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Ramslyer & Miller Inc.

For Canadian Javelin Ltd.

Report discusses the Possibilities of Manufacturing Iron and Steel from Julian Concentrates by Various process

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RAMSEYER & MILLER, INC.
CONSULTANTS TO THE
IRON AND STEEL INDUSTRY
11 WEST 42ND ST., NEW YORK 36, N.Y.

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CANADIAN JAVELIN, LTD.
680 Fifth Avenue
New York 9, N.Y.

Attention: Mr. W. H. Roxburgh,
Vice President - Engineering

Dear Sirs:

The first phase of our work in connection with the preparation of a presentation for the Julian Iron and Steel Plant is presented herein. The Report which follows discusses the possibilities of manufacturing iron and steel from Julian concentrates by various processes.

We have reviewed the Strategic-Udy and Elektrokemisk proposals and have evaluated the data obtained from pilot plant tests. The conclusions reached may be summarized as follows:

1. The manufacture of pig iron from Julian concentrates will increase the returned value of the Julian ore deposit; will boost the economy of Newfoundland by providing the means of livelihood for hundreds of families; and will nucleate the further industrialization of this area.

2. The Blast Furnace - since it requires large quantities of high grade metallurgical coking coal which is not available in Labrador and which would have to be imported at high prices - cannot be considered an economic smelting unit in this area. Additionally, a blast furnace installation, complete with coke plant, requires a huge capital investment.

3. The so-called "direct reduction processes" operating with gas or oil as fuel are uneconomic in Labrador because these fuels are not locally available at advantageous prices. Moreover, these processes are low production units and mostly in the pilot plant stage of development.

4. The electric smelting process with preheating and/or prereduction is recommended for the manufacture of pig iron from Julian concentrates because electric power is the only source of locally available energy. Coal, coke, gas and fuel oil must be brought in to Labrador and thus are relatively expensive.

5. Pilot plant tests of the two available processes for electric smelting with prereduction were studied - the Strategic Udy process and the Elektrokemisk. The tests indicate that Julian concentrates are amenable to commercial smelting by both processes.

6. The Elkem process is preferable because of better thermal efficiency, more economical control of sulphur, better expected availability and most important - a lower cost pig iron. Elektrokemisk should have few problems in scaling pilot plant tests up to commercial operation because of their experience in the operation and maintenance of about 50 installations, in the past 30 years, in all parts of the world.

7. The sulphur content of the Nova Scotia coals (2.8%) ? is too high for an economical operation. Unless lower sulphur coal is available from Nova Scotia it appears to be advisable to use other sources of low sulphur coal.

8. The capital investment required for a plant to produce 600,000 N.T. of pig iron annually by the Elkem process is estimated to be $29,378,000; by Strategic-Udy $27,480,000.

9. The Production Cost of pig iron, excluding royalties, if any, is estimated at $32.33 per gross ton by the Elkem Process; $34.50 per gross ton by Strategic-Udy. These figures are based on 4 mill power which is somewhat high for the load and power factors expected for this operation. A reduction in the cost of power by 1 mill would result in lowering the cost of pig iron by $1.62 per gross ton.

10. A very efficient and low cost production of steel billets is foreseen as a further step in the industrialization of the region, by the installation of Basic Oxygen Steelmaking equipment followed by continuous casting. A plant to produce 250,000 N.T. of billets will require an additional investment of $13,371,000 making the total capital funds necessary for iron and steelmaking $42,749,000.

11. The cost of producing continuous cast steel billets is estimated at $58.06 per net ton. At this stage of the operation, the plant's annual salable products would consist of 300,000 gross tons of pig iron and 250,000 net tons of billets.

Very truly yours,

RAMSEYER & MILLER, INC.

W. Shapiro,
Vice President

WS:MT

SCANNED IMAGE

TABLE OF CONTENTS

APPENDICES

RAMSEYER & MILLER, INC.

JULIAN IRON & STEEL COMPANY

IRON ORE REDUCTION PROCESSES

Basically, converting iron ore to metallic iron consists of removing the oxygen from the ore. There are two general types of processes for reducing iron ore and obtaining metallic iron as an end product. The one in most general use is based on smelting and gives a molten product; the other reduces but does not melt.

In the first category, the conventional Blast Furnace is the common smelting unit that is used to produce metallic iron. In this process the iron is obtained from the ore; the heat for reduction and smelting is obtained from the burning of coke, while limestone is used to flux the gangue of the ore and the ash of the coke.

