iron and steel make the present time appear suitable for undertaking the production of these materials, but the increased cost of supplies and of labour largely neutralize this advantage. If it seemed probable that pre-war prices would return in the course of a year or two, we might base our calculations on this assumption; but in view of the profound change that is taking place in the position of labour, it seems unlikely that wages will ever return to their original level. One effect of this will be that the prices of supplies and products will all reach correspondingly higher figures.

If electric power could have been obtained immediately at a reasonable price, it appeared reasonably safe to undertake the electric production of pig-iron by standard methods; but if we are dependent on developing a water-power for this purpose, the delay and the increased uncertainty in regard to costs and prices makes prediction almost impossible. In a general way, however, we may assume that in the course of a few years costs and prices will again reach some steady relationship to one another, and that this relationship will not be very different from what it was before the war.

On this assumption it would seem that, after prices have once more reached a steady level, the electric smelting of iron ores will occupy, commercially, about the same position as before the war, and by considering the condition in Sweden, which resembles Canada in many respects, we can form a fairly good judgment of the possible development of electric smelting in British Columbia.

We may therefore expect, with the present methods of electric smelting, that the industry would be successful commercially, but that it would depend ultimately on the production of special qualities of iron and steel, and would be unable to compete with the blast-furnace in

the production of ordinary grades of pig-iron. If, however, the new process for the reduction of iron ores is found to be satisfactory, it should produce a decided improvement in the commercial status of electric smelting.

CONCLUSIONS IN REGARD TO THE ELECTRIC SMELTING OF IRON ORES IN BRITISH COLUMBIA.

(1.) The three most essential requirements are: Iron ore, electric power, and charcoal or similar material. In the Coast districts of British Columbia there is a sufficient quantity of suitable iron ore conveniently located, water-powers available for the development of electrical energy, and waste wood from sawmills for the production of charcoal.

(2.) Having regard to the present market for pig-iron and the probable price for this material during the next few years, it appears that the iron ore, electric power, and charcoal could be produced sufficiently cheaply for the commercial smelting of iron ores in electric furnaces.

(3.) The development of a water-power is, however, a long and costly operation and one which it would be highly inadvisable to undertake at the present time. For present operations, therefore, we are dependent on the purchase of electric power from the power companies.

(4.) It appears that one of these companies has a sufficient amount of unused electric power, but it is asking a higher price for this power than the industry can bear.

(5.) In view of the original cost of development, it would appear that the company could afford to offer the power at a decidedly lower price, but it should be remembered that the company must keep a reserve of power for other purposes, and that it cannot at present afford to maintain this reserve by undertaking fresh development.

(6.) A new process is now being investigated by means of which it may be possible to produce electric-furnace pig-iron commercially in spite of the high price charged for electric power.

(7.) In view of the small demand for pig-iron in British Columbia, it would be almost essential, if a smelting plant is to be established on an economic basis, that additional products shall be turned out. Steel for castings and small rolled sections, and ferro-alloys, such as ferro-manganese, ferro-chrome, and ferro-silicon, could be made suitably in such a plant. These additional products would permit of more economical operation, would enable larger profits to be made, and would allow the plant to continue in profitable operation if at any time the price of pig-iron were to fall below the cost of production.

(8.) In view of the present situation it appears advisable:—

(*a.*) To develop one or more of the best iron-ore deposits and to make complete tests of the ore:

(*b.*) To reserve a suitable water-power for future development:

(*c.*) To establish a plant for the economic production of charcoal from mill-waste:

(*d.*) To investigate the new process for the production of electric pig-iron, and if this is found satisfactory to begin immediately to produce pig-iron; purchasing power for this purpose until the water-power can be developed.

ALFRED STANSFIELD.

November, 1918.

APPENDICES.

APPENDIX I.

MARKETS FOR IRON AND STEEL.

This subject should be given the first consideration, as we require to know what amounts and varieties of iron and steel can be disposed of, and at what prices they can be sold. This information will determine the scale of the operations, and will have a bearing on most of the other lines of inquiry. There may be available an export as well as a local market, but I have limited my inquiries almost entirely to the market in British Columbia.

Members of the Metal Trades Association, whom I met in Vancouver, and Mr. Giles, of the Vancouver Engineering Works, expressed the opinion that, if pig-iron could be produced locally at a reasonable figure, there would be a market for about 50 tons daily. As iron was selling at $60 to $70 a ton, it appeared that a local iron selling at from $30 to $40 a ton would be able to secure a large market. Mr. Hart, the secretary of the association, tried to obtain from the members individual statements of the amount, quality, and price of their purchases of pig-iron, to form a basis for my investigation; but I have not received any information from him.

Messrs. Evans, Coleman & Evans, of Vancouver, informed me that the consumption of pig-iron in that district was only 3,000 to 4,000 tons per annum, corresponding to 10 tons daily. In view, however, of the fact that Vancouver iron-foundries are now using about 40 per cent. of new pig-iron and 60 per cent. of scrap-iron, whereas normally these figures would be reversed, it appears that the ordinary demand, with iron at a more reasonable price, would be about 20 tons daily.

Mr. Nichol Thompson estimates the market for foundry iron in British Columbia as 10,000 tons per annum, which would be 30 tons per day; and states that in 1912 British Columbia imported over 7,000 tons of pig-iron. These figures are said to be quite apart from the new ship-building industry, which should lead to an expansion in the market for both iron and steel.

In undertaking the smelting of iron ores, it must be remembered that the amount of pig-iron used in foundries for iron castings is far less than the amount which is converted into steel, and therefore, as the market for foundry iron is somewhat limited, we may suitably enlarge the scale of operations by producing some pig-iron for steel-making. An idea of the relative consumption of the several varieties of iron and steel can be gained from the following table, which was sent to me by Mr. John McLeish, of Ottawa, in reply to an inquiry in regard to the market in British Columbia:—

Imports of Iron and Steel Goods from Foreign Countries through Ports in British Columbia and Alberta during Twelve Months ending March 31st, 1915.

Product.	Quantity, Short Tons.	Value.
Pig-iron	2,341.0	$ 27,838
Ingots, billets, and forgings	67.7	4,564
Scrap	262.0	2,700
Cast-iron pipe	1,411.5	41,319
Steel rails and connections	14,993.5	379,134
Angles, bars, plates, etc.	15,394.5	552,939
Tin-plate	8,217.5	621,051
Wire rods, wire, and wire nails	5,404.4	378,076
Nails, rivets, and nuts	402.0	22,712
Chain	205.4	19,385
Car-wheels, anchors, and other manufactures	282.5	17,058
	48,982.0	$2,066,776
Other iron and steel products and manufactures, valued at	...	4,391,955
Total value	...	$6,458,731

The amount of steel produced from a ton of pig-iron depends to some extent upon the process employed; thus the Bessemer process yields something less than 1 ton of steel, while the open-hearth process or the electric steel-furnace, using a mixture of pig-iron and steel scrap, may produce more than 2 tons of steel per ton of pig-iron. Without attempting to analyse the steel market in any detail, it seems probable that some 25 or 30 tons daily of pig-iron could be converted into steel and disposed of in the form of small steel rods and rolled sections, steel castings, and other steel products.

The price of pig-iron in British Columbia will, in general, depend on the price in the Eastern States, together with the freight and the import duty. The following table, supplied to me by Mr. W. G. Dauncey, shows the cost of pig-iron during the last ten years per long ton of 2,240 lb.—

Cost of Pig-iron during Recent Years.

Year.	No. 1 Foundry, Philadelphia.	Bessemer, Pittsburgh.	Foundry, Cincinnati.	Foundry, Chicago.	Low Sulphur, Chicago.
1908	$17 33	$17 03	$15 83	$17 25	$20 25
1909	17 30	17 46	16 05	17 48	19 50
1910	16 87	17 16	14 85	17 10	18 69
1911	15 20	15 74	13 62	15 19	17 00
1912	15 98	15 04	14 96	15 77	16 75
1913	16 56	17 16	14 98	16 39	16 55
1914	14 59	14 90	13 41	14 15	15 61
1915	15 25	15 85	13 49	14 46	16 31
1916	21 20	24 00	18 74	20 67	21 00
1917	40 68	43 62	38 01	41 06	44 25

During 1917 the prices became very erratic and shot up to enormous figures. The United States Government consequently regulated the price of pig-iron and that of the ore and fuel needed for its production. From September, 1917, to September, 1918, a standard price of $33 was fixed for pig-iron at Birmingham; other varieties of iron ruling at somewhat higher figures. Thus No. 2, Philadelphia, has been sold at $34.40; Bessemer, Pittsburgh, at $36.60; and Lake Superior (charcoal), Chicago, at $37.85. In October, 1918, these prices have been raised in most cases about $1.

Before the war, with Eastern prices about $15 per long ton, the price in British Columbia would be between $25 and $30. Mr. Nichol Thompson states that during his thirty years' experience he has only once seen pig-iron under $22 per ton, and that the price has ranged from $22.50 to $32.50 per short ton; that is, $25.20 to $36.40 per long ton. It is frequently mentioned that Chinese pig-iron has been imported at a price of $19.50. This iron was brought in as ballast, it was ungraded, and I understand that it was of very poor quality and that some of the buyers have been unable to use it. It is possible, also, though I cannot now check this point, that the price was for a short ton, corresponding to $21.84 per long ton. The only importation from China since 1913 was in the year 1916-17, amounting to 400 tons; and in view of the requirements of Japan, it seems unlikely that any Chinese iron will come to British Columbia in the near future.

The present price for pig-iron in the Eastern States is $33 per ton; adding to that a freight of $15 and a duty of $5 would make $53 in British Columbia. As, however, the exportation of iron from the United States has been prohibited, the actual price is higher than this, and has ranged from about $60 to $80 per long ton.

While it is impossible to predict the course of prices after the war, it seems likely, in view of the high cost of living and the increasing powers of the working-classes, that the price of labour, and consequently the price of manufactured products, will not return again in the near future to the pre-war figures. If we may assume that Eastern prices of pig-iron will not fall below $20, it will follow that the normal price of pig-iron in British Columbia will not fall below $35, or at the lowest price $30, for a period of several years.

The freight from Eastern iron centres to Vancouver has been about $10 per ton, but is higher at present. In August the rate from Hamilton to Vancouver on iron and steel was 60 cents per 100 lb., or $13.44 per long ton. Freight rates from American furnaces cannot be

obtained at present, as the export of pig-iron is prohibited. The duty on pig-iron from the States is $2.80 per long ton plus 7½ per cent. *ad valorem*, which at present prices comes to about $2.25 per long ton, or a total charge of about $5 per long ton.

The B. L. Thane Corporation place the price of pig-iron in California as $25 per ton before the war, being the Eastern price of $15 plus $10 freight. At present they take the Government price of $33 at Birmingham plus $10 freight, or $43 a ton. They assume that after the war the price will be about $28 per ton, or an advance of $3 over pre-war prices. They consider that the market for iron and steel on the Coast is at least 600,000 or 700,000 tons a year, and probably 1,000,000 tons.

British Columbia is very well situated for shipping manufactured products to Japan and the East generally, and if pig-iron and steel could be produced cheaply we might be able to command a considerable export market. Electric-furnace iron will, however, be too costly to compete with blast-furnace iron, even when the latter is brought long distances by water. Wherever there is an iron industry there will be a moderate demand for high-grade pig-iron, and an electric-smelting industry in British Columbia will probably be able to develop a fall market for this product throughout the East.

Mr. Dauncey's table of iron prices shows that in normal times there is a difference of $3 or $4 between the price of different classes of pig-iron. In August, 1913, the prices of Bessemer and foundry irons varied from $50 to $55, including freight, at most points in Eastern Canada, and electric-furnace pig-iron was sold at Eastern Canadian furnaces at a standard price of $58.

With regard to the possibility that a blast-furnace plant may be established in the State of Washington, and that it may capture the market for iron in British Columbia, I may state that the B. L. Thane Company estimate the cost, under 1918 conditions, of making iron in the State of Washington at $22, $26, and $30, on three assumptions with regard to the cost of supplies. Taking the middle estimate, $26, and adding the freight, say $2, and the Canadian duty of $4.75, would raise the cost of iron delivered in British Columbia to about $33; a figure which is about the same as the cost of making electric-furnace iron with power at $15. The bounty offered by the British Columbia Government would, apparently, turn the scale in the favour of the electric product. After the war the war duty of 7½ per cent. *ad valorem* will no doubt be withdrawn, and in general we must expect that a blast-furnace plant on the Pacific coast would be able to take a part at least of the market in British Columbia for the cheaper grades of iron, but, with the help of the Canadian duty and the Provincial bounty, an electric-smelting plant in British Columbia should be able to retain the local market for the higher grades of iron.

Information with regard to the price of pig-iron in British Columbia differs considerably: Mr. Watson Griffin, Superintendent of the Commercial Intelligence Branch of the Department of Trade and Commerce, Ottawa, on September 4th quotes "one of the largest ship-building companies on the Pacific coast" as saying: "We beg to advise that we have been paying for pig-iron during the last year between $65 and $75 per ton of 2,000 lb." This would be between $73 and $84 per long ton. On October 19th he quotes the Industrial Commissioner of Vancouver as saying: "The prevailing prices during the past two years have been from $45 to $69 per ton, which is the price at the present time for Hamilton pig-iron delivered at Vancouver. The present quantities required in British Columbia will run approximately from 7,000 to 10,000 tons per year. I have been unable to get an estimate of the quantities that will be required in the next two or three years." Mr. Griffin subsequently ascertained for me that these lower prices referred to the long ton.

APPENDIX II.*

SUPPLIES OF IRON ORE.

There are, in easily accessible parts of British Columbia, a number of deposits of magnetite ore that appear to be suitable for electric smelting. In the absence of a regular demand for such ores, scarcely any of these deposits have been opened up, and it is impossible to state with any degree of accuracy the amount and analysis of the ore or the cost of mining it.

In view of these circumstances, it was arranged that Mr. Wm. Fleet Robertson and Mr. Brewer would furnish me with the best information at their disposal with respect to the ore-bodies, and that I would use this information as the basis of my report; it being understood that I am not accepting any responsibility with regard to the accuracy of such information. I have, however, been able to obtain some independent data, which agree in general with those furnished by the Government officials.

Amount of Ore needed.—As the ore may be assumed to contain, on an average, not much more than 50 per cent. of iron, about 2 tons of ore will be needed for each ton of pig-iron. Thus for a production of 50 tons of pig-iron daily we must have 100 tons of ore, or 35,000 tons per annum. A supply of 50,000 tons per annum for ten years, or 500,000 tons in all, would appear adequate for the present inquiry.

Location of Deposits.—It is assumed, for the purpose of this report, that an electric-smelting plant would be erected at some point on tide-water within a reasonable distance of Vancouver; its location being determined, among other considerations, by the need of obtaining electric power from the lines of an electric power company. It follows from this that the ore-deposits selected for consideration should be those that are situated on tide-water within easy transportation distance by water from Vancouver.

Available Ore-deposits.—A statement compiled by Mr. Wm. Brewer, and approved by Mr. Wm. Fleet Robertson, will be found in this Appendix. It contains a list of the more important deposits of iron ore that are likely to prove suitable for supplying an electric smelter. The statement shows the distance of each deposit from tide-water, the estimated amount of ore, and the percentage of iron, sulphur, phosphorus, and insoluble in samples taken from each deposit. It appears from the statement that there are several conveniently situated deposits, any one of which may be expected to furnish the required amount of ore. There can be little doubt that if two or three of these were opened up a sufficient supply of ore of reasonable richness and purity would be obtained.

Nature of the Ores.—The ores available are almost all magnetites. Such ores are less easily smelted in blast-furnaces than hæmatite ores, and it is usual, therefore, to provide for an admixture of hæmatite when smelting magnetites. It is quite likely that, in electric furnaces, hæmatite ores would smelt more readily than magnetites, although, as very little preliminary reduction of the ore can be effected in such furnaces, the difference is likely to be less marked. It happens, however, that the commercial smelting of iron ores in electric furnaces has nearly always been carried out with magnetites, either alone or with small additions of hæmatites, so that we know definitely that magnetite ores are suitable for electric smelting.

The ores available, while adequate in amount and convenient in location, are neither as rich in iron nor as free from impurities as the magnetite ores that have been smelted in electric furnaces in Sweden or California. Many of the Swedish ores contain as much as 60 per cent. of iron, and the Californian ore has nearly 70 per cent. of iron, but the ores available in British Columbia cannot be assumed to average more than 50 or 55 per cent. The published analyses of ore samples, including those contained in this Appendix, frequently show as much as 60 per cent. of iron, but Mr. Fleet Robertson is satisfied that, if the ore-bodies are mined in a wholesale way, and without any attempt to pick the best ore, it will not be safe to count on an average richness of more than 50 to 55 per cent. of iron. He informs me, however, that the gangue accompanying the ore is limey in character, and that by taking a suitable proportion of the rock with the ore a smelting mixture can be obtained having enough limestone to be self-fluxing, and carrying at least 50 per cent. of iron. It may be pointed out that for making a foundry iron

* A map to illustrate this Appendix and the enclosed report by Mr. Brewer has been prepared by Mr. W. F. Robertson, and should be bound with this report in the event of it being printed.

some silica is essential in the smelting mixture; thus, at Heroult, the ore was so pure that it was necessary to add quartz. Moreover, a certain amount of slag must be produced to flux off the sulphur which is present in the ore. Greater economy would undoubtedly result, however, if the smelting mixture could be made to contain as much as 60 per cent. of iron.

The Swedish ores are exceptionally pure, containing usually from 0.01 to 0.02 per cent. each of phosphorus and sulphur, and the ore at Heroult, in California, containing only 0.01 per cent. each of phosphorus and sulphur. The available ores in British Columbia are reasonably free from phosphorus, containing as a rule less than 0.03 per cent. of this element, so that Bessemer iron can be made from them. The sulphur is, however, somewhat higher than is desirable. Some of the ores, notably those from Texada island, contain some tenths of a per cent. up to 1 per cent. of sulphur, but it seems probable that a supply could be obtained that would not contain more than about 0.1 per cent. of that element. This amount of sulphur will not interfere at all seriously in the production of a good foundry iron, but it will render the ore less valuable for making special grades of "charcoal" iron.

From among the various deposits three groups have been selected—namely, those on Texada island, Nos. 1, 2, and 3; those on Redonda island, Nos. 9 and 10; and those at Nootka sound, Nos. 13 and 14. Mr. Brewer has prepared estimates of the cost of mining the ore from each of these deposits and transporting it to a port on the east coast of Vancouver island, or in the neighbourhood of Vancouver. He finds that, including a royalty of 50 cents per ton to the owner and miner of the ore, the cost of ore delivered at the smelter will be about $4 per net ton. As about 2 net tons of ore will be needed for each long ton of pig-iron, the cost of the ore will be about $8 per ton of pig. This is a very serious item of cost, and is far higher than the usual cost of ore at Eastern furnaces. In view, however, of the nature of the ore-bodies, the moderate scale of mining and transportation, and the high cost of all operations on the Coast, it does not appear that any material reduction can be expected, at any rate during the next few years. If the ore were being mined for sale, there should be added the Provincial Government tax of 37½ cents per ton; but in the present case it appears reasonable to count this as a deduction from the bonus of $3 per ton paid by the Government for pig-iron produced locally from British Columbia ores.

IRON ORES OF BRITISH COLUMBIA.

(Data compiled by Wm. M. Brewer, Resident Engineer, Western Mineral Survey District, Nanaimo, B.C., June 8th, 1918.)

The accompanying tables show:—

First: The estimated cost for mining and transporting iron ore mined from the most accessible properties to any established port on the east coast of Vancouver island or at Vancouver.

Second: The names and locations of the various properties, with the distance from deep water, also the available tonnage, very roughly estimated, in three classifications—"actual," "probable," and "possible" ore. Owing to the lack of development-work it is impossible to measure the ore reserves with any degree of accuracy. Where a star is placed beside the name of a property it indicates that it is impossible to make any estimate of available tonnage at present.

Third: The nature of the ore and assay results obtained from the samples collected at various times, together with the names of the collectors.

Estimated Cost of Mining and Transporting Iron Ores.

Three deposits only have been considered in the following table, viz.: Those located on Texada and Redonda islands and at Nootka sound. These are selected because, owing to their accessibility, together with the quantity and quality of the ore, they would be the natural choice as the first sources of supply.

Texada Island, Nos. 1, 2, 3—

Estimated cost of 3-drill plant	$ 5,000
Estimated cost of transportation	10,000
Estimated cost of bunkers and docks	10,000
Total estimated cost of installation	$25,000

Estimated Cost of Mining and Transportation per Ton of 2,000 Lb.
(Figuring 50,000 Tons per Annum).

Interest and depreciation on installation at 20 per cent	$0 10
Estimated cost of mining	2 00
Estimated cost of tramming	25
Estimated cost of freight	1 00
Estimated cost of unloading	25
	$3 60
Royalty to owner per ton	50
Cost of ore at smelting plant	$4 10

Redonda Island, Nos. 9 and 10—

Estimated cost of 3-drill plant	$ 5,000
Estimated cost of bunkers and docks	10,000
No transportation required.	
Total estimated cost of installation	$15,000

Estimated Cost of Mining and Transportation per Ton of 2,000 Lb.
(Figuring 50,000 Tons per Annum).

Interest and depreciation on installation at 20 per cent	$0 06
Estimated cost of mining	2 00
Estimated cost of loading	15
Estimated cost of freight	1 00
Estimated cost of unloading	25
	$3 46
Royalty to owner per ton	50
Cost of ore at smelting plant	$3 96

Nootka Sound, Nos. 13 and 14—

Estimated cost of 3-drill plant	$ 5,000
Estimated cost of tram-line	10,000
Estimated cost of bunkers and docks	10,000
Total	$25,000

Estimated Cost of Mining and Transportation per Ton of 2,000 Lb.
(Figuring 50,000 Tons per Annum).

Interest and depreciation on installation at 20 per cent	$0 10
Estimated cost of mining by large quarry	1 50
Estimated cost of tramming	25
Estimated cost of freight	1 50
Estimated cost of unloading	25
	$3 60
Royalty to owner per ton	50
Total	$4 10

NOTE.—The estimated cost for freight is based on transportation by scows or barges from the Texada Island and Redonda Island deposits, and by freight-steamers properly equipped for hauling iron ore from the Nootka Sound deposits in cargoes of 500 tons and upwards.

(After consultation with Mr. R. H. Stewart, Mr. Brewer has decided to increase his estimate for a 3-drill plant to $12,000 in view of present conditions. This change will only represent a few cents per ton added to the estimated cost of mining.)

Names and Locations of Properties.

No.	Name of Property.	Location.	Approximate Distance from Deep Water.
1	Prescott	Texada island	1,000 feet.
2	Paxton	Texada island	About one mile.
3	Lake	Texada island	About 1½ miles.
4	Iron River*	Branch of Quinsam river, east coast of V.I.	13 miles.
5	Quinsam Lake Iron Syndicate	Upper Quinsam lake, near east coast of V.I.	About 25 miles.
6	Iron Crown*	Nimpkish (Klaanch) river, near Nimpkish lake, V.I.	About 21 miles.
7	Kitchener*	Wigwam bay, Seymour inlet, Queen Charlotte sound	Close.
8	Alexander*	South shore of Seymour inlet, Queen Charlotte sound	Close.
9	Elsie*	West Redonda island	On shore.
10	Black Warrior*	West Redonda island	On shore.
11	Cumshewa*	Louise island of Queen Charlotte group	On shore.
12	Eagle and Sunrise	West arm of Quatsino sound, V.I.	
13	Glengarry and Stormont	Head bay, Nootka sound, west coast of V.I.	1¼ miles.
14	Fido	Head bay, Nootka sound, west coast of V.I.	1½ miles.
15	Western Steel*	Sechart, Barkley sound, west coast of V.I.	2 miles.
16	Bald Eagle*	Sechart, Barkley sound, west coast of V.I.	2 miles.
17	Crown Prince	Sechart, Barkley sound, west coast of V.I.	2 miles.
18	Sarita	Sarita river, Barkley sound, west coast of V.I.	1½ miles.
19	Clifton	Tzartoos island, Barkley sound, west coast of V.I.	½ mile.
20	Black Prince	Uchucklesit harbour, west coast of V.I.	½ mile.
21	Henderson Lake	Henderson lake, west coast of V.I.	1,000 feet to lake, 12 miles to deep-sea harb'r.
22	Defiance*	Handy creek, Alberni canal, V.I.	1 mile.
23	Rose*	Gordon river, near Port Renfrew, V.I.	5 miles.
24	Sirdar	Gordon river, near Port Renfrew, V.I.	9 miles.
25	Conqueror	Bugaboo creek, tributary of Gordon river, near Port Renfrew, west coast of V.I.	9 miles.
26	Baden Powell and Little Bobs	Gordon valley, west coast of V.I.	7 miles.
27	Prince's Iron*	West arm, Quatsino sound, west coast of V.I.	2 miles.
28	Britton and Monarch	Chromium creek, tributary of Klinaklina river, flowing into Knight inlet, mainland coast	
29	North Pacific Iron Mines	Limonite (Summit) creek, tributary of Zymoetz river, Skeena Mining Division	60 miles from G.T.P. Rly.
30	Glen Iron Mine	Cherry bluff, Kamloops lake, 13 miles west of Kamloops	Adjoins C.P.R. track.
31	Ralph*	East Sooke, V.I.	1 mile.
32	Darby and Joan*	Alberni canal	½ mile.
33	Iron Mountain and Chieftain	Kennedy lake, V.I.	18 miles.

Quantity Roughly Estimated.

No.	Actual Ore.	Probable Ore.	Possible Ore.	Total Ore.	Remarks.
	Tons.	Tons.	Tons.	Tons.	
1	...	1,366,400	993,600	2,360,000	McConnell's estimate.
2	...	1,607,200	...	1,607,200	McConnell's estimate.
3	...	504,000	...	504,000	McConnell's estimate.
5	...	...	5,000,000	5,000,000	Brewer's estimate.
7	...	...	...	...	(*See* report by George Clothier,
8	...	...	...	...	M.E., Minister of Mines' Report, 1917, p. 64.)
13	250,000	250,000	750,000	1,250,000	Brewer's estimate.

Quantity Roughly Estimated—Concluded.

No.	Actual Ore.	Probable Ore.	Possible Ore.	Total Ore.	Remarks.
	Tons.	Tons.	Tons.	Tons.	
14	...	50,000	200,000	250,000	Brewer's estimate.
17	75,000	...	200,000	275,000	Brewer's estimate.
18	...	30,000	25,000	55,000	Provincial Mineralogist's estimate.
19	3,000	5,000	25,000	33,000	Brewer's estimate.
20	15,000	...	15,000	30,000	Brewer's estimate.
21	20,000	...	280,000	300,000	Brewer's estimate.
24	94,000	...	47,000	141,000	Brewer's estimate.
25	16,000	230,000	120,000	366,000	Brewer's estimate.
26	...	500,000	250,000	750,000	Brewer's estimate.
29	...	562,500	1,135,000	1,697,500	McKenzie's estimate. (*See* Lindeman's report in Vol. I., p. 30, "Iron Ore Occurrences in Canada," Can. Dept. of Mines, 1917.)
Totals ..	473,000	5,105,100	9,040,800	14,618,700	

Nature of Ore and Assay Results.

No.	Nature.	Iron.	Sulphur.	Phosphorus.	Insoluble.	Remarks.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	
1	Magnetite "lime gangue"	66.0	*Nil*	Trace	3.3	Average across face of adit 430 feet below the highest outcrop. Brewer's sample.
		68.2	Trace	....	....	Copper, *nil;* manganese, 0.08%; McConnell's sample.
		64.3	0.303	....	....	Copper, 0.14; McConnell's sample.
		55.2	0.266	....	....	Copper, 0.14; McConnell's sample.
		62.57	0.403	0.024	6.46	Lindeman's sampling.
		58.76	0.113	0.011	12.0	Lindeman's sampling.
		63.27	0.347	0.013	4.37	Copper, 0.08%; Lindeman's sampling.
		69.85	0.6	Trace	2.75	Geol. Survey of Canada, 1886, p. 37B.
		67.91	....	Trace	2.96	Fulmer, Geol. Survey of Washington.
		65.71	....	0.013	....	Tenth Census, U.S. Represented lot of 600 tons smelted at Irondale by Puget Sound Iron Co.
2	Magnetite "lime gangue"	59.4	1.07	....	....	Copper, 0.3%; McConnell's sample.
		64.48	1.866	0.005	4.47	Copper, 0.22%; magnesia, 1.13%; lime, 1.32%; alumina, 0.66%; Lindeman's sample.
3	Magnetite "lime gangue"	58.0	1.6	Trace	0.5	Brewer's grab sample from dump.
		57.5	0.046	....	....	Copper, trace; McConnell's sample.
		69.4	0.01	....	....	
		59.57	0.137	0.057	8.33	Copper, 0.08%; alumina, 1.17%; lime, 3.82%; magnesia, 1.05%; Lindeman's sample.
4	Magnetite	56.45	0.53	0.03	7.0	Copper, 0.7%; alumina, 2.07%; lime, 3.77%; magnesia, 1.25%; Lindeman's sample. Property owned by Canadian Collieries (Dunsmuir), Ltd.
		59.77	0.533	0.024	11.0	Lindeman's sample.

Nature of Ore and Assay Results—Continued.

No.	Nature.	Iron.	Sulphur.	Phosphorus.	Insoluble.	Remarks.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	
5	Magnetite, lime, and garnetite gangue	58.6	Trace	Trace	9.3	Brewer's sample from dump.
6	Magnetite	64.23	0.233	0.010	4.12	Lindeman's sample.
		63.89	0.017	0.021	5.30	Copper, trace; alumina, 1.74%; lime, 0.80%; magnesia, 1.86%; Lindeman's sample.
7	Magnetite	65.5	0.5	....	4.6	Clothier's sample, Minister of Mines' Report, 1917.
8	Magnetite	60.0	0.30	0.11	6.37	Alumina, 7.6%; lime, 1.8%; combined water, 0.11%; magnesia, trace; Clothier's sample.
9	Magnetite	71.28	....	....	0.89	Lindeman, Vol. II., "Iron Ore Occurrences in Canada," Can. Dept. of Mines, 1917.
10	Magnetite	....	....	....	....	No samples reported.
11	Magnetite	68.0	0.01	0.008	1.2	Lime, 1.0%; Minister of Mines' Report, 1911, p. 77, and Lindeman's in "Iron Ore Occurrences in Canada," Can. Dept. of Mines, 1917, p. 18.
12	Bog	54.46	0.15	0.038	2.32	Lindeman's sampling.
		56.97	0.447	0.038	1.40	Lindeman's sampling.
13	Magnetite limestone gangue	56.08	0.1	Trace	1.6	Brewer's sample.
		66.17	0.017	0.016	6.1	Lindeman's sample.
14	Magnetite	....	....	....	....	No samples reported.
15	Magnetite limestone gangue	59.69	0.04	0.016	12.76	Lindeman's sample.
16	Magnetite limestone gangue	59.37	0.716	0.006	13.36	Lindeman's sample.
		60.7	Trace	Trace	13.6	Brewer's sample.
17	Magnetite limestone gangue	54.4	1.4	*Nil*	21.2	Brewer's sample.
		55.6	0.4	Trace	17.6	Brewer's sample.
		48.4	0.7	Trace	....	Carmichael's sample.
		48.06	0.623	0.006	23.22	Lindeman's sample.
18	Magnetite limestone gangue	63.8	0.55	Trace	4.2	Brewer's sample.
		63.7	0.3	Trace	3.85	Carmichael's sample.
		60.89	0.76	0.004	3.81	Lindeman's sample.
19	Magnetite	56.2	1.3	*Nil*	17.0	Brewer's sample.
		50.4	0.3	0.053	18.6	Carmichael's sample.
		52.09	0.23	0.025	16.52	Lindeman's sample.
20	Magnetite	70.2	Trace	Trace	1.4	Brewer's sample.
21	Magnetite	50.0	0.24	*Nil*	22.0	Carmichael's sample.
22	Magnetite limestone gangue	52.6	4.2	*Nil*	12.1	Gold, trace; silver, 1.2 oz.; copper, 3.3%; Brewer's sample.
		66.0	Trace	*Nil*	3.3	Brewer's sample.
		65.8	2.2	Trace	4.8	Brewer's sample.
23	Magnetite	61.9	0.34	....	....	Hand sample reported by Carmichael.
24	Magnetite	56.57	2.75	0.121	8.52	Lindeman's sample.
25	Magnetite	67.09	1.6	0.009	4.51	Lindeman's sample.
26	Magnetite	58.3	2.75	0.013	8.88	Lindeman's sample.
27	Bog	54.46	0.15	0.038	2.32	Lindeman's sample.
		56.97	0.447	0.038	1.40	Lindeman's sample.
		52.0	....	0.5	....	Carmichael's sample.
28	Hæmatite	47.6	*Nil*	Trace	....	Galloway's sample.
		48.4	*Nil*	Trace	....	Galloway's sample.
		57.0	Trace	Trace	....	Galloway's sample (selected).