The Blast Furnace requires substantially large quantities of coke. If coke alone is used as a fuel, its weight may be from 70 to 90% of the weight of the reduced iron. The amount required is largely determined by the purity and chemical characteristics of the ore, limestone and coke as well as operating practices and product requirements. The coke required for a blast furnace operation must meet physical and chemical properties within relatively closely defined limits if the blast furnace operation is to be successful. It is therefore necessary to have metallurgical coke, or metallurgical coking coal, available at a reasonable price to insure the success of a blast furnace operation.

The lack of good coking coals in many parts of the world encouraged the development of another type of iron ore smelting furnace using electrical energy as a substitute for some of the coke. This type of furnace also uses carbonaceous material as a reductant and limestone as a flux but the heat required for the endothermic reduction of iron oxide to iron and the heat required for melting both iron and slag is supplied by electric power. The physical characteristics of the carbonaceous material are no longer of prime importance. In contrast with the blast furnace where coke must be strong enough to support the burden, usually about 100 ft. high, the electrically heated furnace carries a burden of approximately 15 ft., in the case of the Elektrokemisk furnace, to practically zero in the Lubatti or Strategic Udy type of furnace. Thus, the electrically heated smelting furnace allows the use of carbonaceous material far inferior in strength to that required for the blast furnace and in effect substitutes electrical energy for a portion of the blast furnace's coke requirements.

Blast furnaces have grown to be huge expensive units. Production rates of 2000 tons per day are no longer considered exceptional; rates as high as 3000 tons per day are fully predictable.

The second type of ore reduction process is the non-smelting variety. Whereas the blast furnace as well as the electrically heated smelting furnace reduces and melts the metal and produces a molten slag to remove the majority of the non-metallic constituents of the raw materials, the non-smelting processes, which generally have been given the name of "Direct Reduction", reduce the metal from the ore without melting and without formation of a slag. Some of these processes use coal, coke or other carbonaceous material as reductant, while others operate on gas - either reformed natural gas or hydrogen. Some of these processes, as exemplified by Hoganaes and Wiberg, have been in operation for some time, but their production is in limited quantities and for special purposes. Recent developments have brought forth a host of others, mostly in the pilot plant stage - R-N, H-iron, Esso-Little, HyL, etc.

Although limited quantities of metal produced by direct reduction methods have been used for steelmaking, none of the processes, except that practiced at Hojalata y Lamina in Mexico, has been used as a source of metal, on a commercial scale, for the manufacture of the common grades of steel.

In general the fuel requirements of the direct reduction processes are high, the size of the operation small, and the cost of finished product prohibits its use as a basic steelmaking source of metallic iron. The one exception, Hojalata y Lamina, does use their direct reduced material as a source of metallic iron for the manufacture of flat rolled products. The consumption of natural gas is approximately 25,000 cu. ft. per metric ton of reduced metal but the gas is supplied to them at less than current wellhead costs. The thermal requirements of the other processes are of the same order and with the exception of the Hoganaes process, which is a very low production, high cost process, all require fuel in the form of either gas or fuel oil.

A disadvantage of all these processes is that because of the lack of a melting or smelting operation, the end product - metallic iron - contains practically all of the gangue found in the raw ore. It is thus necessary to start with very pure iron ore and/or concentrate; or to add a post-reduction separation process to remove the undesirable gangue from the reduced metal. In the R-N process this is done by crushing and separation; in the case of Hojalata y Lamina it is accomplished during the steelmaking process with a considerably increased cost of operation at this point.

In reviewing the situation in Labrador, the available processes eliminate themselves quite rapidly. The Blast Furnace requires metallurgical coke in large quantities at reasonable prices. The coals that are easily available to Labrador first are not of prime metallurgical quality and secondly are far removed from the ore deposit. Moreover metallurgical coke cannot be obtained at what is considered to be a reasonable price for a blast furnace operation. Additionally if high priced coke were purchased it would suffer considerable loss and size decrepitation while being shipped to the vicinity of the iron ore deposit. The lack of good quality, reasonably priced metallurgical coke in Labrador, therefore, removes a blast furnace operation from consideration.

The so-called "Direct Reduction" processes require large quantities of cheap fuel, and for most of the processes the fuel must be gas or oil. Neither of these two fuels can be considered cheap in the Labrador area. The only relatively cheap fuel in the Labrador area is electrical energy.

Thus the electrical smelting processes which offer the means of using the cheapest local smelting fuel, electrical energy, and the cheapest reductants, non-metallurgical coke and/or coals are most suited for Labrador with its huge potential of hydro-electric energy and limited supply sources of carbonaceous materials.

The electrical smelting process has undergone refinement and technical advances in the last few years. The original conception of electric smelting was to supply the thermal requirements of the process from electrical energy and the chemical requirements from carbonaceous material. The present trend is to substitute carbonaceous material or other fuels for a portion of the thermal requirements previously supplied entirely by electricity. This procedure has been a natural development. As the demand for larger and larger electric reduction units developed, the size of the furnaces grew almost in direct proportion. As the electrical load per furnace increased, the complexity, cost and power demand of the electrical systems continued to increase.

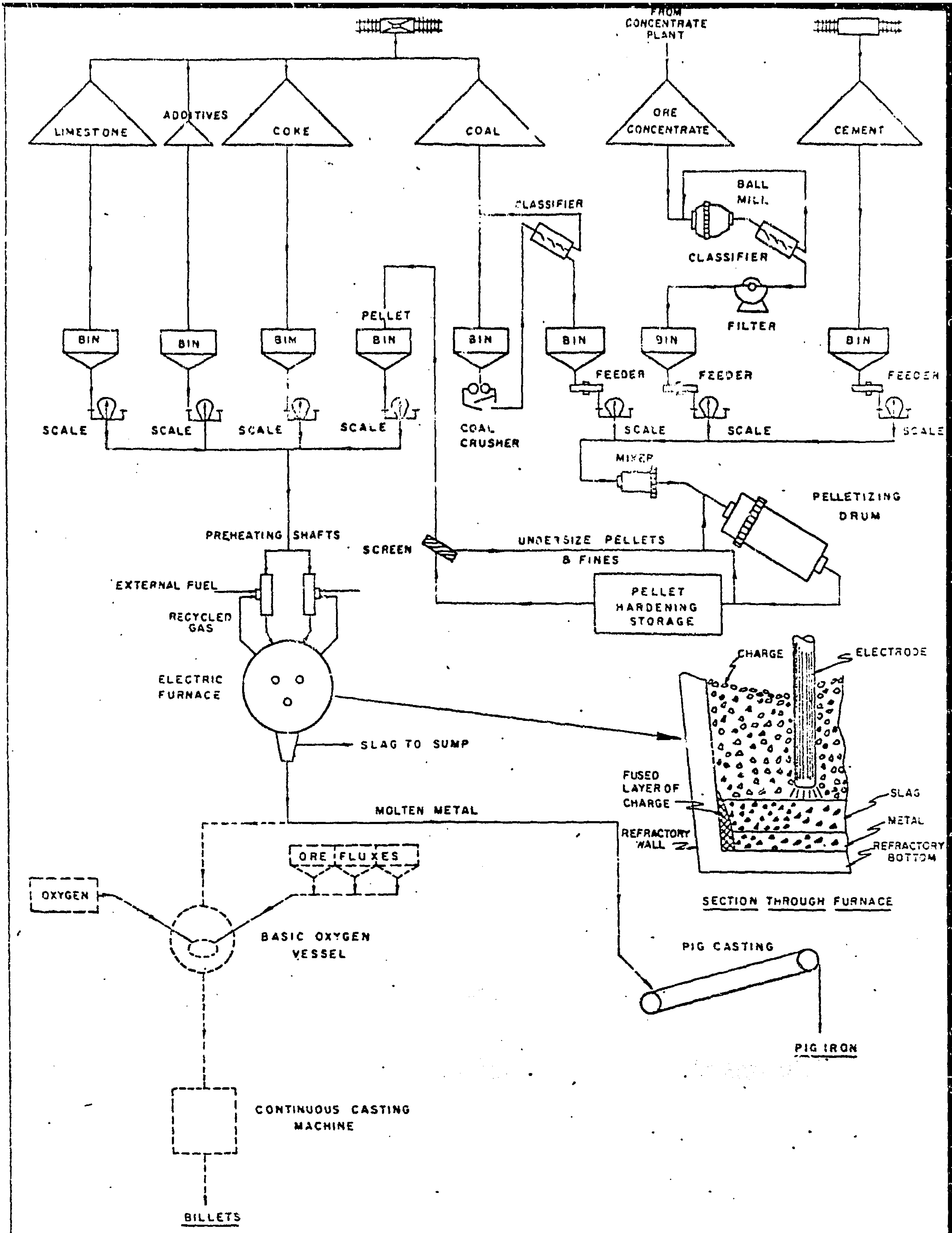
To reduce the electrical thermal load and lessen power consumption, operating procedures were modified to pretreat the raw materials, by preheating and/or partially prereducing, before charging them into the smelting furnace.