Nature of Ore and Assay Results—Concluded.

No.	Nature.	Iron.	Sulphur.	Phosphorus.	Insoluble.	Remarks.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	
						First four samples by McKenzie.
29	Limonite	54.20	1.16	0.407	1.02	Manganese, 0.85; water combined, 18.54.
		56.01	1.52	0.016	0.83	Manganese, 0.51; water combined, 16.02.
		54.32	1.14	0.065	1.99	Manganese, 0.39; water combined, 20.47.
		52.19	1.47	0.616	1.56	Manganese, 0.70; water combined, 19.61.
		51.0	1.7	*Nil*	2.0	Brewer's sample.
		50.6	0.8	*Nil*	1.7	Owner's sample.
		53.2	2.65	0.0016	1.31	Owner's sample.
		53.2	1.89	0.014	1.62	Owner's sample.
		54.0	1.15	0.002	1.04	Owner's sample.
30	Magnetite	64.81	0.158	Trace	4.21	McEvoy's samples. (*See* "Iron Ore Occurrences in Canada," Can. Dept. of Mines, 1917, p. 31.)
		62.03	0.170	Trace	3.85	
		63.24	0.17	Trace	4.05	
31	Magnetite	....	....	....	....	Ore carries too much copper to be suitable for iron-making.
32	Magnetite	50.96	0.083	0.004	25.96	Lindeman's sample.
		55.9	1.0	....	16.0	Carmichael's sample.
33	Magnetite	30.1	0.31	Trace	51.5	Brewer's sample.
		63.07	0.043	0.016	7.64	Lindeman's sample.

(End of Mr. Brewer's report.)

IRON ORE FROM HEAD BAY.

In view of the importance of obtaining more exact information in regard to the richness and other characteristics of the available ore, I discussed with Mr. W. F. Robertson the possibility of having a quantity of ore taken from one or more of the deposits, and sending large samples to Victoria for analysis and for tests in regard to magnetic concentration. Mr. Robertson considered that it was not necessary to undertake this at the present time, but he instructed Mr. Brewer to obtain a large general sample of ore from the deposits at Nootka sound, Head bay. In a letter from Mr. Robertson dated August 12th, 1918, and enclosing an assay certificate dated August 9th, he informs me that Mr. Brewer took nine samples from various parts of the deposit, including two near the margin. He also took a sample of the foot-wall. The nine samples were assayed separately for iron and were found to contain: 63 per cent., 70 per cent., 67.2 per cent., 63 per cent., 63 per cent., 44.8 per cent., 47.8 per cent., 67.2 per cent., and 68.2 per cent. The samples containing 44.8 and 47.8 per cent. were taken near the margin of the deposit. A composite sample was made up containing equal amounts of each of the above nine samples and of the one foot-wall sample. This composite sample was analysed and was found to contain:—

	Per Cent.		Per Cent.
Iron	57.1	Sulphur	Trace.
Silica	15.5	Phosphorus	0.05
Lime	0.6		

The average richness of the ore itself is 66 per cent. of iron, and the average richness, including the two samples near the margin, is 61.6 per cent. The composite sample contained 57.1 per cent. of iron, from which it can be calculated that the wall-rock would contain 16.8 per cent. of iron. If we assume that the samples are representative of the deposit, we learn that the rich ore contains 66 per cent. of iron, and that a general sample, including ore near the margin and some of the wall-rock, contains 57 per cent. of iron. We may apparently conclude from this that in general mining an ore of at least 55 per cent. of iron can be expected. It appears, further, that the gangue-matter is siliceous and contains very little lime, and that the ore is free from sulphur and below the Bessemer limit in phosphorus.

The Head Bay deposits appear as Nos. 13 and 14 in Mr. Brewer's list, but Mr. Brewer does not state from which of these properties his present samples were taken, or whether the samples were taken from both properties. The weight of the samples is also not mentioned. Mr. Robertson considers that the above results are higher than would be obtained from an average shipment of ore from this deposit.

NOTES FROM THE B. L. THANE COMPANY.

The following notes on four deposits of iron ore in British Columbia were given me by the B. L. Thane Company, of San Francisco, and are of value as supporting the conclusion that there is available an adequate supply of magnetite ore. The analyses quoted indicate a higher grade of ore than that on which I have based this report.

Texada Island.—Deposit of magnetite owned by the Puget Sound Iron Company. The deposit contains 1,000,000 tons and probably an additional 2,900,000 tons. The ore is loaded into ships near the mine. The ore contains:—

	Per Cent.		Per Cent.
Iron	62.9	Magnesia	0.75
Silica	6.66	Nickel	0.014
Phosphorus	0.016	Cobalt	0.005
Sulphur	0.51	Copper	0.13
Alumina	1.4	Titanium	*Nil.*
Lime	2.0	Arsenic	*Nil.*

The estimated cost (pre-war) at a Puget Sound port was:—

Mining	$0 56
Land transportation	10
Sea transportation	50
Royalty	25
Fixed charges	20
Export duty	50
Total	$2 11

Or $3.18 per ton of pig-iron.

The assumed output was 200,000 tons a year for twenty years. A tram from the mine of 1.1 miles would cost $10,000; equipment and development of mine, $290,000; total, $300,000.

Cumshewa.—A deposit of magnetite on Louise island, owned by H. K. Owens, contains 570,000 tons, with a probable 344,000 tons more. The ore is loaded into ships near the mine. The ore contains:—

	Per Cent.		Per Cent.
Iron	60.0	Sulphur	0.020
Silica	7.0	Lime	2.0
Manganese	0.83	Titanium	0.07
Phosphorus	0.008		

Pre-war cost:—

Mining	$0 75
Land transportation	15
Sea transportation	75
Fixed charges	71
Export duty	50
Total	$2 86

Or $4.86 per ton of pig-iron.

Assumed output, 100,000 tons per annum for nine years. An aerial tram of 1.5 miles from mine to wharf would cost $20,000; purchase of mine, $200,000; equipment and development, $100,000; total, $320,000.

Head Bay.—A deposit of magnetite on Vancouver island, owned by Glengarry, Canadian Collieries (Dunsmuir), Limited, and Clarence Dawley, Clayoquot, contains 150,000 tons, with a probable 250,000 tons more. Ship from Nootka sound. It contains:—

	Per Cent.		Per Cent.
Iron	60.0	Phosphorus	0.008
Silica	8.0	Sulphur	0.013

Pre-war cost:—

Mining	$0 90
Land transportation	10
Sea transportation	65
Royalty	25
Fixed charges	30
Export duty	50
Total	$2 70

Or $4.27 per ton of pig-iron.

Assumed output, 60,000 tons per annum for seven years. Would need an aerial tram of 1.5 miles from mine to wharf, costing $20,000; development and equipment, $50,000; total, $70,000.

Quinsam Lake.—A deposit of magnetite owned by Jones & Thomson, probably contains 500,000 tons. Ship from Campbell river. It contains:—

	Per Cent.		Per Cent.
Iron	60.0	Lime	1.7
Silica	4.0	Phosphorus	0.002-0.976
Manganese	0.65	Sulphur	0.005-0.068
Alumina	2.6		

Pre-war cost:—

Mining	$0 90
Land transportation	60
Sea transportation	50
Royalty	25
Fixed charges	2 12
Export duty	50
Total	$4 87

Or $7.71 per ton of pig-iron.

Assumed output, 60,000 tons per annum for eight years. Needs a twenty-mile aerial tram, costing $220,000; development, $60,000; total, $280,000.

With regard to the estimated cost of mining and transporting these ores, we find (excepting the last in view of the unusually heavy fixed charges) the total costs to be $2.11, $2.86, and $2.70 per ton of ore. Deducting the export duty of 50 cents, these become $1.61, $2.36, and $2.20 per ton. Messrs. B. L. Thane consider that the 1918 costs for labour, materials, transportation, and capital charges would all be doubled, thus leaving a duty-free cost of $2.97, $4.22, and $4.15 per ton, or an average cost of $3.78 per ton. Remembering that these relate to outputs of 200,000 tons, 100,000 tons, and 60,000 tons respectively, it does not appear that Mr. Brewer's estimate of $4 a ton on an output of 50,000 tons is at all too high.

NOTES ON COST OF MINING AND TRANSPORTATION.

I. Mr. W. M. Brewer in a letter dated July 8th, 1918, writes me that he has had interviews with Mr. R. H. Stewart in regard to the cost of mining and with Captain Simon MacKenzie in regard to the cost of transportation.

Mr. Stewart stated that where the iron ore would be mined by quarrying and there would not be very much development-work and only a reasonable amount of sorting, the cost of mining iron ore at the deposits on Texada island, Redonda island, and Nootka sound (Head bay) should not exceed $1 per ton, even when a quantity of only 100 tons a day was being mined. He also said that Mr. Brewer's estimate of $5,000 for the cost of installing a 3-drill compressor plant at any of these mines should be increased to about $12,000 in view of present conditions.

Captain MacKenzie stated that Mr. Brewer's estimate of $1 per ton for transporting iron ore from Texada island or Redonda island to the neighbourhood of Vancouver was reasonable, provided that good dispatch were given in loading and discharging, and that a regular business could be ensured averaging not less than 700 tons a week. He also stated that if the ore was only to be hauled a short distance, as, for example, from the west coast of Texada island or Redonda island to the east coast of Vancouver island, say in the neighbourhood of Union bay, the charge for transportation should not exceed 50 cents or at the outside 75 cents per ton, provided that regular business, handling 700 tons a week, were established with reasonable dispatch, say ten hours for loading and twenty-four hours for discharging cargo. Captain MacKenzie considered that Mr. Brewer's estimate of $1.50 per ton for transporting iron ore from Nootka sound to the neighbourhood of Vancouver would be all right under reasonably normal conditions, although at the time of writing the transportation companies were asking about $3 per ton in cargoes of 700 tons.

II. I have received from Mr. Robertson, under date of July 6th, 1918, the following memorandum *re* transportation of ore, etc., from Mr. H. L. Drummond, Manager, North-west Lighterage Company, Seattle.

Iron Ore from West Coast, Vancouver Island—

In lots of 1,000 tons .....Estimated at $1.50 to $2 per ton.
In lots of 2,000 tons .....Estimated at $1.50 per ton.

Iron Ore from Texada Island (on Long Contract)—

In lots of 500 tons ..... 90 cents per ton.
In lots of 800 tons ..... 80 cents per ton.
In lots of 1,000 tons ..... 65 cents per ton.

The Drummond Lighterage Company are transporting:—

Coal from Comox to Seattle at 90 cents per ton.
Coal from Nanaimo to Seattle at 75 cents per ton.

They take 1,200 tons per trip and from 15,000 to 18,000 tons per month. The charge for carrying copper ore from Sidney inlet to Tacoma is from $3.50 to $4 per ton.

Conclusions.—(1.) Raising the estimate for the 3-drill plant from $5,000 to $12,000 will increase the cost of equipping each mine by $7,000, but will only increase the cost per ton of ore by about 3 cents.

(2.) The original transportation estimate of $1 a ton from Texada and Redonda and $1.50 a ton from Nootka sound are supported by the above notes.

(3.) With reference to the cost of mining, Mr. Robertson considers that, in view of the need of obtaining an ore of reasonable richness, the cost of mining would certainly be higher than Mr. Stewart's estimate of $1 per ton, and that $2 is as low as can safely be estimated under present conditions. We may reasonably suppose, however, that in course of time, when the industry becomes better established, and if the ore-deposits are found to be large enough, the cost of mining may possibly come down to about $1 per ton, even with the present rates of wages.

Notes on Various Iron-ore Deposits.

I. *Iron-deposit at Sarita River.*—I received from the Hon. Wm. Sloan a letter dated June 7th from Mr. J. F. Bledsoe, Manager of the Central Iron Committee of Vancouver Island, enclosing a note from Mr. Wm. Lorimer, of 576 Toronto Street, Victoria, B.C., in regard to the iron-ore deposit at Sarita river. Mr. Lorimer, under date of June 6th, states that this deposit has been mined to the extent of forming a dump of ore, and suggests that some of this ore should be sent to the laboratory at Victoria for treatment. He offers to sack and ship as much ore as may be required, and would make no charge for this beyond his expenses. This deposit is No. 18 in Mr. Brewer's list. It is estimated to contain probably 30,000 tons, with a possible 25,000 tons additional. The deposit is one mile and a half from deep water. It would certainly be of interest to have a quantity of this ore supplied for chemical analysis and other tests, but it will be more worth while to open up some of the larger deposits which are situated close to deep water. Moreover, the samples received from this deposit have been rather high in sulphur, as is shown in Mr. Brewer's report.

II. *Kitchener Group, West Redonda Island, and other Deposits.*—Mr. Nichol Thompson, of Vancouver, has placed at my disposal certain information respecting the iron-ore deposits in

British Columbia. This includes a general synopsis of the iron-deposits in British Columbia, and reports with regard to the *Kitchener* group, the *Elsie* claim, on West Redonda island, and other claims, from which I extract the following:—

The *Kitchener* group (No. 7 in Mr. Brewer's list) is located on Wigwam bay, Seymour inlet, Queen Charlotte sound. A report by G. A. Clothier, February, 1918, shows vein No. 2 to contain 65.5 per cent. iron, 4.6 per cent. insoluble, and 0.5 per cent. sulphur; and vein No. 3 to contain 64.4 per cent. iron, 1.8 per cent. insoluble, and 0.1 per cent. sulphur. Further surface work would be needed to prove the continuity of the ore-shoots on the surface before diamond-drilling to prove them at depths would be justified. A sample of the *Kitchener* ore supplied by Mr. Thompson on July 24th, 1916, was found to contain:—

	Per Cent.	
Peroxide of iron	64.35	Iron, 64.5 per cent.
Protoxide of iron	25.16	
Protoxide of manganese	0.47	
Alumina	0.96	
Lime	1.00	
Magnesia	3.89	
Sulphur	Slight trace.	
Phosphorus	Slight trace.	
Insoluble	4.70	
Total	100.53	

A report of the *Elsie* claim, on West Redonda island (No. 9, Mr. Brewer's list), by Alexander Sharp, Vancouver, October, 1917, contains the following summary: "The *Elsie* mineral claim has a well-defined magnetite-iron ore vein, fully 30 feet wide, probably extending from the east to the west boundary, and to depth. The ore is high grade, almost free from sulphur, phosphorus, and other impurities. Situated on tide-water, where the largest ocean-going ship can be loaded at any tide, the mineral can be easily and cheaply mined."

Mr. Sharp quotes the following analyses for this ore:—

	Per Cent.		Per Cent.
Iron	65.0	Iron	61.10
Sulphur	None.	Silica	7.31
Insoluble	9.20	Lime	3.10
		Phosphorus	0.015
		Sulphur	0.30

Some 626 tons of this ore was shipped to the Oswego Iron and Steel Company's furnace in Oregon. The average iron content was 60.8 per cent., and the ore was reported to work well in the puddling-furnace.

Mr. Thompson also supplied me with reports by J. H. Scott, of London, and W. Newman, of Vancouver, with regard to the *Shoo Fly* and *Nellie C.* claims of iron ore situated near Cardero channel, in the Coast District of British Columbia, 120 miles north of Vancouver City. The reports speak very favourably of the amount and nature of the ore, but the analyses they quote show only 50 per cent. of iron and as much as 2 per cent. of sulphur, which does not support their statements with regard to the value of the ore. The complete analysis quoted is:—

	Per Cent.
Ferric oxide	51.80
Ferrous oxide	25.63
Silica	19.50
Sulphur	2.10
Phosphorus	*Nil.*
Titanium	*Nil.*
Water and oxygen	0.97
Total	100.00

Three samples assayed for sulphur showed: 1.75 per cent., 4.5 per cent., and 0.71 per cent. respectively. Eight samples assayed for iron showed: 59.7 per cent., 57.5 per cent., 54.6 per cent., 58.8 per cent., 54 per cent., 59.3 per cent., 51 per cent., and 53.2 per cent. respectively.

APPENDIX III.

MAGNETIC CONCENTRATION OF IRON ORES.

In smelting low-grade ores of iron, it is sometimes economical to dress the ore before smelting it, in order to eliminate most of the barren rock-matter, and thus to reduce the cost of the smelting operation. This preliminary dressing is particularly desirable in the electric smelting of iron ores, on account of the small size of the furnace and the high cost of the smelting operation. Magnetite ores of iron are readily concentrated by means of an electric magnet which picks out the magnetite mineral and leaves the rock. It is necessary, however, to crush the ore sufficiently fine to separate the grains of magnetite from the grains of rock, and the concentrate must therefore be briquetted, or sintered into lumps, to make it fit for the smelting operation.

In the case of an ore containing 50 or 55 per cent. of iron, and costing $4 per ton delivered to the furnace, it would scarcely pay to concentrate, obtaining a product of 65 to 70 per cent. of iron, because the extra cost of the ore (as some is lost in the tailing) and the cost of the operation would about equal the economies to be gained in the smelting. If, however, by mining the ore in a more wholesale manner the cost of mining can be considerably reduced, and if the dressing operation is carried on at the mine or loading-wharf, so that the freight is only charged on the concentrated ore, there is a possibility of obtaining a smelting concentrate at a moderate price.

We may assume, for example, that the ore can be mined to contain 40 per cent. of iron at a cost of $1 per ton, where the 50-per-cent. ore cost $2 to mine. Adding the fixed charge of 10 cents and the royalty of 40 cents (50 cents for a 50-per-cent. ore), the crude ore will cost $1.50 per ton. The crushing to 80 mesh and magnetic concentration may cost 80 cents per ton, making a total of $2.30. Suppose that 2 tons of ore yield 1 ton of a 70-per-cent. concentrate, then the cost will be $4.60 per ton of concentrate. To this we must add a charge of, say, $1 for sintering and $1 for freight, making a total of $6.60 per ton. This corresponds to $9.45 per ton of pig-iron, which is $1.45 more than the cost using raw 50-per-cent. ore at $4 a ton. The saving in the smelting process, due to the use of a richer ore, would be in the order of $3 a ton of iron, thus making a saving of about $1.55 per ton. The items of cost mentioned above have been made higher than usual on account of the increased cost of labour and supplies at the present time.*

Messrs. Beckman and Linden in their report (Appendix XI.) claim a net saving of $3 a ton of iron by dressing a 50-per-cent. ore up to 65 per cent. of iron. They consider the 65-per-cent. ore to cost: 1.3 tons of ore at $4=$5.20, and cost of crushing, dressing, and sintering, $1.25 per ton of concentrate, or a total of $6.45 per ton, or $9.43 per ton of iron. In view of the loss of iron in the tailings, they would probably need about 1.5 tons of ore, costing $6, while the crushing, dressing, and sintering will cost, at present rates, about $2, making a cost of $8 per ton of concentrate, or $12.30 per ton of iron. This is an increase of $4.30 over the cost of using the raw ore, and the saving in the furnace operation will be $2 or $3. Messrs. Beckman and Linden find a gross saving of $4.79, but I believe this is an overestimate. In any case, even allowing for some error in my own estimate, it appears that no material advantage would be gained by dressing a 50-per-cent. ore to obtain one of 65 per cent.

In the Swedish practice a moderate proportion, perhaps 25 per cent. of concentrated ore, "slig," is used unbriquetted in admixture with lump ore, but finely crushed concentrates cannot be used to any great extent in the charge. If the preliminary reduction process (Appendix XII.) is found to be practicable, the ore will have to be crushed, and magnetic dressing will form an essential part of the scheme. The metallized powder can be melted without briquetting, because it will be, largely, a simple melting operation and there will not be a great production of gas in the furnace.

* The foregoing figures refer to a short ton of iron instead of a long ton, but as the discussion is comparative no serious error has thus been introduced.

APPENDIX IV.

ELECTRIC POWER FOR SMELTING.

The possibility of the commercial operation of an electric-smelting plant for the production of pig-iron from iron ore depends on an adequate supply of electric power at a moderate rate. For the electric smelting of iron ores a large amount of power is needed, the amount varying somewhat with the richness of the ore, the grade of iron to be produced, and the kind of furnace employed. Under usual conditions the consumption of electrical power for each long ton of pig-iron lies between one-third and one-half of a horse-power year. For the production of foundry iron from rather low-grade ores, and in a simple pit furnace, it will not be safe to count on the production of more than 2 long tons of iron per annum for each electric horse-power supplied to the works. For a production of 50 tons of pig-iron daily some 8,000 or 9,000 electric horse-power will be needed, and if provision is made for the production of ferro-alloys and the making of steel in electric furnaces, some 10,000 to 15,000 horse-power must be provided.

It was recognized that such a supply could be obtained by developing certain water-powers on Vancouver island or on the mainland, but in view of the need of establishing the smelting industry at the earliest possible date, and of the extreme difficulty and expense of new development-work under present conditions, it was decided, if possible, to use power that was already developed for the initial operation of the plant, and to defer until later the development of fresh power for the permanent operation of the industry.

With this in view a letter was written from the Department of Mines to the general manager of each of the power companies of British Columbia, as follows:—

June 4th, 1918.

DEAR SIR,—Will you kindly furnish me at your very earliest convenience with the following information:—

Whether your company is in a position to supply electrical power, starting, say, at 15,000 electrical horse-power, in the hope of increasing the power within a few years up to 50,000 electrical horse-power.

At what point could you supply it?

The cost for the same, showing how the cost is estimated.

The voltage and frequency of the electric current.

The extent to which a constant supply can be depended on.

I desire to have this information in order to be prepared with the statistics requisite for a thorough investigation into the possibilities of establishing electric iron-furnaces in British Columbia, which will be investigated by Dr. Alfred Stansfield, of Montreal, who is expected to arrive here on the 10th inst.

Yours faithfully.

The following replies were received:—

BRITISH COLUMBIA ELECTRIC RAILWAY CO., LTD.,
HASTINGS AND CARRALL STREETS,
VANCOUVER, B.C., June 10th, 1918.

The Hon. Wm. Sloan,
Minister of Mines,
Parliament Buildings, Victoria, B.C.

DEAR SIR:

Power for Electric Furnaces.

With reference to your letter dated June 5th, enclosing questions regarding the power available from my company's plants for the operation of electric-smelting furnaces, the following data may assist Dr. Alfred Stansfield in his investigation of this subject:—

Our hydro-electric plants are now developed to supply a greater demand for power than exists at the present time, and a portion of this energy might be used for the operation of electric furnaces. You give no information regarding the load factor or power factor at which this energy could be taken, and the amount of power which we could supply necessarily depends on these factors. It is probable, however, that we could furnish 15,000 electrical horse-power with the power-factor and load-factor conditions under which electric furnaces generally operate.

As regards increasing the supply of power from 15,000 horse-power to 50,000 horse-power during the next few years, our Coquitlam-Buntzen power scheme is now fully developed, and it would not be possible to install additional machinery at either of our Lake Buntzen plants. We have, however, in view other water-power schemes on which stream-flow data is now being obtained and which could be developed in the future as the need arises. It might also be possible for us to purchase an

increasing amount of energy if the load conditions on our system warranted such action. My company is therefore in a particularly favourable position to supply the energy which would be required for a large power-load, subject to great expansion.

From the point of view of power-supply, an electric-furnace plant should be located, if possible, in close proximity to the power-house supplying energy for its operation.

Our water-power plants are located on the east shore of the North arm of Burrard inlet, about fourteen miles from the city of Vancouver. The North arm is almost entirely surrounded by high mountains which slope steeply to the water's edge, and there is therefore comparatively little level ground available on which buildings or other structures could be erected. There is, however, a small piece of level ground, triangular in shape, and about ½ acre in extent, at the north end of our No. 1 Power-house, but whether this piece of ground would be sufficiently large I do not know. The advantages of locating the electric-furnace plant adjacent to our power-house may be summarized as follows:—

(1.) Power could be supplied directly from the power-house bus-bars at 2,300 volts, or possibly at a slightly higher voltage. The use of transformers to step up to a voltage suitable for transmission would thus be avoided, and the construction of additional transmission-lines would be unnecessary. If power were taken at any point on our existing transmission-lines, the voltage would be approximately 34,600.

(2.) Two or more of our generating units could be set aside to supply the furnaces, and this load could therefore be entirely independent of our transmission system. In order to make a similar arrangement for any other location of the furnace plant, the construction of a separate transmission-line from the power-house to the furnaces would be necessary. The operation of the furnace plant independently of the remainder of our system would have obvious advantages, both from the standpoint of the consumer and of the power company.

(3.) A substantial concrete wharf equipped with a power-operated derrick is available at No. 1 Power-house. There is sufficient depth of water at this wharf to allow large scows and steamers of fair size to tie up.

(4.) An abundant supply of pure fresh water at a low temperature and at a pressure of approximately 175 lb. per square inch is available at Power-house No. 1.

On account of the location of this plant, the air is clean and contains fewer impurities than would be found in air nearer the city.

If the location at the north end of Power-house No. 1 does not provide sufficient area, another site might be found about half a mile north of No. 1 Power-house. The construction of a plant at that point, however, would involve the building of a short piece of transmission-line over very rough country and the use of transformers, etc.

It is extremely difficult to reply by letter fully and satisfactorily to your questionnaire, but we shall be glad to go into this matter with Dr. Stansfield on his arrival in British Columbia should he desire to investigate the capacity of our plants.

Yours faithfully,
(Signed.) GEORGE KIDD,
General Manager.

WESTERN POWER COMPANY OF CANADA, LIMITED,
VANCOUVER, B.C., June 13th, 1918.

Hon. Wm. Sloan,
Minister of Mines, Victoria, B.C.

DEAR SIR,—I have your communication of June 5th, asking for information in respect to the possibility of a considerable power-supply for electric iron-furnaces, and I must apologize for delay in making answer.

Western Power Company of Canada, Limited, has now in operation in its plant at Stave Falls three 13,000-horse-power units capable of supplying a maximum demand of about 25,000 kilowatts. Of this power the British Columbia Electric Railway Company may demand 15,000 kilowatts, and the balance is nearly all taken up by the company's other customers.

The company has the greater part of the machinery on hand for the installation of the fourth 13,000-horse-power unit, which can be installed when necessary at a comparatively small cost. The turbine for this unit is, however, at the factory in Zurich, Switzerland, where it was built, and there is some question as to when it could be shipped. If this unit were installed, Western Power Company of Canada, Limited, would be in a position to sell 7,000 to 9,000 kilowatts more than at present.

The company has a second site lower down on the Stave river which, if developed in conjunction with the existing plant, could be built very economically, and from this site there could be produced about 40,000 horse-power continuously.

There is nothing in the development of this lower site which would cause the construction to take longer than usual for this class of work.

Power could be delivered from either of these plants at any point between Stave Falls and Vancouver. The most economical point of delivery, so far as power is concerned, would, however, be at Ruskin, which is close to the power-site. In some ways Ruskin would be an advantageous spot for the establishment of an iron-smelter, but if a point on or near Burrard inlet were selected the transmission-line would not be more than twenty-five miles long.

With the above-mentioned developments a very reliable and constant supply of power could be depended upon, for the power plant has a storage-reservoir twenty-four square miles in area and

25 feet deep; besides, the large snow-field and glaciers which feed the Stave river tend to give great regularity in the annual flow, and no trouble of any kind is experienced in operating the plant in winter on account of ice.

The electric current supplied by Western Power Company of Canada, Limited, is of frequency 60 cycles and can be supplied at 60,000 or 12,000 volts. The company has just connected up a 6-ton electric furnace, which has been installed at the works of the Aetna Iron and Steel Company, at Port Moody, and this furnace, which is now producing pig-iron from scrap, is operating very satisfactorily on the 60-cycle current.

For the supply of electric power for smelting iron ores the question of the "cost of power" is more difficult than the question of "quantity of supply." All the plants in the neighbourhood of Vancouver have been designed and built for the supply of general power business, and it is a question whether the electric-smelting furnace could pay a price for the power that would be remunerative to the power companies.

For smelting steel the quantity of power required per ton of product is such that the steel-makers can pay rates which, though low, are remunerative to the power companies. The amount of power required per ton of iron produced from the ore is, however, so much greater than that required for merely melting iron or steel that the price of power for smelting would have to be very low, and it is difficult to see how a price that would have to be secured for smelting would be remunerative to the British Columbia Electric Railway Company or Western Power Company of Canada, Limited.

Western Power Company of Canada, Limited, is selling power to the British Columbia Electric Railway Company at a price which is equal to three mills per kilowatt-hour, and while it would be impossible for the company to sell more power at this low price, it might be possible to do something in co-operation with the British Columbia Electric Railway Company.

It is difficult to present the whole situation in a letter, but the financial organization of Western Power Company of Canada, Limited, is very simple, and its costs are shown very clearly upon its books and monthly statements, so that it would be an easy matter to show Dr. Stansfield exactly how the situation stands. I would very much like to have the opportunity of explaining our costs and possibilities in an interview, either with yourself or with Dr. Stansfield, as my company is interested in doing everything possible to establish the industry of electric smelting, and any information which we have will be at your disposal.

I am, dear Sir,
Yours very truly,

WESTERN POWER COMPANY OF CANADA, LIMITED.
(Signed.) R. F. HAYWARD,
General Manager.

CANADIAN COLLIERIES (DUNSMUIR), LIMITED,
VICTORIA, B.C., June 21st, 1918.

Hon. Wm. Sloan,
Minister of Mines, Victoria, B.C.

DEAR SIR,—Replying to your letter of June 5th *re* information required *re* electric iron-smelting inquiry:

In reply to your question No. 1, we have developed on the Puntledge river about 10,000 horse-power, composed of two units of 5,000 horse-power each. One unit is about working to its capacity, the second being kept in reserve. We would not be able to supply anything like the power you mention without adding further units. The plant is partly developed for another 10,000 horse-power, which would be the total capacity of the plant owing to the volume of water that can be taken out of Comox lake.

I would be glad some time at your convenience to discuss the power situation with you with a view to any iron-development taking over the power plant as a whole and our installing individual steam plants at each mine.

Yours truly,

(Signed.) J. M. SAVAGE,
General Manager.

THE WEST KOOTENAY POWER AND LIGHT CO., LTD.,
ROSSLAND, B.C., June 13th, 1918.

Hon. Wm. Sloan,
Minister of Mines, Victoria, B.C.

DEAR MR. SLOAN,—I beg to acknowledge receipt of yours of the 7th *re* power-supply for electric furnaces.

At present our developed power is all contracted for, and to supply 15,000 horse-power it would be necessary to extend our hydro-electric plant at Bonnington, and for your information would state that we would be able to supply up to 50,000 horse-power.

It will take some time to prepare an estimate as to the cost of developing the power required, and before starting on this I would be very pleased to meet Dr. Alfred Stansfield in order to get further information. In other words, if it so worked out that power could be used at the point of

development, then we would be in a position to quote a lower price than if we were called upon to transmit at any distance, and it appears to me that if you could arrange a meeting it would place me in a very much better position to comply with your request.

Yours very truly,

West Kootenay Power and Light Co., Ltd.

(Signed.) L. C. Campbell,

General Manager.

During my visit to British Columbia I had interviews on this subject with Mr. George Kidd and other officials of the British Columbia Electric Railway Company; with Mr. R. F. Hayward, General Manager of the Western Power Company; and with Mr. J. M. Savage, General Manager of the Canadian Collieries, Limited. In view of the necessity of locating the proposed plant on or near tide-water, it was not worth while to discuss the possibility of obtaining power from the West Kootenay Power Company.

The information obtained verbally from the above-mentioned officials was substantially as follows:—

The Western Power Company have some unused electric power, but this has been contracted to the British Columbia Electric Railway Company. If this contract could be set aside, the former company might be able to supply as much as 15,000 horse-power, at a rate of, say, $15, for a few years until it was needed for better-paying purposes. On the other hand, the British Columbia Electric Railway Company might be willing themselves to resell this block of power for electric smelting. Although the development expenses of these companies have undoubtedly been high, they could apparently make a reasonable profit by the sale of power at $15. As, however, their usual sale price is not less than $25, it would not pay them to tie up power at $15 which they might be able in a year or two to sell at $25. This argument would not hold in normal times, because they could develop some of their reserve power to supply the growing market; but at the present time it is very undesirable to have to undertake any fresh development, and the power companies naturally wish to sell their developed power to the best advantage.

It may be noted that $25 a horse-power year probably refers to an 80-per-cent. load factor, under which conditions the cost is substantially 0.5 cent per kilowatt-hour. Under regular working conditions an electric-smelting plant should use about 90 per cent. of its maximum load, and $25 power would then cost about 0.43 cent per kilowatt-hour, or, conversely, 0.5-cent power would represent nearly $30 a horse-power year.

The British Columbia Electric Railway Company have some unused power on Vancouver island, but the amount is less than they have on the mainland, and the supply on the island is less dependable owing to the danger of dry seasons.

The Canadian Collieries, Limited, have a water-power on the Puntledge river of which 10,000 horse-power has already been developed, and a further 10,000 horse-power is available for development. Of the 10,000 horse-power now developed, some 5,000 horse-power is employed at the mines, leaving only 5,000 horse-power unused. The management are considering the use of steam-power at the mines in place of electrical power on account of its greater reliability and its small cost, using coal from the mine. It is therefore possible that, if they could obtain a market for the 10,000 horse-power now developed, they might decide to make the above change. I have at present no information with regard to the price at which they would be willing to sell this power. Such an arrangement would afford an immediate supply of 10,000 horse-power, and an additional 10,000 horse-power when development-work again becomes possible.

As it appeared that the surplus developed power of the Western Power Company was controlled by the British Columbia Electric Railway Company, I discussed the situation fully with Mr. George Kidd, of the latter company, and wrote him the following letter:—

Vancouver, B.C., June 18th, 1918.

Dear Mr. Kidd,—I have been appointed, as you are aware, by the Provincial Government to obtain information in regard to the commercial possibility of smelting the magnetite ores of British Columbia by means of electrical power, and for this purpose I should be greatly obliged if you could furnish me with information with regard to the amount and cost of electrical power which it would be possible for your company to place at the disposal of any firm undertaking such operations.

In the smelting of iron ore by electrical energy, the amount of power needed per ton of pig-iron is somewhat high, being in the order of 0.4 electrical-horse-power year, and it is therefore necessary, in order to produce pig-iron commercially, that the cost of this power shall be as low as possible, and shall be considerably below the prices at which such power is sold for mechanical use.

Speaking from memory, the cost of power in Sweden, which is the only locality in which the electric smelting of iron ores has become a commercial fact, is below $10 per electrical-horse-power year, but it seems reasonable to suppose that in this Province, in view of the higher price of pig-iron and supplies generally, a somewhat higher figure would not be out of the question, say as high as $15 per horse-power year. I understand that you could not offer a figure so low as that under ordinary commercial conditions, but only by some special arrangement, as surplus power which you would not guarantee to supply for any definite length of time.

My impression with regard to the development of such a project would be that a furnace using perhaps 2,000 kw. would first be installed, and that after the experimental stage larger furnaces would be put in so as to use 5,000 or 6,000 horse-power, with the expectation of increasing the consumption to about 10,000 horse-power, or possibly as much as 15,000 horse-power. At the latter figure the production of pig-iron would be about 100 tons per day, which is, I believe, as much as would be needed in the near future in this locality.

For the commercial smelting of iron ores electrically it will undoubtedly be desirable to locate the plant ultimately at some point remote from a large city, where the power could be developed specially for this purpose at the cheapest rate and without any cost for transmission. In view, however, of the fact that the electric smelting of iron ore has not reached its final condition in regard to details of furnace-construction, and possibly even in more fundamental respects, it seems undesirable in the start to undertake a new development of power for this purpose, and the more satisfactory method appears to be to obtain power from your own or other developed system for a period of, say, four or five years, with the intention of obtaining a fresh source of power and rebuilding the plant at the end of that period.

With respect to the details of the supply, I may say that the load factor for electric iron-smelting purposes has been very satisfactory, and would probably be as high as 90 per cent. after the initial difficulties of a new plant had been overcome. I have no definite information with respect to the possibility of modifying the demand so as to avoid the peak-load of a distributing system, but in my opinion this would be possible, so that, for example, if the furnaces were using 10,000 horse-power the draught could be reduced to perhaps two-thirds of this amount during three or four hours of the day during the peak-load. It would be possible, further, to run a larger number of furnaces during the winter months, when your water-supply was ample, than in the summer months, when there might be a shortage of water, but this would, of course, reduce the output from a given cost of electrical installation.

The power factor of these furnaces has been found to be very high in Sweden, where the supply is one of 25 cycles, but in California, using a 60-cycle supply, the power factor of the furnace has been found to vary from nearly unity when the furnace is empty to as low as 65 per cent. when the furnace is ready for tapping. I should think, however, that if special attention were paid to this side of the design of furnace, it could be made to keep the power factor above 80 per cent. at all times.

With respect to the voltage of the supply, I may point out that in these furnaces the regulation is effected by a series of taps on the primary of the service transformers, there being usually three such transformers for each furnace which are independently regulated. On account of this the transformers are of special design, and the primary voltage would not be more than about 10,000, and preferably in the order of 2,000.

With regard to the location of an electric-smelting plant, I cannot speak at all definitely, but as a basis for discussion it would be satisfactory for you to take the site at Port Moody, adjacent to the present electric-furnace plant.

Further, with regard to the date at which the use of power might be expected to commence, it will require a month or two for the completion of this report and for the Government to study it, after which, if action were decided on immediately, I understand that in view of the difficulty of obtaining electrical supplies it would be necessary to allow as long as twelve months for the construction of the plant, which would thus place the possible start of operations in the fall of 1919.

I believe that the above will give you the more essential facts with regard to the possible use of electric power for smelting iron ores. I expect in the course of a week or ten days to be back in Vancouver, and will then be able to give you further information in view of the conditions which I expect to find in California. I should be very glad if in the meantime you could draw up some memorandum which would give me information in regard to the price and amount of power which might be available for this purpose and any available particulars with regard to the conditions of the supply.

I remain,
Yours very truly,
(Signed.) ALFRED STANSFIELD.

In view of the fundamental importance of the information asked for, I was hoping to receive a reply before leaving British Columbia. On returning from California early in July, I found that no reply had been prepared, and that the street-railway strike would make it impossible for the company to supply the information in the near future. I was therefore obliged to prepare my report without any definite information in regard to the price at which power could be obtained. Under the circumstances, I made the provisional assumption that some 10,000 kw. of electrical power could be obtained at a cost of $15 per electrical-horse-power year of about 85 or 90 per cent. load factor.

On September 19th, when my report was nearly completed, I received the following letter from Mr. George Kidd:—

BRITISH COLUMBIA ELECTRIC RAILWAY CO., LTD.,
VANCOUVER, B.C., September 12th, 1918.

Dr. Alfred Stansfield,
Department of Metallurgy,
McGill University, Montreal.

DEAR SIR:

Electric Smelting of Iron Ores.

With reference to your recent visit to this Province and in regard to the information then promised you respecting the supply of electric power available in the districts served by this company on the mainland and Vancouver island for the purpose of smelting iron ores, I regret that there has been unavoidable delay in submitting this data at an earlier date.

Mainland (Vancouver and Districts).—Since our representatives discussed with you the power situation there has been a very considerable change in local conditions, caused by contracts having been entered into disposing of our excess electrical energy on a surplus-power basis. Any contracts entered into would not, therefore, have to be made on a commercial-rate basis.

We would be willing to enter into short-term contracts to furnish power from 2,000 to 10,000 kw. for restricted service during this company's peak-load periods from its water-power plants at a rate of 0.5 cent per kilowatt-hour, based on a power factor of 80 per cent. Should the average monthly power factor fall below 80 per cent., then this rate of 0.5 cent per kilowatt-hour would be increased in the ratio of 80 to the actual average monthly power factor at which the furnace is operated. The minimum charge would be 50 cents per month per connected horse-power, based on the full capacity of the furnace installation.

There are two sites on the east shore of Burrard inlet which may prove suitable for an electric iron-ore-smelting plant. One of these is at a distance of half a mile north of No. 1 Power-house; the other is about five miles south of No. 1 Power-house, in the vicinity of Bidwell bay. There is no data available regarding the areas of vacant land at these places, and it is impossible to say whether sufficient level ground could be obtained.

The site half a mile north of No. 1 Power-house would be most suitable from the power-supply standpoint, and would involve the construction of only half a mile of transmission-line.

The Port Moody location, referred to by you, would be satisfactory from a rail-transportation point of view, and by the time an electric-smelting plant would be ready for operation we would probably arrange to supply the necessary power at that point.

Vancouver Island (Victoria and District).—On Vancouver island we have at present an excess of power of about 2,000 kw. which we are prepared to dispose of on a surplus-power basis at $15 per electrical-horse-power year, in blocks of not less than 500 kw. and the power factor to be not less than 80 per cent. This figure is not a commercial rate, but an experimental rate, and could only be granted for a short-term contract, and, of course, subject to peak-load restrictions and depending upon the amount of storage-water which we may have available in our reservoirs during the dry season.

This amount of power could not be reserved, and would only be available after the filling of all requirements for electrical energy for the company's use and those of its present and future customers.

In respect to available sites on the island, there are several which may be found suitable. One at Jordan river, near our power plant; another at Brentwood, on the Saanich peninsula, adjacent to our steam auxiliary power plant. Other sites might be found at Sooke harbour or near Esquimalt.

Covering both the mainland and island systems, 3-phase, 60-cycle, alternating current would be supplied at or near our existing transmission-lines, which are of sufficient capacity to supply the furnace plant; the transmission-line voltage would be 34,600 or 11,000, depending upon the location on the mainland, and 60,000 volts on the island.

I trust the above will generally cover the information desired, and should there be any further particulars needed we shall be very glad to supply same upon hearing from you in this matter.

Yours faithfully,
(Signed.) GEORGE KIDD,
General Manager.

Before leaving British Columbia I wrote the following letter, at present unanswered, with a view to obtaining further information about the supply of power from the Canadian Collieries, Limited:—

VICTORIA, B.C., July 9th, 1918.

Honourable William Sloan,
Minister of Mines, Victoria, B.C.

SIR,—In the letter to yourself of June 21st from the Canadian Collieries with regard to power for electric smelting, Mr. Savage states that he might be willing to install steam plants at each of his mines and to turn over the whole of the hydro-electric power for the purpose of iron-smelting. This would apparently supply 10,000 horse-power already developed, with a further 10,000 horse-power now partly developed.

I should be glad to learn, for the purpose of my report, at about what price per horse-power year of 80 per cent. load factor he would be able to supply these blocks of 10,000 or 20,000 horse-power for the purpose of electric iron-smelting at a point on tide-water in Comox harbour or Baynes sound.

I regret that owing to Mr. Savage's absence from the city I have not been able to discuss these matters with him personally.

I have the honour to be,
Sir,
Your obedient servant,
(Signed.) ALFRED STANSFIELD.

With a view to the future development of the electric-smelting industry, I obtained information with regard to water-powers in British Columbia that could be developed for the purpose of electric smelting. In general, it appeared that there was ample power available, and that some of these powers could be developed so cheaply as to yield electric power for smelting purposes at about $10 per continuous horse-power year. Mr. H. K. Dutcher, of Vancouver, considered that the following powers could be developed at about that cost:—

	Horse-power.
Campbell river	100,000
Cheakamus river, Howe sound	200,000
Stamp falls, Alberni	40,000

Mr. William Young, Comptroller of Water Rights, Victoria, gave me the following particulars with regard to the Campbell River and Stamp Falls power-sites:—

MEMORANDUM RE CAMPBELL RIVER POWER-SITE.

The drainage area is approximately 520 square miles; no definite precipitation data are available, but the British Columbia Hydrometric Survey report a variation from 80 inches at the mouth to 130 inches at headwaters.

Gore & McGregor's second report proposes the erection of a dam at Irene pool, mean water-level at this place being 415 feet; the power-house to be situated on the canyon, with an assumed flood-level of 98 feet. The proposed elevation of the dam is 440 feet, giving a head of 342 feet.

A constant discharge of 2,700 c.f.s. is assumed, calculated to develop 78,000 to 80,000 horse-power, with another 6,000 horse-power by storage. This discharge is, however, too high, as the mean over six years is 2,650 c.f.s., with a minimum of 450 c.f.s., and one low-water period of nine weeks below 1,000 c.f.s. On the Strathcona survey map, tracing of part of which is attached, the level of Lower Campbell lake and McIvor lake is given as 543 feet.

Stamp Falls Development—Summary of Report by Ritchie-Agnew Power Co., Ltd.

Drainage area	360 sq. miles.
Results of seven months' gaugings, continuous flow available	2,394 cu.-sec. feet.
Estimated run-off per square mile of drainage area	6 cu.-sec. feet.
Estimated storage per square mile of drainage area from short mass diagram	716 acre-feet.
Estimated mean annual run-off	2,160 cu.-sec. feet.
Storage available on Great Central lake, dam 20 feet high	307,200 acre-feet, or 853 acre-feet per sq. mile of drainage area.
Pipe-lines, three 11 feet diameter and one 7 feet 6 inches diameter	600 feet long.
Intake dam, crest length	605 feet.
Maximum height	90 feet.
Mean effective head	110 feet.
Power available based on 60 per cent. load factor, 80 per cent. efficiency factor	35,000 horse-power.
Proposed installation, three units	10,000 horse-power; 5,600 kw.
Proposed installation, one unit	5,000 horse-power; 3,000 kw.
Transmission-lines to Alberni, seven miles	12,000 volts.
Transmission-lines to Nanaimo, sixty miles	66,000 volts.

The Stamp Falls power is estimated at 35,000 horse-power on a basis of 60 per cent. load factor. As, however, an electric-smelting plant would operate at 85 per cent. or even 90 per cent. load factor, this will only correspond to about 24,000 horse-power or 18,000 kw. Such a power could be developed and utilized entirely for electric smelting. The plant could be located at or near Port Alberni, with a seven-mile transmission-line, and could obtain iron ores from the deposits around Barkley sound, from Nootka sound, and from the Renfrew district. An alterna-

tive plan would be to transmit the power about fourteen miles to Deep bay, on the east coast of the island, where ores could be obtained readily from Texada island and Redonda island.

The Campbell River estimate indicates about 84,000 continuous horse-power, or 100,000 horse-power, at 84 per cent. load factor. This would be more than could be utilized for electric smelting in the near future, and it would be necessary to develop it for use in part by some other large consumer of electric power. An electric smelter placed on tide-water within a short distance of the proposed power-house would be supplied with ore very readily from Redonda island, and also from the deposits No. 4 and No. 5 in the Quinsam Lake district.

The water-power available on the Cheakamus river is estimated at 200,000 horse-power, which is twice as large as the Campbell River power, and would need development in conjunction with other power-users. It is not situated so conveniently with regard to the ore-supplies as the powers on Vancouver island, and it may ultimately be needed for the development of Vancouver City.

With regard to the general estimate that these water-powers would yield electric power for smelting at about $10 a continuous horse-power year, it will be understood that such development would be out of the question at the present time in view of the high cost of labour and supplies and the difficulty of obtaining apparatus. In view of the present unsettled state of labour, it is useless to try to predict how long it may be before these costs become low enough to permit of economic construction, or whether costs will ever again revert to pre-war levels. It seems probable, however, that within a few years after the termination of the war, wages and costs in general will arrive at some more settled condition; and even if these are twice as high as before the war, that will not prevent construction-work, as the price of commodities generally will also be much higher than before the war and will tend to assume a definite relationship to the enhanced cost of labour and supplies.

The bearing of this consideration on the electric smelting of iron ores in British Columbia may be stated as follows: Before the war with electric power at $10, and other costs as they were then, the cost of a ton of electric pig-iron, using the Swedish process, would be between $20 and $25, leaving only a small profit, as pig-iron was selling at $25, unless a higher price could have been obtained for electric pig-iron. If, after the war, prices were to settle down at double the pre-war figures, electric power would cost $20 and pig-iron would bring $50, while labour would be about as high as at present. The cost of making electric pig-iron might be about $45, leaving the same proportionate profit as before the war. The reason which makes electric pig-iron making profitable at the present time is the temporary dislocation of prices during which the cost of pig-iron and steel has risen more rapidly than the cost of power, labour, and other supplies.

In regard to the cost of power for electric smelting, it may be pointed out that in developing a power for this purpose the turbines and electrical machinery will cost less per kilowatt-hour utilized than in the case of a power plant for ordinary power-users. This is because the load from a smelting plant can be kept almost constant for twenty-four hours daily and 365 days in the year, whereas an ordinary plant has to supply a very varying load, and so the machinery is not used to the best advantage. It follows that electrical power for smelting purposes can be developed to cost considerably less per kilowatt-hour than when developed for ordinary use.

APPENDIX V.

THE SUPPLY OF CARBONACEOUS REDUCING MATERIALS.

In the electric smelting of iron ores, carbonaceous material is needed for reducing the ore to the metallic state and for supplying carbon to the pig-iron. The amount needed varies from about ⅓ to ½ ton per ton of pig-iron produced. For this purpose either charcoal or coke may be used, but charcoal is preferable on account of its greater purity—that is, freedom from sulphur and ash—and because its physical condition renders it more suitable for electric-furnace operation. For the production of special grades of pig-iron charcoal would always be preferred,

but for ordinary grades a good quality of coke, if obtainable at a low price, might be employed on account of its smaller cost. In British Columbia, however, nearly all the coals are abnormally high in sulphur and ash, and the cost of coke produced from them is so high that there is no inducement to use it instead of charcoal in a country where timber is so abundant. While, however, charcoal should be regarded as the normal supply of reducing carbon, coke can be used to some extent in admixture with charcoal as a substitute without seriously affecting the operation of the furnace, and it can be used in this way in case of shortage of charcoal.

There is at present no large-scale production of charcoal in British Columbia, and the small quantities now obtainable cost in the order of $30 a ton, a price which would be prohibitive for iron-smelting. The production of 20 or 30 tons of charcoal daily constitutes an important industry, utilizing 50 to 70 cords of mill-waste and yielding by-products that will meet a part of the cost of operation. The problems involved are many and complicated, and before discussing them in detail it may be stated: (1) That the mill-waste of Douglas fir should be suitable for the production of charcoal for electric smelting; (2) that while the lumber-mills in and near Vancouver utilize their waste very largely, there are mills situated at more remote points from which an adequate supply of waste could be obtained at a nominal cost; (3) that the by-products from this material are not so valuable as to make it desirable to treat the wood in retorts for the recovery of turpentine, etc., regarding the charcoal as a by-product, but that it should be possible to char the wood on a large scale for the production of charcoal and still to recover a part of the by-products; such a plant would be located at or near one or more sawmills, and the charcoal would be transported by water to the smelting plant; (4) if a charcoal industry were established in suitable relationship to the lumber industry, charcoal should be produced and delivered to the smelter at a cost of about $6 or $8 per ton, corresponding to $3 or $4 per long ton of pig-iron.

An electric iron-smelting industry in British Columbia will almost certainly use charcoal, wholly or in large part, for the reduction of the iron ore. The establishment on an economical basis of a charcoal-making industry will therefore be essential to the commercial production of electric pig-iron.

METHODS OF CHARCOAL-MAKING.

Charcoal is used in some parts of the world for the production of "charcoal-iron" in small blast-furnaces. In general, hard woods are preferred for making this charcoal, because the resulting charcoal is stronger and better able to stand the load in the furnace without crushing, and because hard woods yield more valuable by-products in their distillation, which meet to a considerable extent the cost of the operation.

For the electric smelting of iron ores the strength of the charcoal is less important, because the height of the shaft is less, even in the Swedish furnace, and because, unlike the blast-furnace, no blast of air need be forced through the charge, although in the Swedish furnace there is a circulation of the furnace gases.

In Sweden the charcoal for electric smelting (as well as for blast-furnaces) is made from soft wood, and the charcoal-making is carried on at numerous points throughout the country, using in part the waste wood from the lumbering industries.

E. Arosenius (International Institute of Agriculture, Rome, January, 1918) gives some particulars of the Swedish charcoal industry. He states that the raw materials used in Swedish sawmills are soft woods, mainly Scotch pine and spruce. He estimates as follows the production and uses of charcoal in Sweden during 1913:—

	Bushels.
Forest wood charred in ovens	8,000,000
Wood-waste charred in piles	29,000,000
Wood-waste charred in ovens	1,300,000
Forest wood charred in piles (about)	75,500,000
Charcoal imported from Finland and Norway	3,300,000
Charcoal used in metallurgical works	117,300,000

For rough purposes we may assume a bushel of charcoal to weigh 20 lb., so that the consumption in Sweden must be over 1,000,000 tons. If this were all used in electric smelting it

would represent a production of at least 2,000,000 tons of pig-iron. Actually, however, a large proportion is still employed in charcoal blast-furnaces and in the production of wrought iron, for which purposes the consumption of charcoal per ton of iron is much larger.

I have not been able, in the time available, to obtain full particulars of Swedish charcoal-making, but I would recommend that such information should be obtained before deciding on the methods to be used in British Columbia.

In the Coast districts of British Columbia the largest production of any variety of timber is the Douglas fir. In 1917 some 676,000,000 board-feet of this wood was cut in these districts. The Douglas fir appears to be suitable for the production of charcoal, and I have, for my own information, made a small amount of satisfactory charcoal from a sample of this wood.

Apart from the use of "piles," which we need scarcely consider, charcoal is made in "kilns;" in "retorts," and in "ovens."

Kilns.—These are large brick structures holding as much as 50 cords of wood. The heat needed is furnished by the combustion, within the kiln, of part of the volatile products and a little of the charcoal itself. A part of the by-products can be recovered, the loss of charcoal is not very great, and this is probably the cheapest method of making charcoal in cases where the by-products are of secondary importance.

Retorts.—These are small, expensive to operate, and only warranted when large amounts of valuable by-products are obtainable.

Ovens.—These are large retorts. The wood to be charred is contained in cars which are run into the ovens, and after the operation the cars, which now contain the charcoal, are run out and placed in large steel boxes where they can cool out of contact with the air. The ovens are heated externally by means of waste wood and the distillation gases. Ovens give a maximum production of the volatile by-products and the charcoal, and are largely used for charring hard wood.

In the charring of hard woods, such as beech, birch, and maple, considerable amounts of valuable by-products are obtained. These are wood-alcohol, acetate of lime, and tar. At the present time the value of these products is greater than that of the charcoal, and it pays to treat such woods in ovens in order to obtain the by-products. The soft woods have different distillation products, and it does not always pay to char them in ovens. Some of these, such as the long-leaf pine, yield considerable amounts of turpentine, pine-oils, and tar, while the production of alcohol and acetic acid is usually too small to pay for their recovery. The following is an average yield from 1 cord of pine-wood (United States Department of Agriculture, Forest Service Circular 114, 1907):—

Refined turpentine	7-12 gallons.
Total oils, including tar	50-75 „
Tar	40-60 „
Charcoal	25-35 bushels.

The turpentine is of inferior quality and the operation has often been unsuccessful commercially.

In British Columbia the Douglas fir is the wood that would probably be used for charcoal-making. Tests have been made on the production of turpentine and pine-oils from this timber, and by the use of selected resinous material considerable quantities of these products have been obtained, both by the ordinary charring process and by steam distillation—the latter being preferable for the production of turpentine and oils. The latter process has appeared particularly attractive because the oils have been found to be suitable for use in the flotation process. Careful investigation has shown, however, that the yield of these by-products from the average run of Douglas fir is so much less than is obtained from the southern pines that the process holds out little hope of commercial success. In view of this it would seem best to char the wood in the cheapest possible manner for the production of charcoal, and either to ignore the by-products altogether, or to save only such as could be obtained at slight additional expense.

Reference may be made to a paper on the "Destructive Distillation of Fir Waste," by George M. Hunt, of the Forest Products Laboratory of the United States Department of Agriculture, Madison, Wisconsin. The paper deals specially with the yields of valuable products obtained by the distillation of Douglas fir. The following is the result of a series of experiments on the destructive distillation of mill-waste:—

Table I.—Average Yields of Valuable Products per Cord of 3,800 Lb. of Douglas Fir Mill-waste.

District.	Turpentine.	Other Oils.	80 per Cent. Alcohol.	80 per Cent. Acetate of Lime.	Still Tar.	Separator Tar.	Charcoal.
	Gals.	Gals.	Gals.	Lb.	Gals.	Gals.	Lb.
Skagit County	0.8	4.4	3.9	71.1	10.7	16.3	1,072
Lake Washington ..	0.8	3.3	3.7	81.7	12.4	15.2	1,025
Grays Harbour	0.7	3.3	4.4	77.4	10.9	26.9	1,175
Hood's Canal	0.5	2.9	5.3	94.5	12.2	16.4	1,136
Average for State	0.7	3.5	4.3	81.1	11.5	18.7	1,102

The yield of turpentine and other oils is far less than is obtained from the southern pines, and the combined value of the by-products is too small to warrant the use of the expensive retort or oven process for their recovery. Mr. Hunt states:—

"In the destructive distillation of Douglas fir the value of the charcoal obtained will be more than the value of all the other products combined. Good charcoal, however, can be produced by burning in kilns and allowing the by-products to go to waste. The simplicity of a charcoal-kiln and the large units which may be employed make its first cost and subsequent operation much cheaper than the operation of a complete distilling and refining plant, and, unless the value of the extra products obtained at a complete plant is greater than the additional cost of operation, there is no advantage whatever in saving them. The yields obtained in these experiments do not show that there is any advantage."

He draws the following conclusions:—

"(1.) The steam and extraction process is not applicable to Douglas fir on account of the very low yield of turpentine and resin and the inferior quality of the latter.

"(2.) The utilization of Douglas fir stumps by destructive distillation is at present impracticable on account of of low yields and high cost of handling the raw material. The yields are practically the same as from mill-waste, which can be more readily obtained and more cheaply handled.

"(3.) The utilization of Douglas fir mill-waste by distillation has not in the past proved successful, and under present market conditions, and with the methods of distilling and refining now in use, it is of doubtful feasibility:—

"(*a.*) Because the yields are, on the whole, considerably lower than those of the southern pine and Norway pine, which are hard to distil at a profit:

"(*b.*) Because the products have not been standardized and successfully refined, and are hard to sell:

"(*c.*) Because there is only a limited market on the whole Pacific coast for wood-distillation products."

It will be seen from Table I. that a cord of mill-waste, weighing 3,800 lb. yields about 1,100 lb. of charcoal when treated in a retort. The yield in a kiln would be slightly less than this, but it seems safe to assume that 2½ cords of such waste would suffice for the production of a net ton of charcoal.

The regular charcoal-kiln is a circular brick structure holding about 50 cords of wood. It is charged and discharged by hand, and the volatile by-products are partly saved by being drawn through condensers; the permanent gases being returned and burnt in the kiln. If a battery of these kilns were established at a large lumber-mill so that the waste wood could be delivered mechanically to the kilns, the production of a ton of charcoal might cost:—

2½ cords of mill-waste at $1	$2 50
Labour and other expenses of operation after deducting the value of the by-products	2 50
Carriage of charcoal to smelter	1 00
Total	$6 00

For the electric-smelting plant about 40 tons of charcoal would be needed daily. Each kiln would yield 20 tons, but as the process is slow, requiring about fifteen days, some thirty kilns

would be needed. The consumption of mill-waste would be about 100 cords daily. The lumber-mills in Vancouver are able to dispose of their waste as firewood in the city, but it seems reasonably probable that an adequate supply could be obtained at a nominal price by locating at one or two mills away from the city. In regard to mill-waste, it should be remembered that a large part of this is "slab-wood," and this consists largely of bark, which yields an inferior charcoal. I made some charcoal from Douglas fir bark and found that the charcoal, although light and weak, was coherent, and could probably be used for electric smelting in the open-pit type of furnace in admixture with wood charcoal. The wood charcoal is extremely pure, containing scarcely any ash, but the bark charcoal from my experiment contained as much as 3 per cent. of ash. This probably indicates an appreciable amount of phosphorus, which would be undesirable when smelting for low-phosphorus pig-iron.

For the economical charring of mill-waste it seems likely that a kiln could be devised that would allow of mechanical charging and discharging, and thus reduce the charge for labour, which must be the largest item in the cost of charcoal-making. I have given some attention to the design of such a kiln, but realize that numerous problems are involved, and that much experimental work would be needed before a full-sized kiln could be constructed. The recovery of by-products can be effected very economically by the use of the Cottrell electrical-precipitation process. Dr. J. G. Davidson has made a special study of this, and expects to continue his experiments at the plant of the Electrical Turpentine Syndicate in Vancouver.

One recent process for the production of charcoal is that of W. Thomas, which depends on forcing heated distillation gases through the charge of wood. I met Mr. Thomas and visited his plant in Nanaimo, but he had not at that time any information on which I could base a conclusion in regard to the cost at which he could make charcoal. Messrs. McPherson and Fullerton Bros. have, however, carried out a preliminary test with this process, and have sent me figures from which I conclude that if mill-waste could be supplied at $1 a cord, charcoal could be made at a cost of about $6 per net ton.

In regard to the possibility of establishing an electric-smelting plant in some more remote location, such as the Campbell river, and in view of the difficulty and expense of carrying so bulky and fragile a material as charcoal, it might be necessary to cut timber specially for charcoal-making near the plant. Such timber felled, carried to the charcoal plant, and cut into pieces of suitable size would be likely to cost at least $3 a cord, and allowing 2½ cords per ton of charcoal, the wood alone would cost $7.50. Taking the net cost of charring as $2.50, after allowing for the value of the by-products, the final cost of a net ton of charcoal would be $10.

Charcoal Consumption per Ton of Pig-iron.

For the production of pig-iron in the electric furnace, I estimate on a consumption of 0.4 net ton in the Swedish furnace, or 0.5 net ton in the open-pit furnace, per gross ton of pig-iron. In view of the statement, frequently made, that only ⅓ ton of charcoal is needed, I may explain why the higher estimate should be accepted.

It is recognized that in the open electric furnace reduction of iron oxide is effected substantially by means of carbon, with the liberation of carbon monoxide, which burns above the charge and is wasted. Theoretically, 1 ton of foundry pig-iron will need 0.269 ton of carbon for its reduction from magnetite and about 0.035 ton for its carburization, assuming it to contain 3.5 per cent. of carbon. It will also need 0.026 ton of carbon for the reduction of 3 per cent. of silicon. The combined carbon requirement will thus be 0.33 ton per ton of pig-iron. On account of the well-known purity of wood charcoal, it is often assumed that it contains at least 90 per cent. of carbon, and that some 0.38 ton of charcoal will be sufficient per ton of pig-iron. Actually, however, charcoal contains from 70 to 75 per cent. of fixed carbon; the average over a long period in Sweden being 73 per cent.; the balance being volatile matter and moisture, and accordingly some 0.44 to 0.47 ton of charcoal must be provided. In view of the custom of weighing iron by the long ton and charcoal by the short ton, it appears that ½ net ton of charcoal will be required. There is, indeed, a small amount of reduction by carbon monoxide, even in the open furnace, but this will be balanced by the combustion of charcoal at the top of the furnace and the other mechanical losses. Assuming that 5 per cent. of the carbon monoxide is utilized in the open furnace and 25 per cent. in the Swedish furnace, we find that 0.4 net ton of charcoal should be enough in the latter type of furnace. Mr. Gronwall, in his estimate, quoted in my report on "Electrothermic Smelting of Iron Ores in Sweden," allows 0.370 metric ton of charcoal

per metric ton of foundry iron, and this would be 0.414 net ton per long ton of pig-iron. It will be seen, therefore, that my estimate is supported both by theoretical calculations and by the results of practice in Sweden.

I place here an account of my experimental production of charcoal from Douglas fir and of my investigation of Mr. Thomas's processes for the production of coke and charcoal.

Charcoal from Douglas Fir.

(Test made at McGill University, August, 1918.)

I was furnished by Dr. Bates, Superintendent of the Forest Products Laboratories, with samples of wood and bark of the Douglas fir, on which the following tests were made:—

I. Piece of Wood.—14 inches long, 6 inches wide, and 4.75 inches high. The piece was not square, but of the section shown. Weight, 3,375 grammes; moisture, 14.74 per cent. of dry wood or 12.85 per cent. of moist wood.

The wood was placed in a muffle-furnace and heated slowly to a temperature of 440° C. The operation lasted in all about seven hours, and it remained at the highest temperature for about one hour. When cool the charcoal came out in three pieces, it having broken transversely. The pieces put together measured 13 x 5.5 x 4 inches, or 71.6 per cent. of the original volume, and the weight was 1,134 grammes. This is 33.6 per cent. of the original weight, or 38.5 per cent. of the weight of the dry wood. The charcoal was tested by heating to redness in a covered crucible and lost 28 per cent. of its weight; as the ash is very small, this means 72 per cent. of fixed carbon. The charcoal, while not quite as dense as hardwood charcoal, was satisfactory in character, except that a part of the interior was soft and spongy. This was not due to a difference in the wood itself, as this was uniform, but to the decomposition of the issuing gases, which consolidated the outer portions of the charcoal. These denser layers varied from 0.25 to 1.5 inches in thickness, and occurred on all the surfaces. The ash in this charcoal was extremely low, being only 0.1 per cent.

II. Piece of Bark.—12.25 inches long, 6.75 inches wide, and 4.4 inches thick, of the shape shown in section. Weight, 2,595 grammes; moisture, 16.73 per cent. of dry bark or 14.34 per cent. of moist bark.

The bark was placed in the muffle-furnace and heated like the wood, except that the final temperature was a little higher, being about 500° C. Next morning it was found that air had entered through cracks and had burned part of the charcoal, which was actually ignited when taken out. The charcoal was in one piece and measured 11.25 x 6.5 x 4.5 inches, or 91 per cent. of the original volume. It will be noticed that the bark had swelled somewhat in a radial direction while charring. The weight was 882 grammes, and it would probably have been 890 grammes if no combustion had taken place; 890 grammes would be 34.3 per cent. of the original bark or 40.1 per cent. of the dried bark.

The charcoal lost 19 per cent. of its weight on ignition in a closed crucible, which would correspond to 78 per cent. fixed carbon, allowing for the ash. The ash was 3 per cent. of the charcoal.

The charcoal was light and weak, so that it would crush easily under a load; it was reasonably coherent and did not crumble very much on handling.

Conclusion.—The slow charring of Douglas fir wood yields a charcoal which, though not as strong and dense as hard-wood charcoal, would be quite satisfactory for use in electric smelting. The charcoal is extremely free from ash, from which it may be inferred that the phosphorus will be very low. The bark yields an inferior charcoal which, however, might be used in admixture with the wood charcoal. The high percentage of ash makes it probable that the phosphorus would also be high, and indicates that bark charcoal should probably be excluded in the production of specially pure low-phosphorus pig-iron.

Comparative tests were made on the density of pieces of charcoal from Douglas fir and from hard wood. The volume of each piece was determined by surrounding it with fine sand. The following results were obtained:—

	Specific Gravity.	
Douglas fir charcoal	0.394 0.363	mean 0.38.
Douglas fir bark charcoal	0.308 0.289	mean 0.31.
Hard-wood charcoal	0.441 0.486	mean 0.46.

I wish to express my thanks to Mr. Stokes, of the Forest Products Laboratories, who made the moisture determinations and prepared the pieces of wood and bark for the test.

A NOTE ON THE WALTER THOMAS PROCESSES FOR MAKING CARBONIZED FUEL.

At the request of the Honourable Mr. William Sloan, I made a short investigation of these processes and of the plant at Nanaimo where some of them have been tested.

In general, these processes are for the purpose of producing coke from coal and charcoal from wood. The general principle employed is to heat the coal or wood in a closed vessel by passing through it hot gases obtained by distillation from the same material; these gases being heated in a pipe stove or a regenerative brick stove. The distillation products from the fuel are cooled and treated by the Cottrell electrical-precipitation process, thus obtaining oils and other condensible by-products; the permanent gases being then reheated and forced into the coal or wood, as stated above; the chief advantage to be gained being the production of certain oils which would not be obtained by the usual high-temperature distillation. Another claim is that the passage of the distillation gases through the fuel causes the deposition of carbon, and thus increases the yield and improves the quality of the coke or charcoal. It is also claimed that the operation will be more rapid, as the heat is conveyed by the gases directly into the fuel to be treated instead of by conduction through the walls of a retort.

Another process for the production of charcoal from sawdust is carried out in a revolving drum, which is heated by burning the permanent gases from the distillation in flues in the walls of the drum. The charred product is briquetted with tar, and is heated in a carbonaceous gas in such a way as to produce a very dense charcoal.

I visited the plant at Nanaimo on July 4th, 1918, in company with Mr. Walter Thomas and Mr. Wm. Brewer. The plant occupied two or three rooms in an old brewery, and consisted of the following apparatus:—

(1.) A distillation retort consisting of a vertical iron cylinder about 14 feet high and 5 feet in diameter. It was lined with bricks, so that the internal diameter was about 3 feet at the top and about 3 feet 6 inches at the bottom. The retort was intended for treating coal, which was introduced through a door in the top, while the resulting coke was withdrawn through a lateral door near the bottom. The coal rested on a perforated iron plate level with the bottom of this door, leaving a space below the plate for the removal of the products of distillation.

(2.) A pipe stove consisting of some iron pipes heated by a fire of wood, through which the permanent distillation gases passed on their way to the retort.

(3.) A condenser consisting of some water-cooled pipes for cooling the vaporous products of distillation.

(4.) A "treater-tube" or electrical-precipitation apparatus, consisting of a vertical pipe containing centrally an insulated piece of piano-wire, which could be charged to 60,000 volts, for precipitating the oil and tar vapours.

(5.) A fan or blower for causing the circulation of the gases.

(6.) A series of pipes connecting the several apparatus together, and permitting by means of valves various changes in the circulation system.

When the plant was in operation a charge of coal was placed in the retort, which was then tightly closed. The blower was started and the pipe stove heated. The air contained in the system was forced in a heated condition into the top of the retort; it passed down through the coal and passed out at the bottom, after which it passed through the condenser and the "treater-tube," and so back to the blower and again through the pipe stove to the retort. As the coal became hotter, gases would be given off, which would replace the air in the system, and thus after a time the blower would be forcing distillation gases through the stove and retort.

The plant was not in operation at the time of my visit, but had previously been tried with about 9 tons of coal from the Nicola valley. I understand that the charge of coal in the retort was about 3 tons. Difficulty was experienced in making the gas pass through the coal in the retort, using a pressure on the inlet side and a suction on the outlet side of about 10 inches of water. Oils were obtained, amounting to about 60 gallons for the 9 tons of coal, and a semi-coked smokeless fuel was obtained from the retort; but as far as could be observed there was no production of permanent gas.

The above-mentioned test was made about February, 1917, and lasted for about five weeks. Dr. J. R. Davidson, of the University of British Columbia in Vancouver, installed and operated the electrical-precipitation apparatus and supervised the whole test. I have discussed the matter with him, and he stated that the non-production of any permanent gas was inexplicable to him, as there was not enough leakage to account for it, and that in view of this it was not desirable to attempt to draw any definite conclusions.

Speaking generally, however, I may point out that the processes have the following drawbacks:—

(1.) When treating coking-coal it will be difficult to pass the gas through it at all rapidly, and the coking will consequently be extremely slow.

(2.) The circulating gases have not a great heat capacity, and a very rapid circulation will be needed to obtain even moderate rapidity of operation. This will be less serious in the case of wood than of coal, as the necessary temperature is so much lower.

(3.) The thermal efficiency of the system will be small, as much of the heat produced in the pipe stove will go up the chimney, and the fuel-consumption will in consequence be high.

(4.) The pipe stove will be costly to build and to maintain, as the pipe will burn out rather quickly.

(5.) It does not seem probable that the circulating gases will deposit carbon in the coke or charcoal, as claimed, because they must first pass through the pipe stove, which must be at a higher temperature than the fuel, and they are more likely to decompose and deposit carbon in the pipe stove. It is conceivable, however, that the coke or charcoal may in some way cause the deposition of carbon in itself, even though the gas has previously been exposed to a higher temperature.

Mr. Thomas has shown me samples of his carbonized charcoal, which is certainly a very satisfactory product. He has not, however, as far as I am aware, published or patented his method of making this dense product, and I have no reason for supposing that it can be done economically on a large scale.

In conclusion, although I am not prepared, on the information at my disposal, to recommend the processes and apparatus of Mr. Thomas for commercial operation, I recognize his ingenuity as an inventor, and think it quite likely that some of his ideas, if carefully tested and applied, may prove fruitful. Since returning to Montreal I have heard from Messrs. McPherson and Fullerton Bros., of Vancouver, who have taken over the Thomas patents and have been making some tests at the Nanaimo plant. I have received from them samples of charcoal made from fir-wood in the large retort. The operation was stated to occupy only six hours and the charcoal appears to be of satisfactory quality. I have also received from them some small briquettes made from charcoal powder by the Thomas process. They state that they can obtain mill-waste for a few cents per cord; and apparently they can make charcoal at a cost of about $5 per ton.

SUBSTITUTES FOR CHARCOAL IN ELECTRIC SMELTING.

Coal and Coke.—For the purpose of this investigation I have been furnished by Mr. Wm. Fleet Robertson and others with information with regard to the supplies of coal and coke in British Columbia. In view of my belief that charcoal will be the main reducing agent in the electric smelting of iron ores in this Province, I have not paid much attention to the supply of other fuels. Coke can be used to some extent in admixture with charcoal, and coal or oil would be needed for the operation of open-hearth and other furnaces.

The following information with regard to the supply, analysis, and price of coal and coke was supplied by Mr. W. F. Robertson under date of June 5th, 1918:—

Vancouver Island.—Monthly coal production, 145,000 tons; price per ton, $2.50 to $5.86, depending on grades. Monthly coke production, 3,000 tons; price, $10.25 per ton.

The coke contains 74 per cent. fixed carbon, 3 per cent. volatile matter, 23 per cent. ash, and 1 per cent. sulphur; but under improved conditions coke could be made that would contain 84 per cent. fixed carbon, 3 per cent. volatile matter, 13 per cent. ash, and 1 per cent. sulphur.

The following information with respect to the Nicola Valley coal was supplied to me by Mr. Nichol Thompson under date of June 10th, 1918:—

"The Nicola Valley coal produces a superior metallurgical coke with well-developed cell-structure and ample strength for iron-furnace stacks. From English coking tests the following results were obtained:—

	From Raw Coal.	Coke produced in:—	
		Bee-hive Ovens.	Retort Ovens.
	Per Cent.	Per Cent.	Per Cent.
Moisture	3.40	1.20	1.00
Volatile matter	34.90	1.20	0.50
Fixed carbon	56.70	84.00	91.25
Ash	5.00	13.60	7.00
Totals	100.00	100.00	99.75
Sulphur	0.65	0.63	0.25"

From another source in England:—

"The coal sent to me and numbered 1 is a very fine coal for metallurgical, steaming, or domestic purposes. We can take away every trace of sulphur if necessary, and it would then remain a splended metallurgical coke, supposing you had a steel plant in British Columbia. I should imagine that this No. 1 sample is about the highest-grade coal you have in Canada, and it should be used as a superior coal when British Columbia has commenced steel production. In other words, it is a coal which will find higher values as British Columbia develops. The other coal, main coal and numbered 2, seam 1, carried 38 and 40 per cent. volatile matter, and are excellent for oil and motor-spirit production, and for the production also of an excellent coke either for ordinary household fuel or for metallurgical work. The oil extracted from the coal would depend entirely on the grade of coal which you wished to produce. The coal could be distilled to destruction or any stated quantity of hydrocarbons could be left in the coke. I enclose you a sheet showing the product from 1 ton of Nicola Valley coal obtained from a by-product oven. There is no question as to the success of the by-product coke-ovens, as evidenced by the fact that the entire coal product of Germany previous to the war was made into coke so that the products might be saved."

Mr. Thompson gave me further information with regard to the chemical by-products obtainable in the coking of the Nicola coal, but it does not seem suitable to discuss these in the present report.

Gas-retort Residue.—The electric-smelting plant at Bay Point, San Francisco, employs for reducing reagent in the production of ferro-alloys a carbonaceous residue produced in the manufacture of illuminating-gas from oil. This material is practically ash-free, it contains about 70 per cent. of fixed carbon, and is obtainable at a nominal price of about $4 a ton. It is not very satisfactory physically, but in view of the scarcity of charcoal and coke in that locality the management have been obliged to use this residue and have overcome the difficulties attending its use.

Comparison of Coke and Charcoal.—The comparative values of these as reducing materials depend in the first place on their fixed-carbon content. Thus, if charcoal contains 73 per cent. of fixed carbon and coke 84 per cent., the coke would appear to be the more valuable. The remainder of the charcoal, however, is volatile matter and moisture, which is driven off harmlessly in the furnace, while the coke would contain some 13 per cent. of ash, which has to be melted, and will usually necessitate the addition of a flux. The sulphur in the coke also will need fluxing, in addition to lowering the purity of the resulting pig-iron. It follows, from these and other considerations, that charcoal is somewhat more valuable than coke as a reducing reagent. Referring to Mr. Gronwall's estimate in my Swedish report, the following figures show the relative consumption of fuel and of electric power for 1,000 kilograms of pig-iron, according as charcoal or coke are employed:—

	Using Charcoal of 73 Per Cent. Carbon.		Using Coke of 85 Per Cent. Carbon.	
	Kilos Fuel.	H.P. Year.	Kilos Fuel.	H.P. Year.
White pig-iron	340	0.37	370	0.39
Grey pig-iron	370	0.40	400	0.42

It will be clear from this table that not only is there a larger consumption of coke than of charcoal per ton of iron, but the power consumption is larger with coke.

In localities where coke is of good quality, cheap, and abundant, while charcoal is expensive and scarce, it may be worth while to use coke on account of its greater cheapness. In British Columbia, however, it appears that charcoal should be made at a cost of $6 to $8 a ton, while coke would cost about $10 a ton. As long as these conditions last there can be little doubt that charcoal will be preferable as a reducing agent in electric smelting.

APPENDIX VI.

ELECTRODES.

Electrodes are needed in most electric furnaces for conducting the electric current into the furnace. They should be good conductors of electricity and poor conductors of heat, and they should be strong and capable of withstanding high temperatures. Electrodes are usually made of some form of carbon, and their wear in the furnace, from exposure to air or to other oxidizing materials, constitute a serious source of expense. The cheapest kind of electrodes are "carbon" electrodes, which are made of some form of carbon, such as crushed anthracite coal, bonded together with pitch, and baked. "Graphitized" electrodes are obtained by heating carbon electrodes to a very high temperature in an electric furnace. The process converts the amorphous carbon of the electrode into graphitic carbon, which is a much better conductor of electricity, and is superior in some other respects. Graphitized electrodes cost about three times as much per pound as carbon electrodes, and the latter are therefore more generally used in electric smelting.

The electrodes used in the Swedish furnaces at the time of my visit in 1914 were 24 inches in diameter and 4 or 5 feet long. They were provided with threaded ends, so that fresh lengths could be added as the electrodes wore away. They were of amorphous carbon and cost about 4 cents per pound. The consumption of electrodes, when making white pig-iron from high-class ores, was about 10 to 15 lb. per ton of pig-iron; thus costing about 50 cents per ton of product. In melting lower-grade ores for foundry iron the consumption might be from 15 to 20 lb.; at present prices in British Columbia this would mean about $1.50 per ton of pig. A furnace of 3,000 kw. uses six of these 24-inch electrodes.

At Bay Point, California, the 3,000-kw. open-pit furnace, smelting ferro-manganese, uses three 24-inch carbon electrodes. The consumption is 100 lb. per ton of ferro-manganese, and Beckman and Linden expect that in using this furnace for making pig-iron the consumption would be 20 lb. per ton.

It will be noticed that the Swedish furnaces have twice as many electrodes as the Californian furnace. The size and number of the Swedish electrodes are in agreement with the generally accepted formulæ of Dr. Hering, and it seems likely, therefore, that the Californian furnace should have more electrodes if it is to be used for iron-smelting. Beckman and Linden do not agree with this suggestion, and, of course, these points must ultimately rest on practical demonstration, but it must be remembered that they have not as yet applied their type of furnace to smelting iron ores.

At Heroult, California, a 3,000-kw. ferro-manganese furnace is furnished with four 12-inch graphitized electrodes, which would be about the same in effect as the three 24-inch carbon electrodes at the Bay Point plant. Judging by the consumption of electrodes at this point, it appears that it would be preferable to use carbon electrodes, and I understand that this change will be made.

Under ordinary conditions carbon electrodes cost 3 or 4 cents per pound, but at the present time the price in the East is about 8 cents and on the Pacific coast nearly 10 cents. In view of the expense of shipping electrodes across the continent it is desirable to make electrodes locally, but this should not be undertaken until the smelting plant is in good running-order, because the manufacture of electrodes is not easy, and the use of poor electrodes might delay, seriously, the operation of the plant. Messrs. Beckman and Linden have put up an electrode plant at the Bay Point plant, and they are trying to make electrodes from the carbon residue, which they use as reducing material in the furnaces. They prepared for me the following estimates of the cost of plant and of making electrodes:—

300-ton-per-month Electrode Plant.

Baking-kilns complete, including all burning apparatus	$ 20,000
Hydraulic press (500 tons per month, 600-ton pressure)	6,000
Mixers (two)	6,000
Moulds	5,000
Calciner complete	40,000
Building complete	25,000
Crane	8,000
Conveying equipment and elevators	2,500
Crushing and screening apparatus	3,000
Kiln-sand	1,000
Tools, chains, etc.	1,000
	$118,500
Contingencies, 10 per cent.	11,850
	$130,350
Beckman & Linden Engineering Corporation fee	15,000
Total	$145,350

Cost of making 2,000 Lb. of Electrodes.

Anthracite coal, calcined, crushed, and sized	$20 00
Pitch at $20 per ton put into electrodes	5 00
Baking fuel, pound per pound ratio	4 50
Labour, 50 cents per hour	12 75
Operating superintendence	1 85
Supplies	1 00
Maintenance	2 00
Plant office expense	75
Main office expense	4 00
Total	$51 85

Cost per pound, $0.0258.

The iron-smelting plant under consideration for British Columbia was to have two 3,000-kw. furnaces making pig-iron and three 300-kw. furnaces making ferro-alloys. The consumption of electrodes in these furnaces would amount to 1,000 or 1,500 lb. daily, or about 20 or 25 tons per month. This is less than one-tenth of the output of the plant described above, and the cost of making electrodes in a smaller plant would necessarily be somewhat higher, say 3 or 4 cents per pound.

APPENDIX VII.

THE SUPPLY OF LABOUR.

Although a supply of competent labour is essential to the success of any industrial undertaking, and although the variations in the wages that must be paid may mean the difference between profit and loss, it is impossible for me at the present time to put forward any really reliable information with regard to labour conditions in British Columbia.

The Department of Labour in Victoria has furnished me, through Mr. W. Fleet Robertson, with a statement of the supply, nature, and cost of labour in the Coast District of British Columbia; this statement is added in the following pages. It will be seen that there is a fair supply of labourers at nearly $4 a day, and that most skilled men are scarce at about $6 a day. The cost of labour per ton of iron depends very much on the size and output of the plant. Thus, at the figures mentioned, in a fully equipped plant making 50 or 60 tons of pig-iron, and steel and ferro-alloys as well, the cost of labour might be $4 or $5 per ton of iron, but if only one or two furnaces were operating the labour cost might be about $7 per ton of iron.

While electric furnaces offer difficulties and dangers of their own, it appears to me that a well-established electric-smelting plant, such as those I saw in Sweden, presents far less difficulty

and discomfort to the workman than the average blast-furnace plant, and that the management should experience less difficulty in keeping a good crew of men.

On page 34 of my Swedish report it is stated that at Hagfors three 3,000-horse-power furnaces are operated by fifty men, working eight hours daily, at a wage of about 12 cents per hour. At this rate, with bonuses and the higher rates of foremen, the cost would amount to about 80 cents a ton of pig-iron. In a plant of three 3,000-kw. furnaces in British Columbia fifty men might be assumed to cost: Thirty at $4 and twenty at $6, or $240 a day. With an average output of 75 tons daily of foundry iron this would mean $3.20 per ton. A plant of this size would probably need a few additional men, say ten or twelve, which would increase the charge for labour to about $4 a ton.

Messrs. Beckman and Linden have given me a list of the men needed daily for one 3,000-kw. furnace of the open-pit type. I have added to these the rates of pay, estimated with the aid of the attached memorandum:—

Daily Labour for One 3,000-kw. Pit Furnace.

One furnace foreman at $8	$ 8 00
Twelve furnacemen at $5	60 00
One chief electrician at $6	6 00
Three sub-station operators at $5	15 00
Three mechanics at $6	18 00
Six mixing-men at $4	24 00
Six metal-handlers at $4	24 00
Two locomotive-crane men at $5	10 00
Total	$165 00

With an output of 25 tons per day this would mean $6.60 per ton of iron, which agrees with Beckman and Linden's estimate in Appendices X. and XI. This charge is unduly high, because they figured on a single furnace only. A plant having three furnaces would only need about twice as many men as a plant with one furnace, so that the cost for labour would be about $4.40 per ton.

MEMORANDUM FROM DEPARTMENT OF LABOUR, VICTORIA, B.C., JUNE 10TH, 1918.

Supply, Nature, and Cost of Labour, Coast District of British Columbia, such as would be required at Plant for Electric Smelting of Iron.

	Normal Pre-war Conditions.	Present Conditions.	
	Wages per Day of Eight Hours.	Supply Plentiful or Scarce.	Wages per Day of Eight Hours.
Engineers, 1st	About $15 less than at present	Scarce	$225 per month of 26 working-days.
Engineers, 2nd	...	Scarce	$165 per month of 26 working-days.
Machinists	$4.00 per day	Scarce	$6.00 per day.
Machinists' helpers	2.50 per day (Not quite sure)	Scarce	4.50 per day.
Boiler-makers	$4.50 per day	Scarce	6.00 per day.
Boiler-makers' helpers	3.25 per day	Scarce	4.30 per day.
Blacksmiths	4.50 per day	No great supply	6.00 per day.
Blacksmiths' helpers	3.25 per day	No great supply	4.50 per day.
Plumbers and pipe-fitters	5.00 per day	Scarce	6.00 per day.
Plumbers' and pipe-fitters' helpers	3.25 per day	Scarce	4.00 per day.
Painters	4.00 per day	No great supply	5.50 per day.
Electrical workers	5.00 per day	Very scarce	6.00 per day.
Electrical workers' helpers	3.50 per day	Very scarce	4.00 per day.
Operators of electric, steam, or air winches and donkeys	4.50 per day	Scarce	6.60 per day.
Engineers in charge of boilers	4.00 per day (Not quite sure)	Scarce	5.50 per day.
Labourers	$3.00 per day	Supply fair	3.85 per day.
Sheet-metal workers	...	Fair	6.60 per day.
Coppersmiths	...	Fair	6.60 per day.

APPENDIX VIII.

TYPE OF FURNACE TO USE FOR ELECTRIC SMELTING.

The furnaces that have been in commercial use, or that seem suitable for the electric smelting of iron ores, are:—

(1.) The Electric-Metals furnace used in Sweden:
(2.) The Helfenstein furnace tried in Sweden.
(3.) The Noble Electric Steel Company's furnace used at Heroult, California; and
(4.) The 3-phase open-pit furnace used for ferro-alloys.

The simplest of these is No. 4, the open-pit furnace. This furnace has no roof or cover and has three electrodes, which are supported from above and are surrounded with the material to be smelted. The main objection to this furnace is that heat and gases escape from the furnace and are lost, besides creating a nuisance. As far as I am aware, this furnace has not been used commercially for smelting iron ores. Nos. 2 and 3 are like No. 4, except that the top of the furnace is closed in, thus lessening the loss of heat and enabling the gases to be drawn away through flues and used elsewhere for heating. Both these furnaces have been used on a commercial scale, but full particulars of their operation are not available. No. 1 is more elaborate than the others and resembles an iron blast-furnace with an enlarged hearth. In this type, not only is the furnace closed to retain the heat and the gas from the smelting charge, but the gases are made to pass up a shaft, so as to heat and reduce the iron ore; being, indeed, returned again to the furnace for this purpose after escaping at the top. This furnace has been in successful commercial use for a number of years in Sweden, and some are now being built in other countries.

In this Appendix I give references to a number of descriptions of these furnaces, and compare the available data with regard to their operation.

I. ELECTRO-METALS FURNACE.

An illustrated account of the furnace and plant at Trollhattan, entitled "Recent Progress in Electrical Iron-smelting in Sweden," is given by T. D. Robertson in Amer. Electrochem. Soc., 1911, Vol. XX., page 375. Full illustrated reports of the work at Trollhattan by J. A. Leffler, E. Odelberg, and E. Nystrom are given in Swedish in the *Jern-Kontorets Annaler* for 1911, 1912, and 1913. Translations of parts of these appeared in *Iron and Coal Trades Review*, June 9th and 16th and November 10th, 1911, and May 2nd, 1913, Vol. 86, page 744. Articles entitled "Electric Iron Smelting" by Jens Orton-Boving appeared in the *Canadian Engineer*, December 18th, 1913, Vol. XXV., page 877, and in *Iron Age*, May 21st, 1914, Vol. 93, page 1269. The Swedish and other furnaces for the electric smelting of iron ores are described in my book, "The Electric Furnace," 1914 edition, pages 174-211, and in my report on "Electrothermic Smelting of Iron Ores in Sweden," Ottawa, 1915.

The following account of the Swedish furnace and process is from a memorandum by J. O. Boving dated July, 1915:—

"*Reduction of Iron Ore.*

"The methods and processes for obtaining pig-iron by electric reduction have mainly been worked out and put to commercial use in Sweden, but in a smaller degree the United States of America and Canada have contributed towards the experience gained. (Experiments have also been carried out in France and in Switzerland, but no commercial results have matured so far.) The reason for this is fairly obvious, as the development is based on the following cardinal conditions: Presence of cheap water-power and suitable charcoal.

"Sweden's iron trade has been based on the production of high-class charcoal pig since the earliest days of established industry, and it is chiefly on account of the high quality thus produced Sweden became famous for these products.

"Before the new processes of making steel in open-hearth and Bessemer converters were known, Sweden commanded high prices for her iron, but prices fell with the development of newer methods, and Sweden had to seek other ways in order to cheapen the cost of production and at the same time maintain the quality. Such means were found in the electric-reduction furnace. Sweden has an abundance of cheap water-power, and there are few countries in the world that have taken such beneficial advantage of it.

"The first electric-reduction furnaces were established in 1907. Now a great number of them are working and giving splendid results, as will be seen below.

"In Russia there are large districts where the conditions are similar to those in Sweden, and I am strongly of the opinion that developments could as profitably be made in the Urals, and maybe also in the Caucasus. The iron industry is already well established in the Urals. The ore is good. There is an abundance of water-power which would be easy to harness, and the supply of wood for charcoal is practically unlimited.

"As mentioned above, the development of electric reducing has been most marked during the last few years in Sweden. At present some fourteen high furnaces are in operation, and the total output represents about 140,000 tons of pig-iron per annum. This pig is of the highest quality that can be made, and it commands, therefore, high prices. It is mostly used in Sweden for producing high-grade steel, but a certain amount is also sold to the Sheffield market.

"There are, further, many more installations contemplated, and it is safe to say that wherever there is cheap water-power the old blast-furnace will be replaced by electric producers. Generaly speaking, it holds good that wherever 1 horse-power per annum can be produced cheaper than the cost of 2 tons of charcoal or coke (depending upon the class of iron to be made) it is a commercially successful undertaking to substitute electric heat for fuel-heat.

"The system of furnace which is used throughout Sweden is that patented by Electro-Metals, Limited.

"It will be seen that the furnace consists of two principal parts—the furnace-shaft and the hearth or crucible. The shaft, which is of similar design to an ordinary blast-furnace shaft (but, of course, without any blast-tuyeres), is supported independently on an iron framework or on heavy girders resting on the walls of the furnace-house. It consists of a shell of steel plates and is lined with firebrick. It is provided with a closed furnace-top, the charging-bell of which is raised or lowered by means of an electric motor and winding-drum. The hearth, which is situated immediately below the shaft, is so constructed that when it is expanded by the heat the central hole in the arch which covers it fits closely around the neck of the shaft.

"The hearth also consists of a strong shell of steel plates lined with refractory material and is covered by an arch, the weight of which may be supported entirely on the circular lining of the hearth, or else partly in this manner and partly by iron straps riveted to the shell of the shaft.

"The electrodes are preferably of circular section and provided with screw-joints for joining up end to end. They pass through the arch of the crucible at a slight inclination from the vertical. Water-cooled stuffing-boxes with asbestos packing are provided to prevent leakage of gas around the electrodes. The electrodes project into the hearth through the free space between the roof and the charge, which on descending into the hearth falls at an angle from the lower end of the shaft. The electric current is supplied to the electrodes through bronze contacts. Only carbon electrodes have, so far, been used owing to the high costs of graphite electrodes.

"The Electro-Metals furnaces are generally provided with an arrangement for gas-circulation, the gas being drawn by means of a fan from a gas outlet at the upper end of the shaft and forced through a number of nozzles into the free space between the roof of the crucible and the descending charge. The object of this gas-circulation is twofold—viz., to prevent overheating of the roof of the crucible and to facilitate the reduction process in the shaft. As regards the latter object, it is evident that the gas which becomes highly heated in the crucible assists in conveying heat to the charge in the shaft, thus extending the reduction zone and rendering it more effective through the increased volume of gas passing through.

"In this manner the percentage of CO_2 in the furnace gas can be kept higher than if no gas-circulation were used, and it is evident that this indicates a reduction in the fuel-consumption.

"The furnaces are placed in the central bay. On one side all the electrical gear is placed—transformers, switches, regulators, etc.—and this part is isolated from the metallurgical part. The power is derived from a hydro-electric plant nine miles and a half away, which power-station belongs to the company. The voltage of the line is 12,000 volts and is reduced to low pressure by transformer and adjusted by regulators to between 50 to 100 volts, as required.

"Each furnace has six electrodes, cylindrical in shape, and arranged to be used continuously without waste by using a screw-joint.

"The pouring-bay is fitted with electric overhead travellers, as well as trolly-tracks for transporting iron and slag. The iron can either be poured to pig or conveyed in ladles to the Bessemer and open-hearth furnaces. The slag is run into block moulds and makes excellent building-stone.

"The crushing-room is at the end of the furnace building. There are three crushers of the ordinary jaw type. There is a railway-track outside, and the daily requirements are supplied in the trucks, so that there is no need for large storing-bins. One of the crushers is fairly large, with wide enough jaw-space for the biggest lumps, and the ore passes from this crusher to the smaller ones, and thence by a bucket elevator to a belt-conveyor above the charging-platform, so that the raw material may be unloaded where required. There is a small ore-store, but this only contains some limited reserve amounts of the various kinds of ores used. The charcoal is transported from the stores by a ropeway.

"Three different kinds of pig-iron have been produced:—

(1.) Pig-iron for open-hearth treatment.

(2.) Pig-iron for Lancashire treatment.

(3.) Pig-iron for Bessemer treatment.

"The quality which is desired from the open-hearth pig is semi-spiegel and contains: Si, 0.40 to 0.60 per cent.; Mn, 0.30 to 0.50 per cent.; P, 0.011 to 0.018 per cent.; S, 0.015 per cent.

"It will be seen that it is more economical to produce spiegel iron in the electric furnace, and arrangements have been made to alter the open-hearth furnaces so as to use spiegel iron only.

"It has been assumed in various quarters that it would probably be difficult to maintain a constant product in an electric furnace. Experience has proved, on the contrary, that a much more constant product is obtained from the electric furnace than from the old blast-furnace. One reason for this is that there is such a large receiver or collecting-basin in the lower part of the electric furnace that it acts as a regulator on the quality.

"The Lancashire pig required is quite white and has the following analysis: Si, 0.20 to 0.30 per cent.; Mn, 0.20 to 0.30 per cent.; P, 0.011 to 0.018 per cent.; S, 0.015 to 0:020 per cent.

"During the early operation of the plant in question there was a tendency for the sulphur to be unduly high, but this was remedied by making the slag more basic whenever the furnace was run for Lancashire pig.

"The analysis of Bessemer pig used was as follows: Si, 1.00 to 1.40 per cent.; Mn, 2.50 to 3.00 per cent.; P, 0.015 to 0.019 per cent.; S, 0.005 per cent.

"Excellent Bessemer has repeatedly been made of this pig. The early attempts were not good, but it was soon found that Si and Mn had to be increased. It had been assumed that the amount would be normal, but apparently the lower temperature of the electro-Bessemer pig as compared with ordinary Bessemer pig from blast-furnaces necessitates a higher content.

"General experience points to the following results: It is cheaper to make spiegel than grey pig, because: (1) More current can be put through the furnace; (2) the current consumption is lower (per ton of product); (3) thus the production is higher; (4) the electrode consumption is lower; (5) the repair costs are lower.

"It may further be stated that rich charges give better (economic) results than poor ones. The quality of the pig however, is not influenced by the percentage of iron contents of the ore.

"For some time past the gas from the furnaces has been used as fuel in the open-hearth furnaces, and it is estimated that the value of the gas is from 2 to 3 shillings (50 to 75 cents) per ton of pig-iron produced.

"Finally, regarding the influence of the electric pig on the finished steel, experience has shown that the change tends to make better steel; this applies both to Bessemer and soft and hard open-hearth steels.

"The steel produced at Hagfors is of the highest quality and is mainly used for locomotive-boiler tubes, piano-wires, and high-tension wires generally.

"In Sweden, generally, the electric reduction of iron ore is regarded as revolutionizing this industry, and preparations are being made for constructing mills of considerable capacity. Recent experience has shown that large electrodes can be used at the same time as the current intensity on the electrodes is increased. Large furnaces will therefore be designed, and some of those now building have a capacity of 8,000 horse-power each.

"The general experience has been that the handling of the electric-reduction furnace is considerably simpler than an ordinary blast-furnace. More even quality is obtained without so careful watching. The quality can be changed easily, and the various grades from grey pig to spiegel can be obtained by simple manipulation. Less attention and less labour are required."

During the present investigation I have been in correspondence with Messrs. Electro-Metals, Limited, 56 Kingsway, London, W.C. 2, and reproduce the following extracts from two of their letters:—

Letter from J. O. Boving, June 28th, 1918.

"We have received your kind letter of the 5th inst., with regard to electric reduction of iron ore in Canada. It was exceedingly pleasant reading to the writer personally, who has for many years been in touch with various parties in Canada and could never understand why the electric reduction had not made any progress in a country where the conditions are so singularly suitable for the development of this industry. . . .

"Since you were in Sweden very great developments have taken place, and this has, of course, been especially accentuated by the war, when importation of coke has been difficult, and therefore the power existing in the country has been of greater value than ordinarily for electro-thermical operations.

"You will probably remember most of the plants you visited in Sweden, but we shall here recapitulate what has been done as far as we are acquainted up to now.

"There are two furnaces at Trollhattan—the original one and another of 3,000 kw. capacity.

"There are five at Hagfors—the two original ones and three later of 4,000 kw. capacity.

"There are three at Domnarfvet (the Helfenstein furnace was found quite useless and has been pulled out)—one of 7,000, one of 3,000, and one of 2,000 kw. capacity—and there are two more building of 3,000 kw. capacity.

"There is one at Soderfors of 5,000 kw.; one at Ljusne of 3,000 kw.; two at Porjus of 3,000 kw.; and three at Lulea of 3,000 kw.

"Some have been built in Norway, two in Switzerland, and two or three in Japan.

"The most important plant we have tackled is, however, the one in the Aosta valley, North-west corner of Alpine, Italy. Here we are erecting for the firm of Ansaldo & Co. (the largest armament firm of Italy) a reduction plant consisting of six units each of 3,000 kw. capacity. Two of these furnaces will be run on charcoal and four on coke. Half of the furnaces are built here and the half to our drawings in Italy.

"We are going to work out a revised estimate of the cost of this plant as applied to Canadian conditions and send along as soon as possible. This will give you a good idea of what you could look forward to. We shall also give you data regarding power-consumption, electrodes, labour, charcoal, and other supplies.

"Whilst we write you about reduction-furnaces, we think it is only right that we should inform you about the most remarkable developments which have been achieved with our steel-furnaces.

"The electric steel-furnace is undoubtedly the easiest apparatus existing to-day for melting steel and purifying it afterwards. The great flexibility of the electric heat and the possibility of applying it at the right point makes the removal of impurities, such as phosphorus and sulphur, and further complete deoxidation a very easy matter, and steel-makers in Europe are now unanimously of the opinion that as soon as the war is over electric furnaces will be installed by all large steel-mills, even for ordinary grades of steel. The process will be that whilst open-hearth furnaces and Bessemer converters will be maintained, these will only be used for taking the steel a certain part on the way towards perfection, and the final touch up will be made in the electric furnace. Treating molten steel in the electric furnace and refining it from impurities requires for a large unit between 80 and 100 kilowatt-hours per ton. This consumption is not prohibitive even under conditions such as are prevailing in this country, where power under ordinary conditions is available at a price of about one-third of a penny (0.7 cent). But it is a remarkable fact that even now during the war, when price for power ranges from 1 to 2 cents per unit, certain manufacturers, such as Brown-Bayley, Hadfield's, Cammell-Laird, and the Partington Steel Works, find it profitable to use our electric furnaces for treating ordinary carbon steel, starting from the cold. It should be, of course, remembered that this can only be done in fairly large furnaces having a capacity of at least 5 tons, because the current consumption increases very rapidly for small units. Thus, whereas a 1-ton furnace requires about

1,200 units for melting and refining 1 ton of scrap, a 5-ton furnace only requires about 750 units for the same work, and a 10-ton furnace round about 600 units.

"When we come to consider electric furnaces receiving their power from hydro-electric installations, the question comes into quite a different plane. In many cases it is possible to supply the current at the rate of 0.1 cent, and the price of the total current consumption is thus so reduced that the whole process compares very favourably with the most economical coal-gas-fired open-hearth furnaces.

"In connection with Messrs. Ansaldo's Reduction Works a large steel-works is also being installed. The rich gases from the reduction-furnaces are used in the steel-works, but there will also be a battery of ten 15-ton electric steel-furnaces, all energized by water-power. You may be interested to know that Ansaldo's metallurgical engineer is Professor and Dr. Giolitti (*of carburizing-of-steel fame*), and their steel-works are regarded as obtaining higher quality results than any other works.

"On the coast of Norway there are also a number of electric steel-furnaces energized by water-power, and these undertakings are paying extremely well, turning out fine steel and making huge profits."

Letter from J. Bibby, September 21st, 1918.

"The production costs given in our letter of August 19th (*see* Appendix X.) are for the manufacture of white pig-iron as you surmise, and these are to be obtained in the large plant at Messrs. Ansaldo's about which we wrote you. For the manufacture of grey foundry pig-iron in this large plant the consumption will be approximately 0.37 horse-power year per ton of pig-iron, assuming that the ore contains between 65 to 70 per cent. of iron.

"For a plant consisting of only one 4,000-horse-power furnace, for instance, the consumption would be from 5 to 10 per cent. higher, as the diversity factor would be greater. For the case you mention of 9,000 tons per year you could assume a consumption of 0.41 horse-power year per ton of grey iron produced from ore containing 65 per cent. of iron.

"With reference to the sintering mentioned on page 4 of your letter, it is quite a common practice in Sweden to employ as much as 50 per cent. sintered and 50 per cent. lump ore and obtain satisfactory results.

"With reference to the price of current in British Columbia, wo do not see why the cost there under similar circumstances should greatly exceed what is being done in Sweden, where current is being regularly supplied at the equivalent of $8 per horse-power year. The electric suppliers must take into account the favourable nature of an electric-furnace load as regards power factor and load factor. Under the circumstances you give of a 60-cycle supply running one furnace, the power factor would be as high as 0.92.

"With reference to charcoal, we are in a position to supply drawings and specifications for charcoal plants to suit any given requirements, and if desired we could quote you a fee for this work.

"We are pleased to learn that you are contemplating a new edition of your valuable book on electric furnaces, and we believe that you will consider a description of our recent developments worthy of notice. We are therefore preparing a description of the various improvements we have made since your book was published, and will send this on to you in due course. These improvements consist in the employment of a new 2-phase system for small furnaces up to 7 tons, and a new 4-phase system for furnaces between 7 and 30 tons capacity. We have also made improvements in the way of automatic regulators, electrode economizers, etc., all of which we will give you particulars. In the meantime we enclose you two electrical diagrams which no doubt will be quite clear to you.

"As regards the 6-phase arrangement, this is applied to our 3,000-kw. reduction-furnace. As before, we employ three transformers which each supply two diametrically opposite electrodes, but we so connect the transformers that we obtain six independent phases in which the relationships are definitely fixed."

In conclusion, I may say that the Electro-Metals furnace is undoubtedly the most efficient appliance that has so far been applied to the electric smelting of iron ores, but that in view of the large consumption of power by even this type of furnace it will be unwise to put up an elaborate plant of this kind unless an adequate and permanent supply of electric power can be obtained at a moderate price.

Unfortunately, some of the earlier reports gave exaggerated ideas of the economy of electrical power and charcoal that had been obtained with these furnaces, and I myself made the mistake of taking these reports literally when writing the 1914 edition of my book on "The Electric Furnace." After visiting Sweden and investigating the conditions obtaining there, I arrived at more conservative figures as put forward in my 1915 report. In Mr. Bibby's letter of September 21st, quoted above, he states that with a single furnace of 4,000 horse-power producing 9,000 tons per annum, the consumption would be "0.41 horse-power year per ton of grey iron from an ore containing 65 per cent. of iron." It will be obvious that from the available ores, which do not contain more than 55 per cent. of iron, the figure I am assuming of 0.45 horse-power year will not be too high.

Although the Swedish furnace is more economical than any other electric ore-smelting furnace, there still remains a considerable margin for further possible improvement, and I hope that some process of low-temperature reduction of iron ores may be worked out which will show a decided improvement over the Swedish process.

II. THE HELFENSTEIN FURNACE.

The Helfenstein furnace was originally devised for the production of calcium carbide and ferro-silicon. (*See* R. Taussig, Faraday Society, V., 1910, page 254; Soc. Chem. Ind., XXXIX., 1910, page 435; Met. and Chem. Eng., X., 1912, page 686.) A 10,000-horse-power furnace of this type for iron-smelting was started at Domnarfvet in May, 1913, and was in experimental operation at the time of my visit in 1914. A more recent account appeared in *Iron and Coal Trades Review* (London), February 23rd, 1917, and in *Met. and Chem. Eng.*, May 1st, 1917, page 509, from which I have taken the following particulars:—

When charcoal was used, the consumption of power, etc., was 2,170 kilowatt-hours, 380 kg. charcoal (70 per cent. carbon), and 5 kg. of electrodes per metric ton of pig-iron. When coke was used, the consumption was 2,600 to 2,700 kilowatt-hours, 310 to 320 kg. of coke, and 4 kg. of electrodes. The consumption of 2,170 kilowatt-hours with charcoal corresponds to 0.392 horse-power year at 85 per cent. load factor. This is probably for the production of white iron from high-grade ores, though at the time of my visit ores of 50 per cent. iron were being smelted. It does not appear that the efficiency is any better than that of the Electro-Metals furnace, and it should be noticed that the use of coke causes the consumption of a far greater amount of electrical power.

The idea of this furnace is to increase the output and efficiency by using a far larger amount of power in a furnace of a given size than was possible in the Electro-Metals furnace. The furnace gases were not used to reduce the ore in the furnace, but were employed for other purposes in the plant. It is unfortunate that we have no detailed account of the operation of this furnace, or of the reasons which caused it to be abandoned.

III. THE NOBLE FURNACE.

At Heroult, in California, electric smelting of iron ores was undertaken in 1907, and was continued, experimentally, until about 1914. The first furnace was designed by Paul Heroult, and was a 2,000-horse-power rectangular furnace, with three vertical electrodes alternating with four vertical chutes for supplying the ore charge. The furnace had an arched roof and the chutes were heated by the escaping gases. The chutes became choked with the heated ore, the roof broke down or melted, the furnace could only be worked with an open top, and was finally given up. Professor D. A. Lyon experimented in 1908 with a single-phase furnace of 160 kw., and in 1909 put up a furnace of 1,500 kw., substantially like the earlier Swedish type of furnace. Work with this furnace was continued until 1911, when it was finally given up, possibly on account of difficulty in controlling the nature of the product. The Noble Company then reverted to the rectangular type of furnace, using four electrodes and five charging-chutes, which, however, were not heated. A 2,000-kw. furnace was built in 1911, and an additional furnace of 3,000 kw. in 1912 or 1913. The best account of this furnace was written by John Crawford, the plant manager, in *Met. and Chem. Eng.*, July, 1913, Vol. XI., page 383.

Mr. Crawford states that the tall-shaft furnace built in 1909 could probably have been made economically efficient, but that it could not be made to respond readily to changes in the burden, as would be essential for making consistently high-grade foundry iron. He explains the necessity in electric smelting of controlling accurately the addition of carbon in the charge, as an excess

of carbon cannot be burnt off as in the blast-furnace, and a deficiency results in low-grade iron. This difficulty of controlling the amount of carbon does not interfere with the production of a low-silicon iron—such as is used in Sweden—but in his experience it caused great difficulty in the production of foundry iron. In view of this the shaft-furnace was abandoned, and a 2,000-kw. 3-phase furnace of the long and narrow type was tried. This furnace had four electrodes, delta-connected and suspended between five charging-stacks. He considers that this type of furnace, which was operating in 1913, is the one best adapted to their needs. The second furnace of this kind, having 3,000 kw. capacity, consists of a rectangular steel shell 28 feet long and 10 feet wide, lined with standard firebrick. This is surmounted by five charging-stacks 18 feet high, and between the stacks the top of the furnace is arched over. The electrodes are of Acheson graphite, 12 inches in diameter, and enter vertically through the arch between each adjacent pair of charging-stacks. The furnace gases are not used for preheating or reducing the ore, but are led away and used under lime-kilns and charcoal-retorts. The electric current is supplied to the furnace at a voltage of from 40 to 80. He found that coke was less satisfactory than charcoal in this furnace, but that if the coke was crushed a mixture of 60 per cent. coke and 40 per cent. charcoal could be used with fair efficiency. The following is an analysis of a 200-ton lot shipped to a foundry for making steel castings:—

	Per Cent.
Silicon	2.88
Combined carbon	0.09
Graphite carbon	3.38
Sulphur	0.028
Phosphorus	0.031

Mr. Crawford does not consider this type of furnace as efficient as the shaft type, but states that he has kept the power-consumption as low as 2,200 kilowatt-hours per ton of pig in a furnace of 300 kw. This would equal 0.40 horse-power year at 85 per cent. load factor. He states, however, that the long and narrow type offers the possibility of building several furnace units on to each other, like copper blast-furnaces, and this would lessen the radiation and electrical losses and increase the efficiency. It would also enable part of the furnace to be repaired while the remainder was still in operation.

Since Mr. Crawford's article scarcely anything has been published about the Noble smelting-furnace, but I learn that the production of pig-iron was discontinued about the year 1914. This may not have been caused by any technical difficulty, because the commercial situation at Heroult, which can never have been very good, became impossible when the charge for power was raised from $12 to $25 per horse-power year. The plant is situated on the Pitt river, in Shasta County, and is reached by an independent line of rails from Pitt Station, on the Southern Pacific Railroad. The iron ore is about the only element of their supply which can be obtained cheaply at the works; there is not enough timber left near the plant for charcoal-making, and wood for this purpose has to be brought in by rail. All their general supplies and their products have to be shipped over two railroads from or to San Francisco or other industrial centre.

IV. The Open-pit Furnace.

For the production of calcium carbide and ferro-alloys a simple type of open-topped furnace has been developed, and this is recommended by Messrs. Beckman and Linden for the smelting of iron ores. The 3,000-kw. furnace erected by this firm at Bay Point for the production of ferro-manganese may be taken as typical. It consists of a rectangular steel box, about 17 feet long, 9 feet wide, and 7 feet high, suitably braced outside, and lined around the sides with 4½ inches of firebrick. The bottom lining is about 3 feet thick, composed of blocks of carbon, and the furnace is supported on piers to permit of air-cooling. The top of the furnace is open, and the three electrodes, which are of amorphous carbon, hexagonal in section, 24 inches in diameter and 7 feet long, are hung in the middle line of the furnace, being spaced 3 feet 6 inches apart from centre to centre. The lower ends of the electrodes are surrounded and covered by the ore and other materials when the furnace is operating. The upper ends of the electrodes are held by water-cooled metal-holders, which support the electrodes at the correct height and supply the electric current to them. The height of the electrodes is controlled and regulated by automatic machinery, which is designed to keep a constant electrical load on the furnace. Three-phase electrical power at 22,000 volts is supplied to three 1,000-kw. transformers, from which the working-current, at 70 to 100 volts, is led by flexible conductors to the three electrode-

holders. A charging-platform extends around the furnace about 3 feet below the top, and the mixture of ore, carbon, and flux is shovelled into the furnace from this platform. The molten ferro-manganese and slag are allowed to run out of the furnace periodically by means of a spout and tapping-hole opposite the centre electrode.

There can be no question that charcoal pig-iron of any desired grade can be made in this kind of furnace, which is easily and cheaply built and repaired, and should be able to run for a long time without need of repair. By providing an ample supply of power the efficiency should be satisfactory, and may be expected to approach fairly closely to that of the Swedish furnace. The charcoal-consumption will certainly be higher, but, as a poorer quality charcoal can be used, this need not cause any additional expense. The power-consumption will probably be higher; but it is impossible to speak positively on this point, because the loss in heat, due to the open top and the absence of a stack, may be largely balanced by the greater efficiency of a higher-powered furnace, and by the fact that stoppages for repairs will be fewer and less prolonged. The consumption of electrodes will probably be larger per ton of pig-iron, because they are somewhat exposed to the air, and perhaps also on account of the greater current density used in these electrodes. Although, in general, the furnace has much to recommend it as a simple and effective means for making iron, it must be remembered that the furnace gases are allowed to burn above the charge; thus not only are they wasted, but they create a serious nuisance. It is difficult to avoid the conclusion that, in operating such a furnace for the commercial production of pig-iron, the management would ultimately be obliged to close in the furnace-top, so as to remove the gases from the furnace-room, even if the value of the gases were neglected. The furnace, so closed in, would then resemble the Helfenstein or the Noble furnace, already described. If, then, it is decided to smelt in an electric furnace other than the Swedish type, it would be practicable to start with a simple pit furnace as used for ferro-manganese, and to add to this, if it seems desirable, provision for retaining the heat and gases and supplying the charge in a more mechanical manner.

If it is found practicable to reduce the crushed ore to a metallic powder in some gas-fired furnace, this powder can be melted down very simply and cheaply with additions of carbon and ferro-silicon to produce foundry pig-iron. A simple electric furnace provided with a cover will probably be the best for this purpose.

APPENDIX IX.

DESIGN AND COST OF PLANT FOR THE ELECTRIC SMELTING OF IRON ORES.

GENERAL CONSIDERATIONS.

(1.) We have seen that in view of the limited market it is undesirable at present to consider the production of more than 20 or 30 tons of pig-iron daily for use in foundries.

(2.) The cost of production on so small a scale would be very high, and, as there will not be a great profit in making pig-iron, it seems doubtful whether a plant of that size could pay its way under ordinary conditions.

(3.) If, however, we include in the plant furnaces for the production of steel and ferro-alloys, which can probably be made with a greater profit, and apart from this will help to carry the general overhead charges, there is more probability that the plant can be made to operate at a profit.

ELECTRO-METALS PLANT.

Messrs. Electro-Metals, of London, are installing an iron-smelting plant for Messrs. Ansaldo & Co. in the Aosta valley in Italy, and I have received from them the following estimate of the cost of building a similar plant in Canada.

The plant would consist of six electric furnaces of the Swedish type, each using 3,000 kw. and producing 10,000 tons of pig-iron a year. This is for the production of a low silicon or white pig-iron from an ore of about 65 per cent. iron. The plant would consist of a large furnace building, divided lengthwise into three bays. One of these contains the transformers and other electrical apparatus, the central bay would contain the six electric furnaces, and the remaining bay would be devoted to the disposal of the pig-iron and the slag. Besides these, there would

be a storage-house for the charcoal, and stores for electrodes and other supplies, with bins or storage-space for the ores, fluxes, and pig-iron. No mention is made of unloading piers or wharves, or of railroad-tracks, or of the land on which the works would be erected, and it seems probable that further charges should be made for these.

The plant of 18,000 kw. is estimated to cost:—

Six shafts complete with charging-bells and pipes	$170,000
Twenty (1,000 kw.) transformers (two spares)	150,000
Switch-gear	40,000
Elevators	15,000
Pumps and water plant	40,000
Blowers, fans, and ducts	20,000
Motors	5,000
Buildings	100,000
Total	$540,000

This is equal to $9 per ton of yearly output.

For present consideration we may take a plant, producing pig-iron alone, of half this size; that is, of 9,000 kw. This would make more pig-iron than we need, but would be of about the right effective size and expense. Such a plant, with additional charges for the land, unloading-wharf, tracks, and rolling-stock, would cost in the order of $350,000 to $400,000. The estimated output for this would be 30,000 tons per annum, but this should be corrected (1) for the ore being of 53 per cent. iron instead of 65 per cent., which will probably reduce the output from 30,000 tons to 26,000; (2) a further correction, in view of the production of foundry instead of white iron, will reduce it to 24,400 tons, or 8,100 tons for each of the three furnaces.

It is probable, however, that the estimated output of 60,000 tons from a six-furnace plant was a conservative figure, and it appears reasonable to assume an average daily output per furnace of 25 tons of foundry iron, even from the low-grade ores of British Columbia. Twenty-five tons a day per furnace would be 9,000 tons per annum for each furnace, or 27,000 tons for the whole plant, and I shall base my calculations on this.

By way of comparison, I add an estimate, made for me in 1914, of the cost of building in Canada a 9,000-kw. plant of the Swedish type. The estimate was prepared by Mr. Assar Gronwall, of Ludvika, in Sweden. It is probable that the firm have introduced some economics since the date of this estimate, but the cost of construction, especially in British Columbia, has increased rapidly, and it seems likely that a complete plant, including land, wharf, and rolling-stock, will cost in the order of $400,000, or $15 per yearly ton of output.

Plant of Three Electric Furnaces of 3,000 Kw. each.

Excavation, levelling, railway-tracks, store-house for ore and coke or charcoal, foundations for buildings and furnaces	$ 30,000
Buildings—	
House of light iron construction for three furnaces	60,000
Crusher-plant house, laboratory, inclusive of appliances, workshop for repairs, and storehouse, and various smaller shops	12,000
Furnaces—	
Three furnaces at 4,000 horse-power, with fans and gas-pipes	75,000
Electric transformer instruments with low-tension conductors	100,000
Moulds, ladles, tools, and instruments	10,000
Travelling crane of 5 tons capacity	6,000
Ore-crusher, apparatus for transporting crushed ore to the furnace-top	7,000
Side-tracks for transport and other transporting devices	7,000
Water-pipes and waste-pipes	5,000
Drawings, supervision during construction, and unforeseen expenditures	48,000
Total	$360,000

If the Electro-Metals type of furnace is used there would probably be only two of these built, and the remaining power would be devoted to the production of ferro-alloys and to steel-making.

PLANT WITH OPEN-PIT FURNACES.

I visited in California a plant at Bay Point, San Francisco, and another at Heroult, in Shasta County, where ferro-manganese and other ferro-alloys are made in electric furnaces. The largest furnace used was a rectangular open-pit furnace, using 3,000 kw. and having three 24-inch carbon electrodes which are suspended in the furnace. Messrs. Beckman and Linden, who built and operated the plant at Bay Point, consider that furnaces of this type would give entire satisfaction for the production of pig-iron, and that such furnaces would have the added advantage that they could be employed at any time for the production of ferro-alloys. These furnaces would undoubtedly be cheaper to build and the repairs would be less costly, but, on the other hand, they would also certainly be less efficient than the Swedish furnaces. Messrs. Beckman and Linden prepared for me an estimate of the cost of a plant of this type, having one 3,000-kw. furnace for the production of pig-iron and other smaller furnaces for ferro-alloys. I have changed a few of their figures to provide for the construction of two 3,000-kw. furnaces.

7,000-kw. Plant for Pig-iron and Ferro-alloys.

Two 3,000-kw. 3-phase furnaces, installed, including casing, electrode-holders, jib-cranes, regulators, and foundations	$ 30,000
Seven 1,000-kw. single-phase, 33,000-volt primary, 60-cycle oil-insulated and water-cooled transformers, installed, with from 60 to 120 volts in 5-volt steps on the secondary side (one of these transformers is spare), at $6,500	45,500
Two sets low-tension busses for 3,000-kw. furnaces, installed	10,000
Two sets high-tension busses for 3,000-kw. furnaces, including oil-switches, switchboard, and meters	12,000
Three 300-kw. furnaces, single-phase, installed, including casing, electrode-holders, and regulating device	10,000
Four 300-kw. 33,000-volt primary, 60-cycle, single-phase, oil-insulated and water-cooled transformers, installed, with a range of from 70 to 100 volts in 5-volt steps on the secondary side	10,000
Three 50-kw. single-phase, 60-cycle, 33,000 volts to 440 volts, air-cooled transformers, installed, with switchboard (to be used for industrial purposes around plant)	2,000
One 25-kw. motor-generator set for regulators, etc., installed	2,000
Three sets low-tension busses for 300-kw. furnaces	1,500
One furnace building, built entirely of reinforced concrete, including electric travelling crane, tracks, metal-handling equipment, etc.	45,000
One transformer building, built entirely of reinforced concrete	13,000
One shipping-store building of wood and stucco exterior finish	7,000
One laboratory with complete equipment	7,500
One store-room and change-room building, built of wood and exterior stucco finish, including steel lockers, toilets, wash-basins, and shower-baths	8,000
One machine-shop with equipment	10,000
One office building	3,000
One gate-house with time-clock and time-keeper's office	500
Railroad-tracks, industrial track, ore-handling equipment, water-supply, sewerage, fence, and industrial lighting, etc.	25,000
Land, 4 acres	4,000
	$246,000
Engineering and contingencies, 20 per cent.	49,200
Total of Beckman and Linden's estimate	$295,200

Brought forward	$295,200
Additional items—	
Dock with unloading locomotive, crane, etc.	30,000
Charcoal storage	8,000
3- to 10-ton ladles for handling metal	6,000
Flues and stack	25,000
Total	$364,200

Say a total of $350,000.

In the above list I have added to Messrs. Beckman and Linden's estimate a few items that should apparently be included. A dock and unloading plant would be needed for economical operation on a large scale, a storehouse would be needed for the charcoal, and it will probably be desirable to use large ladles for handling the molten metal. In the plant at Bay Point the furnace gases escape and burn in the furnace-room, creating a very serious nuisance. I would advise the construction of suitable flues and stack for the removal of furnace gases and the collection of the dust blown out by the furnaces. These flues can be placed below the charging-platform.

The above estimate represents the cost of a complete plant having one furnace making foundry iron for sale, a second making white iron for steel-making, and three smaller furnaces for ferro-alloys. As, however, we are considering in the first place the cost of production of pig-iron alone, I have rearranged the estimate for this purpose, so as to represent a plant of 9,000 kw. making foundry iron in three 3,000-kw. furnaces. This estimate should then be comparable with the Swedish estimates for a 9,000-kw. plant.

Beckman and Linden's Estimate modified for a 9,000-kw. Plant making Pig-iron.

(For details *see* previous estimate.)

Three 3,000-kw. furnaces	$ 45,000
Eleven 1,000-kw. transformers (two spares)	71,000
Three sets low-tension busses	15,000
Three sets high-tension busses	18,000
Three 100-kw. transformers, etc.	3,000
One 25-kw. motor-generator, etc.	2,000
One furnace building, etc.	35,000
One transformer building	15,000
One shipping-store	7,000
One laboratory	7,500
One store-room	8,000
One machine-shop	10,000
One office building	3,000
One gate-house	500
Railroad-tracks, etc.	25,000
Land	5,000
	$270,000
Engineering, etc., 20 per cent.	54,000
Total from Beckman and Linden's figures	$324,000
Additional items—	
Dock, etc.	30,000
Charcoal storage	8,000
3- to 10-ton ladles	6,000
Flues and stack	25,000
Total	$393,000

The corresponding figures, derived from the Swedish estimate, were between $350,000 and $400,000, but this does not mean that the Swedish furnace is the cheaper, as the estimates differ in completeness and are based on different conditions. We may, however, conclude that a com-

plete plant using 9,000 kw. for the production of pig-iron would cost about $400,000. It would appear certain that with an equal completeness of construction the Swedish plant would be somewhat more costly than the other, and for further calculation we may assume the cost of a Californian plant of 9,000 kw. to be $400,000, and of an equally complete Swedish plant $450,000.

In order to obtain an independent judgment in regard to the general arrangement and cost of an electric-smelting plant in British Columbia, I discussed the design with Mr. R. H. Stewart, of Vancouver, and he contributed some general considerations in regard to the design and cost data for the general portions of the plant, exclusive of the electrical furnaces and appliances.

The design was for a plant of 20,000 horse-power (15,000 kw.) for the production of 100 tons of iron daily and 20 tons of ferro-alloys. The plant was designed to handle daily the following quantities:—

	Tons.
Iron ore	200
Charcoal	50
Limestone	20
Electrodes	2
Manganese ore	20
Quartz	10
Chrome ore	10
Scrap-steel	20

Although the plant as a whole was based on a daily capacity of 100 tons of iron and 20 tons of ferro-alloys, the electrical and furnace equipment is only about half of this, corresponding to a consumption of 10,000 horse-power or 7,500 kw., and a production of 50 tons of pig-iron and 5 tons of ferro-alloys: provision being made for extension at a later date.

The furnace building would be 50 feet wide, 30 feet high, and 150 feet long. It would contain along one long side two 3,000-kw. open furnaces for smelting iron ore and three 300-kw. open furnaces for ferro-alloys. On the other side of this wall would be the transformer building, 30 feet wide and 30 feet high. The supplies of ore for the furnaces would be delivered by an elevated track in front of the furnaces and level with the charging-platforms. The furnace gases would be removed by flues below the charging-platforms. The pig-iron could be tapped into large ladles and cast in sand or in a casting-machine or poured direct into a Bessemer converter for steel-making. The ores and other supplies coming by water would be unloaded into storage by a locomotive crane. The charcoal would need a large storage-shed, perhaps 300 feet long and 90 feet wide, which would contain a month's supply, stored not more than 10 feet deep.

The order of operations would be as follows:—

(1.) Unloading from the dock directly into storage.

(2.) Removal from storage, using the same crane, to crushing and sampling plant.

(3.) Removal from crushing plant to the furnace charge-bins.

(4.) Delivering from charge-bins over weighing-hoppers to the charge-cars and thence to the side of the furnace.

(5.) Smelting for pig-iron or ferro-alloy.

(6.) Molten pig-iron received in ladle and handled by crane to casting-bed or casting-machine or to steel-making furnace.

(7.) The slag would be received in a ladle and removed by a locomotive.

The following is based on Mr. Stewart's estimate for the cost of buildings and general plant. Items for the furnaces and electrical equipment have been added from Messrs. Beckman and Linden's estimate:—

20,000-h.p. Plant with 7,000 Kw. of Electric Furnaces and Equipment.

Mr. Stewart's items—

Locomotive crane, buckets, and grab-buckets	$ 19,000
Dock, say	10,000
Electric locomotive, cars, and equipment for handling between the wharf and the crushing plant	10,000
Crushing and sampling, say	17,000
Charcoal storage for one month's supply	8,000
Carried forward	$ 64,000

Brought forward	$ 64,000
Tracks, etc., for the above-mentioned equipment	3,500
Lifting-magnet for steel scrap, etc.	1,200
Storage of manganese ore	3,500
Storehouse for electrodes and other supplies, including a small crane	6,000
Six furnace charging-bins, including weighing-hoppers and mechanical feeders	9,000
Tracks, charge-cars, and locomotive, with supports for the overhead track	10,000
Furnace building, including crane runway	25,000
Transformer building	12,000
3- to 10-ton ladles	6,000
Flues and stacks	25,000
20-ton crane, 50-foot span	18,000
Laboratory and equipment	6,000
Office	5,000
Machine-shop and blacksmith's shop	12,000
Wash-house and change-room	3,000
Slag-handling equipment	8,000
Items from Messrs. Beckman and Linden—	
Two 3,000-kw. 3-phase furnaces, installed	30,000
Seven 1,000-kw. single-phase transformers	45,500
Two sets low-tension busses for 3,000-kw. furnaces	10,000
Two sets high-tension busses, etc., for 3,000-kw. furnaces	12,000
Three 300-kw. single-phase furnaces, installed	10,000
Four 300-kw. transformers, installed	10,000
Three 50-kw. single-phase transformers	2,000
One 25-kw. motor-generator set for regulators	2,000
Three sets low-tension busses for 300-kw. furnaces	1,500
Land, say	6,000
Engineering and contingencies, 20 per cent. on $129,000	25,800
Total	$372,000

Modifying this estimate to represent a plant of 9,000 kw. making pig-iron only, we have:—

9,000-kw. Plant for Pig-iron.

Mr. Stewart's items	$217,000
Three 3,000-kw. furnaces	45,000
Eleven 1,000-kw. transformers	71,000
Three sets low-tension busses	15,000
Three sets high-tension busses, etc.	18,000
Three 100-kw. transformers	3,000
One 25-kw. motor-generators	2,000
Land	6,000
Engineering, etc., 20 per cent. on $160,000	32,000
Total	$409,000

These figures agree with the previous estimate of $400,000.

Design and Cost of Complete Plant.

The foregoing estimates of the cost of a 9,000-kw. plant for making pig-iron are for use in calculating the cost of smelting pig-iron. Any plant actually constructed would be more complex in nature, as it would include furnaces for ferro-alloys and for steel-making.

Such a plant, as has already been indicated, might suitably contain:—

Two 3,000-kw. furnaces making pig-iron.

Three 300-kw. furnaces making ferro-alloys.

This plant will produce daily about 25 tons of foundry pig-iron and about 30 tons of white pig-iron for steel-making, together with about 3 tons of ferro-alloys. The plant would cost in the order of $370,000.

To make the plant complete and self-contained, there should be added electric or other furnaces for making steel, and a steel-foundry and rolling-mill for handling the steel so produced.

I have obtained from Mr. W. G. Dauncey approximate figures for the cost of a steel-foundry and rolling-mill. This plant would handle in all about 50 tons of steel per day.

Cost of Steel Plant.

Main foundry building, including drying-ovens, core-ovens, pits, moulds, and a 25-ton overhead crane and runway	$ 60,000
Lean-to building for furnace-house	12,700
Three 6-ton (rated) electric furnaces	75,000
Transformers and electrical equipment for three furnaces	54,000
One 9-inch rolling-mill, including building, one continuous heating-furnace, and three reheating-furnaces	125,000
Total	$326,700

Only two of the electric furnaces would be in operation at any one time, and they would use between them about 3,000 kw., which would bring the total consumption in the whole plant up to about 10,000 kw.

As an alternative to the above, Mr. Dauncey recommends a steel-foundry equipped with two oil-burning open-hearth furnaces, specified as follows:—

Two 15-ton open-hearth oil-fired furnaces; three 15-ton ladles; one overhead 25-ton travelling crane; twenty charging-trucks and boxes; storage oil-tanks and all necessary small equipment for handling 90 tons of steel per twenty-four hours	$145,000
Necessary buildings for the above	35,000
Total	$180,000

This second estimate is for steel-foundry only, without any rolling-mill, but, on the other hand, it has a capacity of 90 tons of steel in place of some 50 tons provided for in the first estimate.

Collecting the figures together, we find for the complete plant:—

7,000-kw. electric-smelting plant for making pig-iron and ferro-alloys	$375,000
3,000-kw. electric steel-foundry and rolling-mills	325,000
Complete iron and steel plant	$700,000

The final daily product of this plant, after allowing for the use of pig-iron and ferro-alloys in the plant itself, would be about:—

	Tons.
Foundry pig-iron	25
Ferro-silicon, ferro-manganese, and ferro-chrome	2
Steel castings and rolled steel	50

APPENDIX X.

THE COST OF MAKING PIG-IRON.

Although the output of foundry iron for sale will be only 25 tons a day, a further 25 or 30 tons of pig-iron will be made for conversion into steel, and additional power will be used for steel-making and the production of ferro-alloys. Instead, therefore, of calculating the cost of producing iron in a plant of 25 tons daily output, using some 3,000-kw., we may fairly figure on a plant of three times this capacity, or 9,000 kw., with a production of 75 tons of foundry iron daily.

The main items of cost in the production of foundry iron are:—

Iron ore of about 55 per cent. costing $4 per net ton.

Charcoal costing $6 to $8 per net ton.

Electric power, labour, and management.

It was understood that electric power could probably be obtained for about $15 per horse-power year, and the following calculations were made on that assumption. It now appears that a charge of 0.5 cent per kilowatt-hour would be made for electric power, and a calculation on this basis is given towards the end of this Appendix.

The cost of labour is discussed in Appendix VII. and in the following pages; it appears to vary from about $4 to $8 per ton of pig-iron, according to the size and nature of the plant, and with the probable variations in wages.

The following discussion is based on the production of foundry pig-iron by the usual electric-smelting methods in furnaces of the Swedish or of the open-pit type in a plant having a total production of 70 or 80 tons daily. The cost of making electric-furnace iron by a method involving the preliminary reduction or metallizing of the crushed ore is discussed in Appendix XII.

Cost with the Swedish Furnaces.

I have received from Messrs. Electro-Metals, of Sweden, the following estimate of the cost of a ton of pig-iron made in a six-furnace plant of 60,000 tons per year. I quote this unaltered, for interest, as showing the cost at which electric-furnace iron can be made under exceptionally favourable conditions:—

1.5 tons of ore at $1	$ 1 50
0.5 ton of lime at $1	50
0.33 ton of charcoal at $6	2 00
10 lb. of electrodes at 5 cents	50
Electric current at $8 per horse-power year	2 50
Repairs and maintenance	50
Labour	2 00
Management	1 00
Interest and depreciation	1 00
Total cost per ton of pig	$11 50

In this estimate the word "ton" probably denotes in each case the metric ton of 2,204 lb., which is nearly the same as the gross ton of 2,240 lb.

The corresponding figures in British Columbia, in view of the higher costs of ore, power, supplies, and labour, the smaller scale of the plant, the lower grade of the ore, and the production of foundry iron instead of white iron, would be about as follows for 1 gross ton of iron in a plant of three 3,000-kw. furnaces making 27,000 tons of iron per annum:—

2 net tons of ore at $4	$ 8 00
0.4 net ton of charcoal at $8	3 20
15 lb. of electrodes at 8 cents	1 20
0.45 horse-power year at $15	6 75
Repairs and maintenance	1 00
Labour	4 50
Management	2 00
Interest 6 per cent. and depreciation 10 per cent.	2 60
Royalty to Electro-Metals	50
Total	$29 75

It appears that by this system foundry iron can be made at a cost of about $30 per ton.

In regard to these figures it will be noted:—

(1.) That the charge for ore ($8) is high, partly because of the high cost per ton of the ore; this cost could probably be reduced to about $3 per ton of ore if the iron-mining industry should in the future develop on a larger scale. The charge is high, also, because the ore is low grade, containing about 55 per cent. of iron, so that 2 tons of ore are needed to yield 1 ton of pig-iron. If it were possible to obtain a 65-per-cent. ore at $3 per ton, the item of $8 for ore would be reduced to $5.

(2.) I have assumed elsewhere that charcoal could be made from mill-waste at from $6 to $8 per ton. For the open furnace I take the lower figure of $6, but for the Swedish furnace, which requires a better grade of charcoal, I am taking the higher figure. I see no prospect of a material reduction in this item. The amount charged (0.4 ton) is higher than in the previous table, partly on account of the production of foundry iron instead of white iron, and partly because charcoal is weighed by the short ton and pig-iron by the long ton, while the original estimates are doubtless based in each case on the metric ton.

(3.) The electrode-consumption has been increased in view of the production of foundry iron, and the price is that at which electrodes can be imported from Eastern makers. It is possible that by making electrodes locally the cost could be reduced to 4 cents a pound, thus reducing the item from $1.20 to 60 cents per ton of pig-iron.

(4.) The charge of $2.50 for power, estimated by the Electro-Metals Company, corresponds with a consumption of 0.31 horse-power year per ton of iron. This figure must be raised by about 0.05 on account of the lower grade of ore, and a further 0.05 on account of the production of foundry iron, thus making 0.41; 0.45 appears to be as low a figure as it is safe to assume under these conditions.* If in the future power could be obtained at $10 per horse-power year, the item of $6.75 would be reduced to $4.50, effecting a saving of $2.25 per ton.

(5.) The items for labour, management, and maintenance have all been increased from the Electro-Metals estimate in view of the high cost of labour and salaries at the present time. It does not seem likely that any material reduction in these items can be expected during the next five or ten years.

(6.) Interest at 6 per cent. was calculated on the cost of the plant, $400,000, and a working capital of $100,000; and depreciation was calculated at 10 per cent. on the cost of the plant. The output was taken at 27,000 tons per annum. Royalty to the Electro-Metals has been assumed at 50 cents per ton, but I have no grounds for this figure.

(7.) If the economies indicated in (1), (3), and (4) could all be carried out, the cost of making pig-iron would be reduced to about $24 per ton. In view of this, it would appear that a plant making pig-iron in the Swedish furnace with $10 power should be able to continue to operate at a profit even when prices fall considerably below their present level.

The following details of the cost of making electric-furnace iron (probably white pig-iron) at Gellivare, in North Sweden, are contained in a report by J. A. Leffler, which appeared in the *Iron Age*, September 13th, 1917, page 605. I have changed the items from English to Canadian money.

Cost of One (Metric) Ton of (White) Pig-iron.

1.6 (metric) ton of ore (50 per cent. ore and 50 per cent. briquettes) at $2.74	$ 4 38
Limestone	16
0.4 ton of charcoal at $12.50	5 00
0.272 kilowatt-year (0.365 horse-power year at $9.50)	3 46
Electrodes	44
Repair and upkeep	88
Wages	1 56
Management and sundries	54
Royalty	34
Sinking fund	86
Rents	1 38
Carriage to Lulea	1 16
Total	$20 16

Comparing my estimate for present conditions in British Columbia, it will be seen:—

(1.) That we have to face an increase of $3.62 on the cost of ore.

(2.) The consumption of charcoal is taken as the same amount, but we should obtain charcoal more cheaply, thus saving $1.80.

(3.) My power assumption is 0.085 horse-power year more than the above. This is justified by the lower grade of ore used and the higher grade of iron to be made. This difference, together

* A discussion of the power-consumption will be found in Appendix VIII.

with the increased cost per year ($15 instead of $9.50), produces an increase of $3.29 in the charge for power.

(4.) Electrodes cost 76 cents more on account of the greater consumption and the higher price.

(5.) Repairs and maintenance are only 12 cents more.

(6.) Royalty is assumed at 16 cents more.

(7.) Interest and depreciation in my estimate come to 36 cents more than the charges for sinking fund and "rents" in the Swedish estimate.

(8.) Labour and management come to $6.50 in my estimate, but only $2.10 in Sweden. This difference of $4.40 is due partly to the smaller scale of the proposed plant, but mainly to the very much higher scale of wages and salaries now obtaining in British Columbia.

It will be seen that the increased amount of my estimate (about $10 more than the Swedish cost) is due, in about equal proportions, to the increased charges for ore, power, and labour.

Magnetic Concentration of the Ore.

It may be worth while to attempt an estimate of the results of concentrating the ore before smelting it, so as to find whether any economy may be expected to result from this operation.

Assume the ore is a magnetite containing 50 per cent. of iron and costing $3 a ton at the concentrating plant, with a further charge of $1 per ton freight to the smelter. The cost, using the undressed ore, is $8.80 per ton of pig-iron, as 2.2 net tons of ore would be needed. The ore is crushed to a coarse powder at a cost of 50 cents a ton. One ton of the crushed ore will probably yield 0.6 ton of 70-per-cent. concentrate and 0.4 ton of 20-per-cent. tailings. The concentrate is sintered with cheap fuel on the Dwight-Lloyd machine and the briquettes shipped to the smelter. The cost of dressing and sintering will be about $1 per ton of the concentrate. The cost of the product per ton of pig-iron will be:—

2.4 tons of ore mined at $3	$ 7 20
2.4 tons of ore crushed at 50 cents	1 20
1.4 tons of concentrates, dressing and sintering at $1	1 40
1.4 tons of concentrates, freight at $1	1 40
	$11 20
2.2 tons of 50-per-cent. ore at $4	8 80
Increased cost due to process	$ 2 40

On the other side we may expect the following economies:—

2½ lb. of electrodes at 8 cents	$ 20
0.08 horse-power year at $15	1 20
Repairs and maintenance	15
Labour	65
Management	30
Interest and depreciation	40
Total	$ 2 90

It does not appear, therefore, that a great saving could be effected by dressing a 50-per-cent. ore if crushing and sintering were necessary, though Messrs. Beckman and Linden consider that a net saving of nearly $3 per ton could be effected in this way. I may add that for this calculation I have assumed that the operation of sintering would remove the sulphur so completely that it would not be necessary to form a slag for its removal, and also that a white iron would be made and turned to foundry iron by the addition of ferro-silicon, so that it would not be essential to have any silica in the furnace charge. An alternative plan would be to use about two-thirds of sintered concentrates and one-third of undressed ore in the furnace charge, thus obtaining enough silica for the production of foundry iron.

Although the above calculation shows only a small saving by the concentration of a 50-per-cent. iron ore, it is possible that a more important economy could be effected by magnetic concentration in the manner indicated in Appendix III.

PRODUCTION OF FOUNDRY IRON.

On account of the fact that the Swedish furnace is generally used for the production of a white pig-iron containing not more than about 1 per cent. of silicon, we have no exact data for the production of foundry iron of, say, 3 per cent. of silicon in this furnace. We are satisfied, however, that there would be a decided increase on this account in the cost for power, charcoal, electrodes, and maintenance, besides the general overhead, labour, and interest charges. In view of this, it is worth while to consider what the cost would be of converting white iron into foundry iron by the addition of ferro-silicon. One ton of iron containing 1 per cent. of silicon would need the addition of 0.04 ton of 50-per-cent. ferro-silicon to raise its silicon content to 3 per cent. This ferro-silicon would cost, made in the plant, about $85 per ton, or $3.50 for the amount needed.

If the pig-iron were received in a large ladle and the ferro were thrown in red-hot, there should be enough heat to effect a perfect mixture; and as the iron is cast into pigs for sale, and then remelted in a cupola, any irregularity would be remedied before the final casting. The saving in the cost of smelting through producing white iron instead of foundry iron would about equal the cost of the ferro-silicon, and there would be the added advantage of making a single furnace product and turning as much of this as was needed into foundry iron.

Mr. Gronwall, in his estimate made in 1914, places the difference in cost between grey and white pig-iron as:—

0.03 ton of charcoal.
0.03 horse-power year.
5 lb. of electrodes.
10 cents for repairs.
7 cents for petty charges.

Under our conditions this would mean:—

Charcoal at $8	$0 24
Power at $15	45
Electrodes at 8 cents	40
Repairs and petty charges	21
Total	$1 30

We must add, however, a proportion of the charges for labour, management, and fixed charges amounting to about 60 cents, thus bringing the whole up to $1.90. The additional expense may easily be as much as 0.05 ton of charcoal and 0.05 horse-power year, and the increased cost would then be about $3 a ton (everything considered), or nearly as much as the cost of the ferro-silicon addition.

The ferro-silicon used was found to cost $3.50, but, as it replaces an equal weight of pig-iron costing $1, the net cost of the addition will only be $2.50 per ton of the resulting foundry iron.

The foregoing discussion is not intended to prove that the addition of ferro-silicon to white iron is the best way of making foundry iron, but merely that the use of the Swedish furnace for foundry iron would be perfectly safe, because ferro-silicon could be added without much additional expense if it were found impracticable to make foundry iron directly.

COST OF SMELTING IN SIMPLE PIT FURNACE.

The following is an estimate of the cost of making a ton of foundry iron in a 3,000-kw. furnace of the simple pit type. This estimate has been prepared by Messrs. Beckman and Linden, depending on their commercial experience of the production of ferro-manganese in such a furnace. As, however, they have no data with regard to the production of pig-iron, they have accepted my figures for the probable consumption of power and charcoal in such a furnace. These assumptions, which are based on calculation, are that the open furnace would need 0.50 horse-power year of electric power, which is 0.05 more than I allowed for the Swedish furnace, and 0.50 ton of charcoal, which is 0.1 ton more than I allowed for the Swedish furnace.

Messrs. Beckman and Linden argued, from general considerations, that the open furnace would be at least as economical of power as the Swedish furnace, but were not prepared to guarantee such a performance. I do not think it will be safe to assume any better figures than those I have given until the performance of this furnace has been demonstrated in commercial

operation over a considerable period. The figures they give for labour, general expenses, and interest are probably too high, because they are considering a single 3,000-kw. furnace, while the plant we have in view will employ about 10,000 kw. The output of the single furnace is taken as 8,000 tons per annum.

*Beckman and Linden's Estimate of the Cost of One Long Ton of Foundry Pig-iron made in Open Furnace from a 50-per-cent. Ore.**

Iron ore, 2 tons at $4 per ton	$ 8 00
Electrical power, 0.5 horse-power year at $15	7 50
Charcoal, 0.5 ton at $6 per ton	3 00
Electrodes, 20 lb. at 10 cents per pound	2 00
Labour	8 00
Supplies	1 00
Plant and general office expenses	5 00
Interest and depreciation, 20 per cent. on $180,000	4 50
Total	$39 00

If we are considering this furnace as a unit in a plant of 10,000 kw., it seems probable that the cost of labour would be about $6, the general expenses $3, and the interest and depreciation $3. With these changes the total cost would be reduced to $33.50, or about $4 more than my estimate with the Swedish furnace.

Messrs. Beckman and Linden consider that using 50-per-cent. ore at $4 they could obtain a 65-per-cent. concentrate at $6.45 per ton, including the cost for concentrating and sintering of $1.25 per ton of concentrate. Using this concentrate, they estimate the following, assuming an output of 10,000 tons per annum from a 3,000-kw. furnace:—

Beckman and Linden's Estimate of the Cost of Foundry Iron from 65-per-cent. Concentrate.

Iron ore, 1.54 tons at $6.45 per ton	$ 9 93
Electric power, 0.4 horse-power year at $15	6 00
Charcoal, 0.5 ton at $6	3 00
Electrodes, 20 lb. at 10 cents per pound	2 00
Labour	6 40
Supplies	1 00
Plant and general office expenses	5 00
Interest and depreciation, 20 per cent. on $140,500	2 81
Total	$36 14

This estimate shows a saving of $3 as compared with the cost of smelting the undressed ore, but I am doubtful whether so small a degree of concentration would do more than barely pay for itself. Thus, even assuming the small cost of $1.25 per ton of concentrate to cover the crushing of the ore, the magnetic dressing, and the sintering of the concentrate, it appears that Messrs. Beckman and Linden have figured on a perfect dressing, losing no iron in the tailings. If we assume the latter to contain even so little as 15 per cent. of iron, we would need 1.43 tons of ore for each ton of concentrate, which with the above charge would work out at $6.97 per ton, or $10.30 per ton of iron. The difference in power-consumption of 0.10 horse-power year per ton was deduced from my own figures, but is probably rather too high; 0.075 would be a more probable estimate. A mistake appears to have been made in the item for interest and depreciation, which can hardly be reduced from $4.50 to $2.81 by the increased richness of the ore. I believe it would be found in practice that the enrichment of the ore from 50 to 65 per cent. would not effect any considerable saving. On the other hand, as I show elsewhere, if an ore of, say, 40-per-cent. could be mined decidedly more cheaply per unit of iron contents than a 50-per-cent. ore, a concentrate of 65 per cent. or upwards could probably be made from this cheaper ore at such a price as to offer a material saving. It should be added that the whole of the foregoing discussion depends upon the ease and completeness with which the ores of British Columbia can be concentrated. At present we have no information on this subject.

* It will be found that, making reasonable allowance for losses, the ore would have to contain about 55 per cent. of iron in order that 2 net tons of it should yield 1 long ton of pig-iron.

An examination of the above estimate will show that the consumption of iron ore must be taken as 2 *long* tons of 50-per-cent. ore and 1.54 *long* tons of 65-per-cent. concentrate respectively per long ton of pig-iron produced. They differ in this respect from my own estimates, which are in *short* tons of ore per *long* ton of pig-iron. My estimates were made in that way because the cost of ore, charcoal, etc., in British Columbia is quoted on the short ton, while pig-iron is always sold by the long ton.

For the purpose of this report, I furnished Messrs. Beckman and Linden with the following estimate of the commercial consumption of power and charcoal per long ton of foundry pig-iron made in an open-pit furnace. This estimate may be regarded as too conservative, but I have no data on which I could base a closer estimate.

	H.P. Year.	Net Ton Charcoal.
White charcoal iron from 65-per-cent. concentrate	0.35	0.45
White charcoal iron from 50-per-cent. iron ore	0.45	0.45
Grey charcoal iron from 65-per-cent. concentrate	0.40	0.50
Grey charcoal iron from 50-per-cent. iron ore	0.50	0.50

I have no reason for doubting the general correctness of these figures, which, of course, will vary with the size of furnace and operating conditions, but for purposes of comparison I would alter the power-consumption assigned to items 2 and 3 so as to make them equal. Thus the power-consumption for white charcoal iron from 50-per-cent. ore and for grey charcoal iron from 65-per-cent. concentrate would each be 0.42 or 0.43 horse-power year.

COMPARISON WITH BLAST-FURNACE METHODS.

It may be of value to compare with my estimate of the cost of making pig-iron in the Swedish furnace the following estimates by the B. L. Thane Company of the cost of making pig-iron in a large blast-furnace near Puget sound at 1918 prices:—

B. L. Thane Company's Estimate of the Cost per Long Ton of Blast-furnace Pig-iron.

Iron ore, 3,457 lb. at $4.40 per long ton	$ 6 81
Coke, 2,485 lb. at $9.60 per net ton	11 93
Limestone, 1,000 lb. at $1.90 per long ton	81
Labour	1 50
Materials	1 50
Capital charges	3 40
Total	$25 95

(1.) The charge for iron ore, $6.81, is less than my estimate of $8, merely because the ore is assumed to contain 65 per cent. of iron, whereas I have been advised that it will not be safe to assume more than 55 per cent.; the price per ton of ore being the same ($4.40 per long ton instead of $4 per short ton).

(2.) The charge for coke, $11.93, is more than the combined charges for charcoal, electrodes, and power, $11.15.

(3.) The capital charges are nearly the same, $3.40 and $2.50, or including the royalty, $3.10.

(4.) The electric-furnace estimate is higher than the other on account of the heavy charges for labour, $4.50, and management $2, compared with the single item of $1.50 for labour in the blast-furnace plant. This difference is caused mainly by the difference in the scale of operations; a coke blast-furnace turning out at least 300 tons of iron daily, while the electric furnace would scarcely make 30 tons.

In conclusion, there does not appear to be any cause, other than the different size of the furnaces, why electric-furnace iron should cost more than blast-furnace iron under the conditions we find on the Coast, and providing that power can be obtained at $15 or less.

Two other estimates by the B. L. Thane Company place the consumption of coke at 2,240 lb., costing $7.13 per net ton of coke or $7.98 per ton of iron, and at 2,625 lb., costing $12.20 per net ton of coke or $16 per ton of iron; the total cost of a ton of pig-iron coming to $22 and $30.02 respectively.

Since the above was written I have received a letter from the British Columbia Electric Railway Company, which is reproduced in Appendix IV., stating in effect that they would supply large blocks of power up to 10,000 horse-power in the neighbourhood of Vancouver for a charge

of 0.5 cent per kilowatt-hour. This charge is so high as to render impossible any large-scale production of electric pig-iron in the Swedish or open-pit furnace, and unless some other method can be devised that will need decidedly less power, all that can be done will be to make a small amount of pig-iron during the present period of extreme high prices. In view of the necessarily temporary nature of such operation, it would be impossible to install a plant of Swedish furnaces, and we can only consider the simple open-pit furnace, because, although it uses more power per ton of pig-iron, it can be installed more quickly and more cheaply, and can easily be converted to the production of ferro-alloys, or even replaced by electric steel-making furnaces, when the drop in the price of pig-iron shall render its production impossible.

In calculating the cost of making iron in the simple pit furnace with power at 0.5 cent, I must, for comparison with the previous instances, convert this figure into a charge for the horse-power year. For this purpose I shall assume a load factor of 85 per cent., which provides for stops for repairs, as well as the usual degree of irregularity of power. On this assumption the horse-power year would cost $27.80. The cost of making a long ton of foundry iron in a plant of 10,000 kw. would be about as follows:—

Cost of One Long Ton of Foundry Iron using 0.5-cent Power.

Iron ore, 2 tons at $4 per ton	$ 8 00
Electrical power, 0.5 horse-power year at $27.80	13 90
Charcoal, 0.5 ton at $6 per ton	3 00
Electrodes, 20 lb. at 10 cents per pound	2 00
Labour	6 00
Supplies	1 00
Plant and general office expenses	5 00
Interest and depreciation	3 00
Total	$41 90

With so high a charge for power the operations would probably be on a smaller scale, and it would be inexpedient to install as much labour-saving appliances, so that the cost would agree more closely with Beckman and Linden's estimate of $39, corrected for the higher price of power. This would come to $45.40 per ton of pig-iron. Thus it appears that unless cheaper power can be obtained the cost of making electric pig-iron in British Columbia will be in the order of $40 to $45 per ton.

The British Columbia Railway Company offer 2,000 kw. of $15 power on Vancouver island, but this does not improve the situation materially, because the scale of operations would be so small that the cost of a ton of iron would certainly be in excess of $40.

It should also be noted that the above offers of power carry some restrictions with regard to the company's peak-load periods. I have no particulars in regard to this, but no doubt it would further increase the operating cost by reducing the output from a given electrical plant and staff.

APPENDIX XI.

REPORT BY MESSRS. BECKMAN AND LINDEN.

Introductory Note by Dr. Stansfield.

When undertaking the present investigation I considered that it was very important to decide whether the high Swedish furnace or the simpler pit furnace used at Heroult would be the more suitable under the conditions existing in British Columbia.

I was familiar with the Swedish furnaces, but not with the Californian furnace, and I therefore visited San Francisco and Heroult. At San Francisco I met Messrs. Beckman and Linden, an engineering firm who have specialized in electric smelting and had recently erected a plant

for the production of ferro-alloys at Bay Point. Mr. Beckman is familiar with conditions in Sweden as well as in California, and I therefore discussed with him the design of furnace and plant for the production of pig-iron. In spite of his knowledge of the Swedish type of electric furnace, Mr. Beckman concluded that a simple pit furnace of the kind used for making ferro-alloys would, on the whole, be better than the Swedish furnace for the conditions in British Columbia. Such a furnace is substantially the same as the furnace that has been used at Heroult, with the exception of the roof and charging-chutes. In view of Mr. Beckman's knowledge of Sweden and California and of his experience in designing, erecting, and operating the plant at Bay Point, I asked him to prepare a design for an electric-smelting plant in British Columbia. The general outline of the plant was arranged between us, and I furnished him with the necessary data in regard to the nature and cost of the ore, charcoal, power, and labour. I understood that he would give an estimate for the consumption of power and charcoal per ton of pig-iron, but Mr. Beckman finally decided to take my figures for these items as the basis for his report.

I had in mind at that time a plant which would contain:—

Three 3,000-kw. furnaces for smelting ore.
Three 300-kw. furnaces for smelting ferro-alloys.
Two 1,500-kw. furnaces for making steel.

At first, however, the building was to be large enough for two 3,000-kw. and three 300-kw. furnaces; and only one of the 3,000-kw. furnaces, together with the three 300-kw. furnaces, were at first to be installed. Unfortunately, Mr. Beckman based his design of the plant and his estimate of the cost of making iron on the smallest equipment considered, which was only intended to be temporary, and on this account his estimate of the cost per ton of making pig-iron is higher than necessary.

ELECTRIC PIG-IRON IN BRITISH COLUMBIA.

REPORT BY BECKMAN AND LINDEN ENGINEERING CORPORATION, SAN FRANCISCO, JULY, 1918.

GENERAL REMARKS.

The following report is made at the request of, and is based upon figures which have been supplied by, Dr. Alfred Stansfield, of McGill University, Montreal, and has reference to a possible pig-iron industry in British Columbia. All of the conclusions reached are based upon and deduced from information received in this manner.

LOCATION OF PLANT.

In British Columbia there is available a considerable amount of developed hydro-electric power and also a large amount of power which is awaiting development. It would be considered advisable in connection with this investigation to locate the proposed pig-iron plant at a place where already developed power is available, and in such locality that the raw materials essential in this industry are obtainable with the least effort. We may take, for example, such a point as Port Moody, approximately ten miles distant from Vancouver. This community has access to the Canadian Pacific Railway and also deep-water facilities. The British Columbia Electric Railway Company, Limited, have transmission-lines already in Port Moody. Port Moody has a small electric furnace operating for the manufacture of other products, which would facilitate the obtaining of labour to some extent for the undertaking along the lines suggested.

GENERAL OUTLINE OF PROJECT.

It is a well-known fact that in Sweden great quantities of pig-iron are manufactured by means of reducing iron ore in electric furnaces, utilizing charcoal as reducing agent. The conditions existing in Sweden and those existing in British Columbia are very similar. It therefore suggests itself that the manufacture of pig-iron in British Columbia should offer opportunities similar to those in Sweden. The project here would be based on four units. The first to be installed would consist of one 3,000-kw. furnace and possibly three 300-kw. single-phase furnaces; the former furnace for the purpose of manufacturing pig-iron, and the latter furnaces for the purpose of manufacturing ferro-alloys, such as ferro-molybdenum, ferro-chrome, ferro-tungsten, and others. The next step would be the addition of a 5,000-kw. furnace for the manufacture of pig-iron, or it might be thought more advisable to put in a 10,000-kw. furnace for this purpose. The difference in operation and equipment between a 3,000-kw. and a 5,000-kw.

furnace is not very material and would only involve an increase in production, while the operation and equipment of a 10,000-kw. furnace would be materially different and a distinct development over a 3,000-kw. furnace. Of course, the investment on a 10,000-kw. furnace would be considerably greater than on a 5,000-kw. furnace, and on that account it might be considered advisable to take an intermediary step. The furnaces would be built in such a manner that they could easily be adapted to manufacturing other alloys, such as ferro-silicon. The purpose of this would be to make the plant as flexible as possible, so that in case the price of pig-iron went down the plant could be used economically for other purposes.

Raw Materials.

In the manufacture of pig-iron the essential raw materials are:—

A. Cheap electric power.
B. Iron ore.
C. Reducing agent, such as charcoal.
D. Fluxing agent.
E. Electrodes.

A. Hydro-electric Power.—The amount of power necessary to produce 1 ton of pig-iron in the electric furnace is dependent to a great extent upon the purity of the ores. The iron ore which is available for this undertaking would consume approximately 0.5 horse-power per year per ton of pig-iron. In case the ore was concentrated up to 65 per cent. iron content, it would take 0.4 horse-power per year per ton of pig-iron. It is apparent from the following cost data that the power cost is one of the large items, and to make such an undertaking successful it is essential that low power prices are obtainable. It is understood that the British Columbia Electric Railway Company, Limited, has available 10,000 horse-power, 60-cycle power, that could be put into service immediately. Later developments of this industry would necessitate the development of new hydro-electric power sites in close proximity to raw materials.

B. Iron Ore.—The raw material on which the whole industry is based is the iron ore. There are a number of iron-ore deposits in British Columbia on the mainland, as well as on the islands, and it would be a question of its availability to Port Moody which would partially govern as to its use in this undertaking. The ore which has been suggested is a magnetite ore containing lime of an average analysis of:—

	Per Cent.
Iron	50 to 55 (Fe_3O_4 69-76%).
Silica	5 to 6
Alumina	4
Phosphorus	0.02
Sulphur	0.1
Calcium carbonate, etc.	15 to 21

The ore is claimed to be practically self-fluxing and would on that account not necessitate the use of any fluxing agent whatsoever. In a general way this ore is low in its iron content for a very successful pig-iron operation. If there were some ore of higher grade available and at a low price, it would be strongly advisable to consider these deposits in preference to the iron ore under discussion. There is, though, a means by which this ore could be brought up to a higher degree of purity, which would involve a concentrating plant and the sintering of the obtained concentrates. This would, of course, increase the cost of the ore and would give a higher iron content of ore material to work with, which would increase the output per horse-power year in the electric furnace. It would therefore appear that, if no other ore is available, a concentrating plant would be advisable.

C. Reducing Agent.—In the Swedish practice where electric pig-iron is produced charcoal is used as a reducing agent. This is obtained as a by-product from the large lumber and timber operations in Sweden, where pine, spruce, and fir are handled, and there is no timber operation in Sweden of any kind where the refuse is not turned into charcoal either in a by-product charcoal-oven or by pit-charcoaling. British Columbia, as we understand it, has large timber operations, as well as large stands of timber, that in many cases are worthless for timber purposes. These waste lands might be gone over and the timber turned into charcoal, as well as by-products, such as alcohol, acetic acid, creosote-oil, and also turpentine. The creosote-oils are used extensively in flotation purposes where the metal values are separated from the gangue. Charcoal obtained in such a manner, either in by-product coke-ovens or in pit-charcoaling, contains approximately 73 per cent. fixed carbon.

British Columbia holds in its bituminous-coal deposits another reducing agent that under special conditions may be used to advantage. It is high in ash and reported to contain 50 per cent. fixed carbon.

It has also been suggested as a possibility to utilize some of the oil-wastes obtainable on the Pacific coast as a reducing agent in making pig-iron. This material contains practically no ash and about 70 per cent. of fixed carbon.

D. Fluxing Agent.—As has been explained under the heading "Iron Ores," the iron ore proposed to be used in this undertaking would not need any fluxing material. Limestone, though, as a rule is used for this purpose, and is available at various points accessible to Port Moody in a purity suitable for this operation.

E. Electrodes.—All electric-furnace operations for the reduction of ores are dependent on the supply of electrodes. Electrodes are the means by which the electric current is made available in the furnace. There are plants on the Pacific coast which are manufacturing electrodes, and there are large manufacturers of electrodes in the East, both in Canada and the United States. It would seem as though an undertaking of this kind in British Columbia should depend upon its electrode-supply from a Pacific Coast source, and it would be advisable to make an early arrangement with the manufacturers there for this essential.

General Plant Layout.

The plant would be composed of the main furnace building, adjacent to which would be the transformer building. The furnace building would give ample space for the furnace and the necessary electrical connections, as well as the casting-floor on to which the pig-iron would be tapped. This building would have a big electric travelling crane and also the necessary tracks for the purpose of moving raw materials about and moving the finished products. The initial size of the building would be one which could house a 3,000-kw. furnace and three 300-kw. single-phase furnaces. Buildings, such as storehouse, laboratory, office, wash-house, etc., would be placed at convenient points on the ground. The necessary trackage would have to be laid out in the yards for the handling of all materials and incoming and outgoing shipments. Ample storage-space would be necessary in the yards for the storing of raw materials. There should be approximately sixty days' supply of iron ore in stock, amounting to approximately 4,000 tons. Storage-space should also be provided for a large tonnage of charcoal. The amount that would have to be kept in storage would depend upon the physical conditions surrounding the plant and the accessibility to the charcoal-producing installations. It would be advisable to plan for the necessary roof-sheds to cover two to three months' supply of charcoal. In case any fluxing agent should be needed, space should be provided for the storage of same. Electrodes could be stored in suitable numbers in a small building. To handle efficiently the raw materials and finished product from stock-piles to dump-cars, etc., a locomotive crane would be needed.

Type of Furnace.

The type of electric furnace in which pig-iron is made in Sweden has a close resemblance to the shaft-furnace. The shaft carrying the burden is supported by braces, and the reduction takes place in a big bowl at the bottom of the shaft, into which the electrode projects. There is a heavy strain on the structure in general, and the refractory roof of the furnace itself receives very severe treatment and frequently needs rebuilding. It has been carefully considered in this connection that it would be advisable to try out a simpler furnace very similar to those used in the manufacture of ferro-silicon and ferro-manganese—a simple 3-phase open-pit furnace. By installing this kind of a furnace and holding the Swedish shaft-furnace in reserve, if the tests work out as anticipated, a saving in installation will take place and a step forward will have been made in the manufacture of pig-iron. It is expected to produce in such a furnace grey pig-iron containing 3 to 4 per cent. carbon, 2 to 3 per cent. silicon, 0.05 per cent. sulphur, and 0.5 per cent. phosphorus. If the results do not come up to expectations, the furnace can readily be adapted to manufacturing ferro-silicon or ferro-manganese and a duplication of the Swedish furnace can be installed. The Swedish shaft-furnaces are beyond the experimental stage, working successfully day in and day out in manufacturing white pig-iron. Some trouble has been encountered in manufacturing grey pig-iron in these furnaces. The white pig-iron, though, is used very successfully in open-hearth furnaces and in electric steel manufacture.

Cost of Plant.*

(At 1918 Prices of Apparatus and Construction.)

One 3,000-kw. 3-phase furnace, installed, including casing, electrode-holders, jib-cranes, regulators, and foundations	$ 15,000
Four 1,000-kw. single-phase, 33,000-volt primary, 60-cycle oil-insulated and water-cooled transformers, installed, with from 60 to 120 volts in 5-volt steps on the secondary side (one of these transformers is spare)	26,000
One set low-tension busses for 3,000-kw. furnace, installed	5,000
One set high-tension busses for 3,000-kw. furnace, including oil-switches, switchboard, and meters	6,000
Three 300-kw. single-phase furnaces, installed, including casing, electrode-holders, and regulating device	10,000
Four 300-kw. 33,000-volt primary, 60-cycle, single-phase, oil-insulated and water-cooled transformers, installed, with a range of from 70 to 100 volts in 5-volt steps on the secondary side	10,000
Three 50-kw. single-phase, 60-cycle, 33,000 volts to 440 volts air-cooled transformers, installed, with switchboard (to be used for industrial purposes around plant)	2,000
One 25-kw. motor-generator set for regulators, etc., installed	2,000
Three sets low-tension busses for 300-kw. furnaces	1,500
One furnace building, built entirely of reinforced concrete, including electric travelling crane, tracks, metal-handling equipment, etc.	35,000
One transformer building, built entirely of reinforced concrete	10,000
One shipping-store building of wood and stucco exterior finish	7,000
One laboratory with complete equipment	7,500
One store-room and change-room building, built of wood and exterior stucco finish, including steel lockers, toilets, wash-basins, and shower-baths	8,000
One machine-shop with equipment	10,000
One office building	3,000
One gate-house with time-clock and time-keeper's office	500
Railroad tracks, industrial track, ore-handling equipment, water-supply, sewerage, fence, and industrial lighting, etc.	25,000
Land, 4 acres	4,000
	$187,500
Engineering and contingencies, 20 per cent.	37,500
Total	$225,000

It is well to point out that the above figures cover the cost of a plant that is built entirely of permanent construction. Permanent-construction figures in the first cost are higher than any temporary work, of course; but due to the great fire risk of temporary work, such as wooden construction, it is deemed more advisable to make the larger initial investment to cut down the maintenance cost of a temporary plant.

The electrical equipment selected and put into this estimate is such that, according to our experience with identical design and equipment, a power factor can be obtained on the power company's line as high as from 90 to 92 per cent.

Cost of Production.

Two sets of figures have been made out on the cost of production of pig-iron. The pig-iron which is supposed to be produced is grey foundry pig-iron, and would have a market value of $35 per ton at the plant. The figures which have been worked out are based on crude ore and concentrated ore, assuming that the crude ore would be obtained in one case for $4 per ton, and in the other case increased to $6.45 per ton by concentration. Another set of figures is based

* In this cost estimate is not included ore-concentrating and sintering plant, nor charcoal plant.

on price of crude ore at $1.50 per ton, and concentrated ore at $3.20 per ton. This includes the cost of concentrating and sintering, amounting to $1.25 per ton concentrate. The power is assumed to be delivered at the switchboard at $15 per horse-power year. The reducing agent—charcoal—is assumed to be obtained at a price of $6 per ton ($6 per ton being the price for British Columbia coal), and $7 per ton the price of oil-waste carbon. In the following figures charcoal only has been taken into consideration, though the amounts of the different reducing agents needed to reduce 1 ton of 55-per-cent. ore are as follows:—

	Ton.
Charcoal containing 73 per cent. fixed carbon	0.5
British Columbia coal, 50 per cent. fixed carbon	0.8
Oil-waste carbon, 70 per cent. fixed carbon	0.6

In producing from an ore containing 55 per cent. iron, 2 tons per horse-power year is estimated as a safe figure upon which to base calculations. On ore containing 65 per cent. iron, 2.5 tons per horse-power year production is assumed a safe figure upon which to base calculations. It is evident from the above that operating with a 55-per-cent. ore in a 3,000-kw. furnace would give an annual production of 8,000 tons of pig-iron, while the annual production obtained in a 3,000-kw. furnace with concentrated ore would be 10,000 tons of pig-iron. The operation of the furnace would be continuous twenty-four hours' operation and would be operated in three shifts. The costs would be as follows:—

$4 per Ton Crude Ore (50 Per Cent. Iron).

Electric power, 0.5 h.-p. year at $15 per h.-p. year	$7 50
Iron ore, 2 tons at $4 per ton	8 00
Coal, ½ ton charcoal at $6	3 00
Electrodes, 20 lb. per ton of metal produced at 10 cents a pound	2 00
Labour	8 00
Supplies	1 00
Plant and office general expense	5 00
Interest on investment and depreciation, 20 per cent.	4 50
Total	$39 00

Total Production, 8,000 Tons Pig-iron.

Gross earnings at $35 per ton	$280,000
Cost to manufacture at $39	312,000
Deficit	$32,000

$6.45 per Ton Concentrated Ore (65 Per Cent. Iron).

Electric power, 0.4 h.-p. year at $15 per h.-p. year	$6 00
Iron ore, 1.54 tons at $6.45 per ton	9 93
Coal, ½ ton charcoal at $6	3 00
Electrodes, 20 lb. per ton of metal produced at 10 cents a pound	2 00
Labour	6 40
Supplies	1 00
Plant and office general expense	5 00
Interest on investment and depreciation	2 81
Total	$36 14

Total Production, 10,000 Tons Pig-iron.

Gross earnings at $35 per ton	$350,000
Cost to manufacture at $36.14	361,400
Deficit	$11,400

Crude Ore at $1.50

Electric power, 0.5 h.-p. year at $15 per h.-p. year	$7 50
Iron ore, 2 tons at $1.50 per ton	3 00
Coal, ½ ton charcoal at $6	3 00
Electrodes, 20 lb. per ton of metal produced at 10 cents a pound	2 00
Labour	8 00
Supplies	1 00
Plant and office general expense	5 00
Interest on investment and depreciation, 20 per cent.	4 50
Total	$34 00

Total Production, 8,000 Tons Pig-iron.

Gross earnings at $35 per ton	$280,000
Cost to manufacture at $34	272,000
Net profit	$8,000

Concentrated Ore at $3.20

Electric power, 0.4 h.-p. year at $15 per h.-p. year	$6 00
Iron ore, 1.54 tons at $3.20 per ton	4 93
Coal, ½ ton charcoal at $6	3 00
Electrodes, 20 lb. per ton of metal produced at 10 cents a pound	2 00
Labour	6 40
Supplies	1 00
Plant and office general expense	5 00
Interest on investment and depreciation, 20 per cent.	2 81
Total	$31 14

Total Production, 10,000 Tons Pig-iron.

Gross earnings at $35 per ton	$350,000
Cost to manufacture at $31.14	311,400
Net profit	$36,600

It is from these figures very apparent that it would be impossible to go into the pig-iron manufacture using unconcentrated ores; while operating with concentrated ores at $3.20 shows a reasonable return.

Electric Steel-furnace.

It would seem as a logical arrangement in connection with the pig-iron furnace to establish an electric steel-furnace, in which special steel will be manufactured. There is no possibility at the present time for an iron industry on the Pacific coast to compete with Eastern production of heavy steel material. There is a field here legitimate and profitable to manufacture special shapes of light rolled metal, as well as steel castings. With all the mining industries going on in the West and with the ship-building industries growing out here at a pace, there is an urgent need for special alloy steel and special electric steel castings. The raw materials for the alloy steel are available on the Pacific coast and could be readily smelted and put into steel products. The material which comes out of the pig-iron furnace would be carried in a ladle in a molten condition to the steel-furnace, and in such a manner cut down the melting cost and refining cost of the finished steel product. It is certain that better financial success would be made by installing an electric steel-furnace in conjunction with the pig-iron manufacture and a rolling-mill than by operating the plant exclusively on pig-iron.

Ferro-alloy Furnaces.

The three 300-kw. furnaces can be used for the manufacture of alloys which could easily be used in the production of steel. The operation of these furnaces could be carried on easily in conjunction with the large 3,000-kw. furnace.

Conclusions.

The foregoing report shows the following:—

(1.) That conditions in British Columbia lend themselves well to the manufacture of pig-iron under special conditions.

(2.) That the successful manufacture of pig-iron in British Columbia is dependent upon a low-priced iron ore.

(3.) That British Columbia holds by virtue of its large supply of timber and its deposits of bituminous coal two reducing agents suitable for the manufacture of pig-iron.

(4.) That cheap hydro-electric power delivered at a figure not higher than $15 per horse-power year is essential.

(5.) That the concentrating and sintering of concentrates before the ore is used in the furnace is essential in the manufacture of pig-iron from British Columbia ore.

(6.) That a steel industry in conjunction with the pig-iron furnace and alloy-furnaces is a more advantageous undertaking than a pig-iron industry exclusively.

Beckman & Linden Engineering Corporation.

(Signed.) J. W. Beckman, *President.*

Cost of manufacturing Ferro-silicon.

(Appendix to Beckman & Linden's Report.)

In the foregoing report reference is made to the possibility of utilizing the furnace suggested there for the manufacture of ferro-silicon. The following figures would indicate the cost of producing 1 ton of metal and the returns which would be obtained:—

Power at $15 per horse-power year	$15 00
Quartz, 2,400 lb. at $3.60 per ton	4 20
Coal, 1,210 lb. at $6 per ton	3 63
Turnings, 1,500 lb. at $10 per ton	7 50
Electrodes, 60 lb. per ton of metal at 10 cents per pound	6 00
Labour	16 00
Supplies	1 00
Plant and office general expense	5 00
Interest on investment and depreciation, 20 per cent.	9 38
Total	$67 71

The total output of this plant would be about 4,000 tons of 50-per-cent. ferro-silicon per year, and, assuming that 50-per-cent. ferro-silicon sold for $150 per ton, the net profit would be:—

Gross earnings at $150 per ton	$600,000
Cost to manufacture at $67.71 per ton	270,840
Net profit	$329,160

APPENDIX XII.

A NEW METHOD OF PRODUCING ELECTRIC-FURNACE IRON.

The operation of smelting an ore of iron for pig-iron includes two distinct steps, which are, however, carried out in the same furnace and to some extent simultaneously.

The first step is one of reduction, in which the ore, consisting largely of oxide of iron, is converted into metallic iron by means of carbon or carbonaceous gases. The second step is one of fusion, in which the metallic iron, already formed, is melted and becomes pig-iron. The gangue of the ore, together with the flux, is also melted and forms slag.* The first step can be carried out at a moderate temperature of, say, 700° or 800° C., while the second step needs a very high temperature, say, 1,400° or 1,500° C. Although the first step can be effected at a lower temperature than the second, it consumes about twice as much heat, measured in calories or kilowatt-hours, and it is this large requirement of heat that renders so costly the electric smelting of iron ores. That this is practically true will be made clear when I mention that a ton of steel can be melted in an electric furnace by means of 600 or 700 kilowatt-hours, whereas about 2,500 kilowatt-hours are needed to produce a ton of pig-iron from the ore.

In the electric furnace both steps of the smelting operation are carried out more or less simultaneously, and at a high temperature; and this causes waste of heat and unnecessary expense, particularly as the heat is derived from costly electrical energy. The smelting operation produces a large amount of hot carbonaceous gases, which in a simple electric furnace escape and burn above the charge. These gases may be utilized for heating and reducing the ore, and the Swedish furnace is provided with a large shaft for this purpose. A careful analysis shows, however, that the most efficient furnace of this type is decidedly inefficient from an economic point of view; and we are led to consider whether better results can be obtained in some other way.

I have thought, for a long time, that greater economy could be obtained by separating the two stages of the smelting process and carrying them out in separate furnaces. The ore, crushed to a coarse powder, would be reduced to the metallic condition by means of carbon in one furnace using fuel-heat, and the metallic powder would then be melted electrically. It appears that in this way a pig-iron of electric-furnace quality could be obtained more cheaply than by direct electric smelting.

Until recently I had no experimental evidence in regard to the preliminary reduction of the ore, and had intended to undertake a series of experiments for this purpose; but during the last few months I have obtained information with regard to this point, which makes it seem probable that the process can be carried out practically, and that a decided economy will be gained by its use.

The possibilities of the process will be made clear by the following numerical discussion:—

The reduction of magnetite by carbon will probably follow the equation: $Fe_3O_4 + 3C = 3\,Fe + 2\,CO + CO_2$. This requires 115,000 calories for the reduction of 1 kilogram molecular weight of magnetite, or 686 calories per kilogram of iron. This corresponds, if electrical heat is used, to 800 kilowatt-hours per metric ton of metallic iron.

The heat required to melt 1 ton of cast iron would be (theoretically) about 300 kilowatt-hours, but for the production of foundry pig-iron there would be needed an additional 175 kilowatt-hours for the production of silicon, or a total of 475 kilowatt-hours for the melting operation. Thus in round numbers there will be needed:—

	Kw. Hrs.
For reducing the iron ore to metal	800
Converting this into foundry pig-iron	500
Total	1,300

It will be noticed that I have made no specific allowance for melting the slag. This is because the gangue will be practically eliminated by magnetic treatment before fusion, and thus there will be scarcely any slag to melt.

* Actually the second stage is more complicated than I have indicated, as the iron in fusion absorbs carbon and silicon to form pig-iron, the silicon itself being derived from the silica in the ore.

In electric furnaces a working efficiency of at least 70 per cent. can usually be obtained, and therefore we find as the actual operating charges for the two stages:—

	Kw. Hrs.
For reducing the iron ore to metal	1,140
For reducing silicon and melting the iron	710
Total	1,850

The total power requirement shows a decided economy when compared with the 2,500 kilowatt-hours that would be needed for the direct smelting of the ore, even after making allowance for the cost of crushing, magnetic treatment, and double handling of the material. The first or reducing stage can, however, be carried out by means of fuel-heat instead of electrical heat without detracting from the purity of the product. The operation would have to be carried out in some kind of a muffle-furnace, as the reduced metal must be protected from the air and from furnace gases, and the efficiency of the heating fuel would consequently be very low. As, however, cheap fuel, such as waste wood, can be employed, this will not cause any serious expense. The heat theoretically needed for the reduction of the iron ore is 686,000 calories per metric ton of iron; allowing 25 per cent. efficiency, this would mean 2,744,000 calories, which would be furnished by 0.4 ton of a low grade of coal. It would appear safe, therefore, to allow for this purpose ½ ton of local coal or an equivalent amount of waste wood.

Dr. Trood and Mr. W. A. Darrah have carried out a series of experiments at Heroult, in California, on the reduction of pure magnetite ore to metallic iron. The work has been done in a small furnace making a few pounds per hour of reduced iron. This furnace was heated electrically, and in this way an exact determination could be made of the heat that was supplied to it. There was under construction at the time of my visit a large furnace for the reduction of ore which was to be heated by means of fuel. Since my visit Mr. Darrah has been made superintendent of the plant, and this has no doubt interfered with the progress of the experiments. He has, however, written me the following letter with regard to the cost of operating the Trood-Darrah process. I assume that the power-consumption used in this estimate is deduced from their small-scale experiments, and that the other expenses refer to a plant making 100 tons of metallic iron daily.

"NOBLE ELECTRIC STEEL COMPANY,
HEROULT, SHASTA COUNTY, CAL., October 23rd, 1918.

"Regarding the questions which you have raised, I have to advise as follows:—

"(1.) We have made a very substantial success in reducing magnetite-iron ores to metal by heating to a moderate temperature with carbonaceous reducing agents.

"(2.) Reduction begins in the neighbourhood of 700° C., but in order to carry the reaction to completeness, as well as to minimize the time required, we find it expedient to operate at approximately 800° C.

"(3.) For a perfect reduction of particles the size of coarse sand, with the magnetite ore that we are using we find that three hours are required. The time will vary considerably with the different grades of ore, different reducing agents, and different temperatures. Powdered charcoal is the most satisfactory reducing agent, but, of course, is not the only successful one.

"(4.) Total cost per ton of iron product, making ample allowance for power, fuel, etc., about $19.

"The costs are divided as follows:—

Item.	Cost per Ton.	Quantity required.	Total Cost per Ton of Iron.
Power for drying and reduction	½ cent per kilowatt-hour	1,200 kilowatt-hours	$6 00
Charcoal	$25 per ton	570 lb.	7 10
Ore	$3 per ton	2,760 lb.	4 15
Crushing materials	50 cents per ton	....	69
Handling materials	50 cents per ton	....	69
Labour and supervision	....	....	50
Interest and Depreciation, $20,000 Investment	....	....	10

"The above cost may appear rather high, depending upon your local conditions. It is, of course, a direct result of the price of such materials as reducing agents and iron ore, which you will note total considerably over 50 per cent. of the entire cost. The power cost, you will note, is less than one-third of the total cost.

"Dr. Trood and I consider it quite feasible to reduce the iron by our process, and melt it either electrically or after briquetting in an open-hearth furnace. It is then perfectly feasible to make either pig-iron or steel, as the market may demand."

With regard to Mr. Darrah's estimate, I may state:—

(1.) Assuming the ore to contain 67.8 per cent. of iron (published analysis), 2,760 lb. of ore would only yield about 1,870 lb. of metallic iron. It would appear from this that the estimate does not refer to a ton of pure iron, but to a 2,000-lb. ton of an impure iron product containing about 93 per cent. of iron. As this is about the percentage in foundry pig-iron, we need only increase the estimate by about 15 per cent. to provide for the change from the short ton to the long ton and for the mechanical losses in the various operations.

(2.) Mr. Darrah's estimate of 1,200 kilowatt-hours, if increased by 15 per cent., would give 1,380 kilowatt-hours, whereas my estimate, based on calculation, was 1,200 kilowatt-hours. We should for the present take the larger figure, which increases the cost by 90 cents.

(3.) The estimate of 570 lb. of charcoal, increased by 15 per cent., comes to 655 lb. This figure is supported by calculation from the equation I gave above, and I am estimating on a consumption of ⅓ net ton of charcoal; the cost of this in British Columbia will be only about $2.

(4.) The remaining items of cost must be increased by about 50 per cent. on account of the larger amount of ore to be handled. Apart from this, I cannot check them in any detail, but suppose that they would be rather higher under British Columbian conditions. The charges seem to be very small, but it should be remembered that the operation will be continuous and mechanical throughout; there will be no hard labour required, and the cost for labour, superintendence, and maintenance of plant should be small.

The following estimate of the cost of making 1 long ton of metallic iron in the form of powder by the Trood-Darrah process has been prepared in view of conditions in British Columbia:—

Cost of One Long Ton of Metallic Iron, using Electrical Heat at ½ Cent per Kilowatt-hour.

Ore, 2.2 tons at $4	$ 8 80
Charcoal, ⅓ ton at $6	2 00
Power for heating, 1,380 kilowatt-hours at ½ cent	6 90
Crushing materials at 50 cents per ton	1 10
Handling materials at 50 cents per ton	1 10
Labour and supervision	85
Interest and depreciation	25
Total	$21 00

In this estimate I have taken 2.2 tons of ore instead of 2 tons in order to cover the loss in magnetic concentration which would form the first step in the process.

If fuel can be used for heating in this operation the cost will be further reduced; thus the heat should be obtainable by the use in gas-producers of ½ ton of low-quality coal costing, say, $4 per ton. The cost of heat would thus be $2, or at the outside $2.50, and the total cost of the iron $16 or $17 per ton.

With regard to these figures, I must state clearly that, although I have full confidence in Mr. Darrah's statements, yet the operation of the process must be demonstrated on a working scale and its applicability to British Columbian ores must be shown before a commercial enterprise can be undertaken.

I should also state that I believe that foundry pig-iron can be obtained, conveniently and economically, by melting the iron powder with fluxes in an electric furnace. It will be necessary, however, to confirm this point experimentally, and also to ascertain whether the sulphur originally present in the ore will be removed sufficiently well by the proposed process.

The following estimate will give some idea of the cost of 1 ton of foundry iron obtained by melting the reduced powder in an electric furnace:—

Cost of One Long Ton of Foundry Pig-iron.

Reduced metallic powder	$17 00
Electric power, 750 kilowatt-hours at ½ cent	3 75
Charcoal, $^1/_{10}$ ton at $6	60
Electrodes, 7 lb. at 8½ cents	60
Fluxes and supplies	55
Labour	2 00
Management	1 00
Interest and overhead charges	1 50
Total	$27 00

Another favourable feature of the reduction process is that the metallic powder can be melted in electric furnaces for the production of steel without the need of first turning it into pig-iron. In this way one step of the usual process is eliminated and electric-furnace steel may be produced at very reasonable figures.

Reduction of Iron Ore by Hydrogen.

As having a bearing on the above process, I add a brief account of the reduction of iron ores by means of hydrogen. Mr. A. T. Stuart, of Toronto, invented an improved form of apparatus for the production of hydrogen and oxygen by the electrolysis of water. In trying to find uses for the hydrogen, he discovered that iron ores are reduced to metal by means of hydrogen at so low a temperature as 700° C. The process is very convenient, because the hydrogen can be passed again and again through the ore, so that the gas is perfectly utilized. Such a process, however, would only be possible if hydrogen could be obtained extraordinarily cheaply. To produce it by electrolysis would need unusually cheap electric power, and the ore could be smelted directly with less power than would be needed to make the hydrogen and to carry out the reduction with its aid. The only condition under which the process could be employed would be if there were available during off-peak periods of a power plant large amounts of direct-current power, which could be obtained at a very low price, and if, in addition, there was a satisfactory market for the electrolytic oxygen, so that the hydrogen might be regarded as a by-product. I must add, also, that Mr. Stuart's experiments were made on hæmatite ores, and it is likely that magnetites may not be reduced so easily or at so low a temperature. One feature of the process which may prove important is that the hydrogen used to reduce the iron also serves to remove from it phosphorus and sulphur in a gaseous form.

Steel Direct from the Ore.

(A Process described by F. T. Snyder.)

I conclude this Appendix with an extract from a paper on "Steel Direct from the Ore," which was sent to me recently by Mr. F. T. Snyder, of Chicago, the inventor of the Snyder electric steel-furnace. I quote Mr. Snyder, as I consider that his account is of interest in connection with the present investigation, but I do not endorse his process or assume any responsibility for his statements:—

"To expose sufficient surface for rapid reduction the ore is crushed to ¼ or ⅛ inch in diameter. From an ore-storage bin it is fed into a cylindrical kiln in which the ore is dried and heated to 700° C. under oxidizing condition. The sulphur contents of the ore will be substantially eliminated in this preliminary roasting. At 700° C. the ore falls into a reducing-kiln, in which it is exposed to the action of carbon-monoxide gas, which reduces the iron oxide to metallic iron sponge. This iron sponge is conveyed without exposure to air, and while still hot, to an air-tight electric furnace. The reducing carbon-monoxide gas is generated in a gas-producer from powdered coal giving a hot gas low in carbon dioxide. At the part of the reducing-kiln where the iron ore enters, this gas leaves the kiln with about the same composition as the gas leaving the top of a blast-furnace. Part of this gas passes into the roasting-kiln, where it is burned with air from a fan to furnish the heat required to raise the ore to 700° C. before it enters the reducing-kiln. The balance of the gas from the reducing-kiln is burned under a boiler, and with the steam the necessary power is produced for the electric-smelting furnace. By a fortunate coincidence the amount of gas available is somewhat more than the amount needed by the electric furnace.

"This arrangement of equipment meets the three fundamental difficulties of the earlier attempts to make steel direct from ore, and retains the great commercial advantages of the direct method. By the use of fine ore in rotating-kilns, which both expose the ore to the acting gases and at the same time convey it, the difficulty of getting the iron sponge out and trapping the gas is made easy by the low pressure required to pass the gases through the kilns. The electric furnace melts the sponge without oxidation and eliminates the second difficulty. The use of a preheating-kiln which is separate from the reducing-kiln makes it possible to remove the reducing gases from contact with the ore before the gas is cooled to a temperature at which carbon-deposition begins, and furnishes a sponge that is practically free from carbon and ready to melt direct to steel. As the reduction is entirely by carbon-monoxide gas, no solid carbon coming in contact with the ore, the silica, phosphorus, and titanium in the ore are not reduced, but remain in their original form and are melted in the slag in the electric furnace, substantially none of them entering the steel.

"Compared with the direct method of smelting iron ore with electricity, the kiln method. with electric-furnace finishing, has the advantage of a much lower electric-power consumption. The kiln method uses 600 kilowatt-hours per ton of steel produced for all power purposes. The direct electric smelting uses 2,000 kilowatt-hours for the electric smelting producing pig-iron, and 500 kilowatt-hours for the electric-furnace operation of changing the electric pig-iron to steel. When the weight of the electrodes for the pig-iron furnace are taken into account, and the fact that the kiln method uses charcoal from twigs and leaves, the total average of timber required for both methods is approximately the same. A production of 25 tons per day requires 1,000 kw. of power plant for the direct-steel method, and 3,000 kw. for the electric pig-iron method. The difference in the investment cost for power-plant construction is 50 per cent. greater than the total cost of the kiln plant, exclusive of its power plant. If water for power is available without cost, the burden of the investment cost renders the electric pig-iron method non-commercial in comparison with the direct-steel method.

"The economic advantages of this method are:—

"(1.) The use of iron ores of inferior composition. Sulphur is eliminated in the preliminary roasting. Silica, phosphorus, and titanium enter the slag.

"(2.) The use of fuel of inferior quality. As the fuel is burned in a producer in powdered form, raw coal, coke, or charcoal may be used. Sulphur in the fuel enters the reducing gas as sulphur-monoxide gas, which is without action on the iron at the temperatures used. Powdered fuels are in reliable use with ash as high as 20 per cent.

"(3.) The production of steel of electric-furnace quality. This is substantially higher in tensile strength, elastic limit, percentage of elongation, and resistance to shock than is Bessemer or open-hearth steel of the same analysis.

"(4.) The recovery of a high percentage of the iron in the ore. Practically all the iron in the ore passes into the steel, as the electric-furnace melting makes it possible and the production of good steel makes it necessary to produce a slag substantially free from iron. With the present blast-furnace, open-hearth or Bessemer combination, from 10 to 15 per cent. of the iron in the ore is lost in the slags produced.

"(5.) Existing methods use about 1 ton of coke in the blast-furnace per ton of pig-iron. This coke requires for its production 1⅔ tons of raw coal. To turn this ton of pig-iron into steel requires an additional ⅓ ton of raw coal burnt in gas-producers. This is a total consumption of 2 tons of raw coal per ton of steel produced. The direct method, including the gas for electric power and for roasting, requires 1 ton of raw fuel. As the fuel is used powdered, if charcoal is made the small twigs and the leaves may be carbonized as well as the larger pieces, substantially doubling the steel produced per acre of timber.

"(6.) The capital investment, including electric-power plant, is about two-thirds that of the blast-furnace, open-hearth combination for the same output.

"(7.) The production cost per ton of steel ingots is about 80 per cent. of the older practice.

"(8.) Plants for small production are practical with the direct-steel method, outputs as low as 25 tons per day being efficient.

"(9.) Production may be stopped or started in a few hours if necessary to meet market or traffic conditions, without plant deterioration, and without the production of considerable quantities of lower-quality product.

"(10.) As the equipment is low, the entire plant may be traversed by travelling cranes making repairs rapid and low in cost. This latter is also aided by the general low temperatures of operation.

"(11.) As the operation is mostly mechanical, the amount of labour required is small. Skilled labour required only for supervision.

"(12.) As the gas-pressure used is low and no large quantity of molten material is held at a time, the safety of operation is materially greater than with the blast-furnace and open hearth."

APPENDIX XIII.

AUXILIARY INDUSTRIES.

In view of the limited market for foundry pig-iron in British Columbia, it will be essential to make other products, so as to increase the output of the plant. For this purpose an additional output of low-silicon pig-iron can be made, and this can be melted with steel scrap for the production of steel. Ferro-alloys, such as ferro-silicon, ferro-manganese, and ferro-chrome, can also be made in an electric-smelting plant. These auxiliary industries not only increase the general output of the plant, thus reducing, proportionately, the overhead charges, but are themselves likely to yield a higher profit than the production of pig-iron. The production of ferro-manganese and ferro-chrome in the electric furnace depends upon a supply of ores of manganese and of chromium. Quartz is required for the production of ferro-silicon.

Ferro-alloys.

Ores of Manganese and Chromium.—I have been furnished by Mr. W. F. Robertson with the following information, which indicates that there would be a sufficient supply of ores of these metals of a grade suitable for the production in electric furnaces of ferro-manganese and ferro-chrome. Quartz for the production of ferro-silicon can also be obtained.

The Curle Manganese Group.

Report by A. G. Langley, Resident Engineer, Revelstoke, June, 1918.

Report of Assays by the Provincial Government Assayer.

Sample.	Description.	Manganese.	Iron.	Phosphorus.	Sulphur.	Insoluble.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
11675	Manganese ore sacked for shipment..	34.5	...	...	...	...
11676	General sample, dumps, ore for shipment	37.5	...	...	...	...
11677	General sample, dumps, ore for shipment	36.7	...	...	...	...
11678	General sample ore in-place, No. 2 deposit	39.0	2.7	Traces	0.13	0.35
11679	Sample high-grade, No. 1 deposit....	49.5	...	...	...	...
11680	Overburden reject	17.2	...	...	...	...
11681	Iron oxide underlying	9.7	22.6	...	...	...

(Signed.) D. E. WHITTAKER.

Report on the Ore-deposit by Mr. Langley.

"The property, consisting of ten claims, is situated at a distance of seven miles from Kaslo and adjoins the Kaslo & Nakusp branch line of the Canadian Pacific Railway.

"The group was staked by A. Curle, of Kaslo, in 1917, and although the ore is freely exposed along the old Kaslo-Slocan wagon-road it escaped attention for years, due no doubt to the lack of knowledge of the character and commercial value of the deposit. In February, 1918, the property was bonded by the original owners, A. J. Curle and A. G. Larson, to Col. F. B. Millard, of Spokane.

"Seventeen men are now employed and considerable progress has been made during the last month in developing and winning the ore.

"*Character of the Ore.*—The ore chiefly consists of the soft black or brown oxides, which may be classified as wad manganese, while concretionary psilomelane, though in evidence, is less frequent in occurrence.

"*Ore Occurrence.*—At the No. 1 deposit the ore forms a blanket deposit over the surface of the flat, the average thickness of which is hard to arrive at, for its distribution is uneven and irregular, but can safely be taken as not exceeding 6 inches.

"From where the hill rises above the flat and for about 50 feet up the gentle slope, the ore, which occurs underlying a few inches of soil, shows about an average thickness of 1½ feet and appears to be of higher grade than that on the flat.

"At the No. 2 deposit the occurrence is similar to that of the No. 1, but appears to be more uniform and to contain a greater tonnage.

"This deposit has not been mined yet, and its area is less definitely outlined than that of the other. In an isolated patch at about 120 feet east of this deposit a small surface cut shows a 2-foot thickness of high-grade ore dipping slightly under a covering of about 3 feet surface wash; at this point a nice tonnage may be developed, but no work has been done to determine its extent.

"*Geology.*—Underlying the manganese-deposit, a layer of about 6 inches of soft material stained with oxide of iron is encountered, and under this a greenish clay containing pebbles and boulders of what is known locally as the Kaslo green schist. No attempt has been made to sink through the clay, which forms the floor of the deposit. Judging by the rock-exposures along the railway-cutting, the whole area is underlain by schists and slates, which have a dip of 53 degrees and a strike of N. 10° W.

"*Origin of the Deposit.*—The primary deposit of manganese probably owed its origin to deep-seated springs arising from a body of intrusive magma. These waters deposited their burden of lime, iron, manganese, and silica in veins and veinlets of the country-rock. During subsequent erosion and oxidation the manganese has been collected by surface waters and redeposited on the benches and gentle slopes of the hillside.

"The iron, being precipitated first from solution, forms the lower layer of the deposit, while the lime may have been an important factor in bringing about the precipitation of the manganese.

"That this secondary deposit is of fairly recent origin is demonstrated by the fact that it overlies glacial drift. The calcareous sinter which is invariably with the manganese, and generally overlying it, no doubt owes its origin to deep-seated springs, of which there are still a few active ones in the vicinity.

"*Mining.*—The ore being soft is easily mined by pick and shovel, but great care has to be exercised in obtaining a grade suitable for shipment, and a certain amount of sorting is necessary.

"On account of the difficulty in getting cars, no ore had been shipped up to the time of my visit. It was the intention of the owners to ship to Chicago.

"*Prices.*—The prices which were recently fixed in the United States range from 86 cents to $1.30 per unit for ore containing from 35 to 54 per cent. metallic manganese. (Refer.: *Eng. & Mining Journal*, June 8th, page 1053.) Freight rate to Chicago, $11.20 per ton.

"*Samples.*—No. 11675, taken from 800 sacks for shipment; Nos. 11676 and 11677, general grab sample of all dumps of ore, containing 110 tons; No. 11678, sample taken from a number of test-holes on No. 2 deposit; No. 11679, sample across 15-inch width of high-grade ore, No. 1 deposit; No. 11680, sample of overburden reject; No. 11681, sample of oxidized material underlying manganese.

"*Estimate of Available Ore for Shipment.*—Estimates of ore in-place are based on the assumption that 40 cubic feet equal 1 ton.

	Tons.
Total ore in No. 1 deposit	730
Less extracted	160
	570
Total ore in No. 2 deposit	835
Total	1,405

"On account of the irregularity of the deposit and the unsystematic way in which it has been prospected, the estimate is partly based on the amount that has been extracted from various areas, and where the deposit showed regularity, upon the cubic content.

"*Conclusion.*—So far the only bodies discovered that might be considered of commercial importance are the Nos. 1 and 2 deposits as shown on the plan, and although there are manganese indications in patches outlying these areas, at the present time there is not enough exposed to allow one to make an estimate of the possible ore which may or may not exist under a covering of surface wash, but the indications do not encourage one to believe that there is any large quantity.

"(Signed.) A. G. LANGLEY,
"*Resident Engineer.*"

Manganese Ore from Dickie's Claim, Cowichan Lake.

Samples taken by Mr. Turner, August, 1918.

Report of Assays by the Provincial Government Assayer.

Sample.	Manganese.	Insoluble.	Phosphorus.
	Per Cent.	Per Cent.	
No. 1, 4 feet	18.3	66.3	None.
No. 2, 6 feet	55.0	11.0	None.
No. 3, 5 feet	32.8	45.1	None.
Second lens	37.0	38.0	None.

(Signed.) D. E. WHITTAKER.

Mr. W. F. Robertson writes:— "August 14th, 1918.

"I enclose assay certificate of a manganese-deposit within a mile of the Canadian Pacific Railway and Canadian Northern Railway by wire tram, showing over 6 feet of 55-per-cent. Mn. ore carrying 11 per cent. SiO_2, with 4 feet of lower-grade ore on one side and 16 feet on the other. It looks as if we could guarantee 30 tons a day of best grade within sixty days, and possibly up to 100 tons."

Deposits of Chrome-iron Ore.

Report on Deposit at Scottie Creek by R. W. Thomson, Resident Engineer, Kamloops, May 10th, 1918.

Sample 11762 ..... 22.5 per cent. Cr_2O_3 and 27.2 per cent. silica.
Sample 11761 ..... 24.0 per cent. Cr_2O_3 and 35.0 per cent. silica.

II. Sample from Scottie Creek supplied by Provincial Mineralogist, July, 1918—

No. 1, 12974 ..... 40.5 per cent. Cr_2O_3 or 28.5 per cent. chromium.
No. 2, 12975 ..... 42.5 per cent. Cr_2O_3 or 29.5 per cent. chromium.
No. 3, 12976 ..... 24.8 per cent. Cr_2O_3 or 17.0 per cent. chromium.

Mr. Robertson informed me that there was an ample supply of this ore.

III. Sample from Juno Claim, Big Sheep Creek, supplied by P. B. Freeland, Resident Engineer, Grand Forks, July, 1918—

Sample 11471 ..... 36.0 per cent. Cr_2O_3 or 24.6 per cent. chromium.

PRODUCTION OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

The following notes on the technical requirements and the cost of making ferro-manganese, ferro-chromium, and ferro-silicon are based on information given me by Messrs. Beckman and Linden. I have, however, been able to compare their figures for the consumption of ore, electric power, and electrodes in some cases with those given in a valuable paper by R. M. Keeney, "The Manufacture of Ferro-alloys in the Electric Furnace," which was presented at the September, 1918, meeting of the American Institute of Mining Engineers. Beckman and Linden's figures refer in most cases to the operation of a 3,000-kw. furnace, and I have therefore made some

allowance for increased consumption of power, labour, etc., involved in the proposed use of a furnace of only 300 kw.

FERRO-MANGANESE.

This is made by smelting in an electric furnace a mixture of manganese ore, steel turnings, lime rock, coke, and charcoal. For the production of a long ton of 80-per-cent. ferro-manganese from an ore containing 43 per cent. of manganese the following amounts would be needed, using Beckman and Linden's figures:—

	Lb.
Manganese ore	4,700
Steel turnings	300
Lime rock	1,040
Coke and charcoal	1,400
(B. and L. give petroleum coke	1,125)
Electrodes	100
Power	0.8 horse-power year.

A small single-phase furnace of 300 kw. would turn out about 500 tons per annum, or 1½ tons per day, which would be as much as could be utilized locally.

The following estimate of the cost of 1 long ton of 80-per-cent. ferro-manganese is based on information supplied by Messrs. Beckman and Linden:—

Manganese ore, 4,700 lb. at $25 per net ton	$ 58 80
Steel turnings, 300 lb. at $10 per gross ton	1 30
Lime rock, 1,040 lb. at $3.50 per net ton	1 80
Coke and charcoal, 1,400 lb. at $8 per net ton	5 60
Electrodes, 100 lb. at 7 cents per pound	7 00
Power, 0.8 horse-power year at $15 per horse-power year	12 00
Labour	8 00
Maintenance	5 00
Supplies	1 50
Plant, general expense	3 00
Office, general expense	6 00
Total	$110 00

R. M. Keeney states that the power-consumption varies from 4,000 kilowatt-hours per long ton in a 3,000-kw. furnace to 7,000 kilowatt-hours per long ton in a 1,000-kw. furnace, which would correspond to 0.72 and 1.27 horse-power years respectively at 85 per cent. load factor. He also states that the electrode-consumption is high, ranging from 150 to 250 lb. per long ton of the product when using amorphous carbon electrodes. These results were obtained when smelting ores of about 39 per cent. of manganese, and with a consumption of about 1,300 lb. of "coal" per gross ton of product, and about 3 net tons of the 39-per-cent. ore; the recovery being about 75 per cent.

From other sources I learn that the regular practice in a ferro-alloy furnace of 1,500-kw. over a considerable period has been as follows per gross ton of 80-per-cent. ferro-manganese:—

2.5 net tons of 40-per-cent. ore, costing 80 cents per unit.
720 lb. coke at $5 per net ton.
720 lb. charcoal at $20 per net ton.
65 lb. graphite electrodes at 12 cents per pound.
0.66 to 0.85 horse-power year of 85 per cent. load factor.

The ores available in British Columbia appear from the foregoing reports to contain about 40 per cent. manganese, and comparing the various figures given above, I conclude that in a 300-kw. furnace 1 long ton of 80-per-cent. ferro would need about the following:—

40-per-cent. manganese ore, 2.7 net tons.
Coke and charcoal, 1,400 lb.
Electric power of 85 per cent. load factor, 0.9 horse-power year.
Carbon electrodes, 150 lb.
Lime rock, 1,500 lb.
Steel turnings, 300 lb.

An estimate of the cost of 1 long ton of 80-per-cent. ferro-manganese based on these figures would be as follows:—

Cost of making One Long Ton of 80-per-cent. Ferro-manganese with $15 Power in a 300-kw. Furnace.

40-per-cent. manganese ore, 2.7 net tons at $25	$ 67 50
Steel turnings, 300 lb. at $10 per gross ton	1 30
Lime rock, 1,500 lb. at $3 per net ton	2 25
Coke and charcoal, 1,400 lb. at $8 per net ton	5 60
Electrodes, 150 lb. at 7 cents per pound	10 50
Electric power, 0.9 horse-power year at $15	13 50
Labour	8 00
Maintenance	5 00
Supplies	2 00
Plant, general expense	3 00
Office, general expense	6 00
Total	$124 65

If the power were to cost 0.5 cent per kilowatt-hour, the charge for this item would be:—

0.9 horse-power year (0.85 L.F.) at $27.70	$ 25 00
And the final figure for the cost	136 15

Silico-manganese.

In steel-making it is usually necessary to add ferro-manganese and ferro-silicon to obtain a sound product. As manganese ores usually carry a considerable amount of silica, it is economical to reduce this to silicon instead of slagging it off with lime: thus obtaining a "silico-spiegel" containing both manganese and silicon. The following estimate, based on information from Messrs. Beckman and Linden, gives the cost of a long ton of silico-spiegel containing 18 per cent. silicon, 40 per cent. manganese, and 3 per cent. carbon. The ore contains 42 per cent. manganese and costs $23 per net ton.

Cost of making One Long Ton of Silico-spiegel with $15 Power in a Large Furnace.

Manganese ore, 2,140 lb. at $23 per net ton	$24 60
Silica rock, 400 lb. at $4 per net ton	80
Coke and charcoal, 1,200 lb. at $8 per net ton	4 80
Steel turnings, 950 lb. at $11 per gross ton	5 00
Power, 0.8 horse-power year at $15	12 00
Electrodes, 60 lb. at 7 cents per pound	4 20
Labour	8 00
Maintenance	3 00
Plant, general expense	6 00
Office, general expense	4 00
Total	$72 40

I have no figures available to compare with this, but increasing it proportionally with that for ferro-manganese, on account of the small size of the furnace, would give a total of about $85 per ton with $15 power, or $95 per ton with 0.5-cent power.

A higher-grade alloy might have the following composition:—

	Per Cent.
Manganese	59
Silicon	20
Iron	17
Aluminium	3
Carbon	1

The following is the estimated cost of making 1 long ton of this alloy, based on Beckman and Linden's figures:—

Cost of making One Long Ton of High-grade Silico-manganese with $15 Power in Large Furnace.

Manganese ore, 3,200 lb. at $25 per net ton	$40 00
Steel turnings, 440 lb. at $10 per gross ton	2 00
Silica rock, 380 lb. at $4 per net ton	80
Coke and charcoal, 1,800 lb. at $8 per net ton	7 20
Electrodes, 100 lb. at 7 cents per pound	7 00
Power, 0.8 horse-power year at $15	12 00
Labour	8 00
Maintenance	5 00
Supplies	1 50
Plant, general expense	3 00
Office, general expense	6 00
Total	$92 50

Increasing this total to correspond with the use of a small furnace, we get with $15 power about *$100* per ton, and with 0.5-cent power about *$110* per ton.

FERRO-CHROMIUM.

The following estimate, based on the figures of Beckman and Linden, is for the production of an alloy of the following composition:—

	Per Cent.
Chromium	65
Iron	28
Carbon	5
Silicon	1

The ore is assumed to contain:—

	Per Cent.
Chromium	31 (Cr_2O_3, 45 per cent.)
Iron	12
Silica	12
Magnesia	16

Cost of making One Long Ton of Ferro-chromium with $15 Power in Large Furnace.

Chrome ore, 4,750 lb. at $36 per net ton	$ 85 50
Steel turnings, 100 lb. at $11 per gross ton	50
Coke and charcoal, 1,200 lb. at $8 per net ton	4 80
Power, 1.2 horse-power years (0.85 L.F.) at $15	18 00
Electrodes, 100 lb. at 7 cents per pound	7 00
Labour	12 00
Maintenance	3 00
Supplies	2 00
Plant, general expense	10 00
Office, general expense	6 00
Total	$150 80

In a recent paper (September, 1918) R. M. Keeney discusses very fully the production of ferro-chromium, and the following notes are based on his paper: Ferro-chromium can be made of varying carbon contents, usually between 4 and 8 per cent. If chrome ores are smelted with an abundance of carbon, the recovery of chromium is good, being 90 or 95 per cent. of the amount in the ore, but the ferro will contain about 8 per cent. of carbon. If, on the other hand, the supply of carbon is restricted so as to keep the carbon below 6 per cent., the recovery of the chromium will be poor, about 70 or 75 per cent. The recovery depends partly on the richness of the ore, and when this is below 40 per cent. Cr_2O_3, the recovery is low.

American ores from California and Oregon are reported to contain as a rule from 40 to 45 per cent. Cr_2O_3. The ores from Scotty creek, in British Columbia, appear to have in some cases 40 per cent. of Cr_2O_3, and therefore to be rather poorer than the American ores. In making 65-per-cent. ferro-chrome there would be needed per long ton of the product:—

For an 8-per-cent. carbon product at 90-per-cent. recovery.....5,730 lb. of ore.
For a 5-per-cent. carbon product at 70-per-cent. recovery.....7,380 lb. of ore.

The power figures of Beckman and Linden are based on the statement that each pound of ferro-chromium needs 3 kilowatt-hours for its production. This may be correct with high-grade ores and in large furnaces. In Keeney's experiments, using furnaces of about 200 kw., the power-consumption was about 3.4 or 3.5 kilowatt-hours per pound, and this at 85 per cent. load factor corresponds to 1.4 horse-power years.

Beckman and Linden in their original estimate state that 1,100 lb. of petroleum coke would be needed per long ton of the product, and I converted this into 1,200 lb. of coke and charcoal. Keeney used coke in his experiments, and the amount varied from 0.5 to 0.75 lb. per pound of ferro. Taking 0.6 lb. as a mean value, we find the consumption to be 1,344 lb. per long ton of the product.

For the production of ferro-chromium in a small furnace of 300 kw. it will be safer to take the more conservative figures of Keeney, and using, as before, the remaining items from Beckman and Linden, which I have already increased a little on account of the smaller scale of operation, we obtain the following estimate:—

Cost of Production of One Long Ton of 65-per-cent. Ferro-chromium with about 6 per Cent. Carbon from an Ore of 40 per Cent. Cr_2O_3 in a Furnace of 300 Kw.

Chrome ore, 6,000 lb. at $36 per net ton	$108 00
Steel turnings, 100 lb. at $11 per gross ton	50
Coke, 1,350 lb. at $8 per net ton	5 40
Power, 1.4 horse-power years at $15 per horse-power year	21 00
Electrodes, 100 lb. at 7 cents per pound	7 00
Labour	12 00
Maintenance	5 00
Supplies	2 00
Plant, general expense	10 00
Office, general expense	6 00
Total	$176 90

If the power cost 0.5 cent per kilowatt-hour, the charge for this item would be:—

7,700 kilowatt-hours at 0.5 cent	$ 38 50
And the final cost per ton of ferro would be	194 40

Ferro-silicon.

The following estimate is given by Messrs. Beckman and Linden for the cost of making 1 ton of the 50-per-cent. ferro-silicon. The output of a 300-kw. single-phase furnace would be 400 tons per annum, or 1 ton daily.

Cost of making One Ton of 50-per-cent. Ferro-silicon with $15 Power in a Large Furnace.

Power, 1 horse-power year at $15	$15 00
Quartz, 2,400 lb. at $3.50 per net ton	4 20
Coke, 1,200 lb. at $8 per net ton	4 80
Turnings, 1,500 lb. at $10 per net ton	7 50
Electrodes, 60 lb. at 7 cents per pound	4 20
Labour	16 00
Supplies	1 50
Plant and office, general expense	5 00
Interest and depreciation, 20 per cent.	10 00
Total	$68 20

If power were to cost 0.5 cent per kilowatt-hour, the power item would be $27.80, and the whole cost $81.

Prices of Ferro-alloys.

For comparison with the figures of costs given above, I add the present and the pre-war prices of some ferro-alloys.

Ferro-manganese.—Before the war (December, 1913) the 80-per-cent. alloy sold at about $50 per long ton in the Eastern States. Its present price (October, 1918) is $250 for the 70-per-cent. alloy, with a charge of $3.50 per unit from that basis; thus the 80-per-cent. alloy would bring $285 per ton, which is nearly six times its price before the war. Before the war a spiegel (low-grade ferro-manganese) containing 20 per cent. of manganese was worth $25 a ton; at present a 16-per-cent. spiegel is worth $75 a ton, and a 20-per-cent. spiegel would be worth about $90 a ton.

The price of ferro-manganese in British Columbia must be about $20 a ton higher than the above figures, so that if 80-per-cent. ferro-manganese could be made at $150 a ton there would be a very good profit at present prices. On the other hand, the business would be impossible if prices were to return to their original level, unless in the meantime very important economies could be effected in the cost of supplies and other operating expenses.

Ferro-silicon.—Before the war (December, 1913) the price of 50-per-cent. ferro-silicon was $73 a ton, the 10-per-cent. alloy was $21, the 11-per-cent. alloy was $22, and the 12-per-cent. alloy $23. At the present (October, 1918) 50-per-cent. ferro-silicon is quoted at $160 per ton, the 9-per-cent. alloy is $55, the 10-per-cent. alloy is $57, and the 11-per-cent. alloy is $60 a ton. If the 50-per-cent. alloy can be made in British Columbia at anything like the estimated cost of $70 per ton, its manufacture should afford a good profit at present prices, and with reasonable economies should remain profitable even when prices have fallen considerably.

It will be remembered, of course, that the present market for these alloys in British Columbia is very limited, being less than a ton of each alloy daily. One reason for making ferro-alloys will be to supply them to the steel-making department of the plant, which otherwise would have to buy these alloys at excessive prices, and as the steel industry develops the outside market for the alloys will increase.

The design and cost of the plant and furnaces for making ferro-alloys have been considered in other parts of this report.

STEEL-MAKING.

In order to be able to make pig-iron on as large a scale as possible, and also with a view to combining more profitable industries with that of iron-smelting, it is desirable to introduce into the electric-smelting plant furnaces and other appliances for making steel. The general scheme suggested is that about 25 tons of foundry iron should be produced daily for sale to iron-foundries, and a further 25 or 30 tons of white pig-iron should be made for conversion into steel in the same plant or elsewhere. The steel would probably be made in small open-hearth furnaces heated by oil, or in electric furnaces of the Heroult type. Together with 30 tons of pig-iron, about 60 tons of steel scrap could be used if desirable, thus yielding about 85 tons of steel daily. This could be used in part for making steel castings, and the remainder could be rolled into rods and bars of small section in a small rolling-mill. The manufacture and the use of steel are too well known to require any discussion in this report, and it would be impossible for me to treat the subject adequately in the space and time at my disposal. A rough estimate of the cost of a steel plant has been given in Appendix IX., and I may add the following estimate, made by Lyon and Keeney in 1915, for the cost of electric steel-making in the Western States (Trans. Amer. Electrochem. Soc., 1915, XXVIII., page 158) :—

Cost of Production of One Long Ton of Steel in the Electric Furnace in the Western States.

1.1 tons of scrap at $15 per ton	$16 50
Slag materials	1 00
Ferro-alloys	1 00
800 kilowatt-hours at 0.20 cents	1 60
Labour	2 50
Maintenance and repairs	2 40
20 lb. of electrodes at 5 cents	1 00
Amortization and depreciation at 5 per cent. each	1 50
Interest at 6 per cent.	90
General	1 00
Royalty	50
Total	$29 90

The present cost of making steel in British Columbia will be considerably higher than this estimate, on account of the higher cost of supplies and operation.

The present price (October, 1918) of steel billets in the Eastern States is about $50 per gross ton, which might correspond with about $70 in British Columbia. The price in December, 1913, was $20 to $22 in the Eastern States. There would, however, be no attempt, under normal conditions, to compete with heavy structural material, and there are many purposes for which steel can be made at a profit, under present conditions in British Columbia, even in electric furnaces using power at 0.5 cent per kilowatt-hour.

VICTORIA, B.C.:
Printed by WILLIAM H. CULLIN, Printer to the King's Most Excellent Majesty,
1919.