Preheating and partially prereducing the raw materials not only provides a greater annual production per dollar of investment but also a lower cost product when compared with conventional electric furnace smelting. Quite a few organizations have done experimental work on preheating and prereduction. Only two groups, as far as we know, have done sufficient work in this area to evaluate their process - Strategic Materials (the S-U Process) on this Continent and Elektrokemisk (the Elkem Process) in Norway. A detailed comparative study of these two processes has been made - in fact an evaluation of the two processes is one of the purposes of this report. The succeeding pages discuss the operation, production costs, capital investment costs and other matters pertinent to the Elkem Process, which as will later be demonstrated is the most advantageous process for a Labrador plant. An equivalent discussion, flowsheet, production and capital cost data for the S-U process is appended to this report for reference.

BRIEF DISUCSSION OF THE ELEKTROKEMISK PROCESS

A schematic flow sheet of the Elkem process is presented on the next page.

Finely ground iron ore and coal are intimately mixed with 3 to 5% cement. Water is added and the mixture is agglomerated (balled) into pellets. A more detailed description of the mechanics of pellet manufacture is given in a later section of this report which discusses the plant equipment and its operation. The pellets are stored for a few days to allow the cement to harden giving them sufficient strength for further handling and to support the furnace charge in the prereduction shafts mounted directly above the furnace. The hardened pellets together with other burden materials (limestone, coke and miscellaneous additives) are heated to temperatures approaching 1800°F. in vertical shaft furnaces. The application of heat causes a series of chemical reactions to take place. The more important reactions are; drying the materials, release of the water of crystallization within the cement and other materials in the charge, carbonization (coking) of the coal contained in the pellets, some calcination of the carbonates in the charge (the degree depending upon temperature and dwell time), and some prereduction of the iron ore, principally the reduction of Fe_2O_3 to FeO.



FLOW SHEET FOR PIG IRON
USING CEMENT-IRON ORE PELLETS
PREHEATING & PREREDUCTION
ELEKTROKEMISK METHOD

Because of the finely ground state of both ore and coal, the partial reduction reaction proceeds at a high rate of speed. Since the reacting materials, iron ore and coal, have large surface areas per unit of weight and have been intimately mixed, there is a tremendous reaction interface area between them. In addition to the great amount of area for chemical reaction, volatilization of the coal produces reducing gases so that there is gaseous to solid reaction in addition to solid to solid reaction. As the pellets are heated the cement dehydrates and loses most of its strength. Concurrently the coal in the pellet is coking. The net result is a transition from a cement-bonded to a coke-bonded pellet.

The pellets, preheated to the shaft operating temperature and containing partially reduced ore, are fed into the top of the Elkem smelting furnace together with coke and fluxing materials. The smelter is knows as a submerged arc furnace since the furnace burden covers the ends of the electrodes where the principal amount of electrical energy is converted into heat. The furnace is charged full so that the burden is practically level with the top of the furnace.

The electrical energy released is used to:

(1) supply the heat of reaction required for the reduction of the oxides of iron, manganese, silicon and phosphorous;

(2) furnish the heats of formation of the chemical compounds contained in the iron ore and the slag; and

(3) melt the reduced metal and that part of the furnace burden which forms the slag.

The initial step in the reduction of iron oxides in the smelting furnace is accomplished by carbon with the resultant formation of carbon monoxide. As this gas moves upward through the furnace burden, a portion reacts with oxides in the upper section of the burden and carbon dioxide is formed. This secondary reaction reduces the overall amount of carbon that is required for reducing the iron oxides.

In order to obtain the highest yield from the iron units in the burden, it is necessary to reduce the iron oxide content of the slag to as low a figure as possible. This is accomplished by maintaining an excess of carbon in the vicinity of the submerged arc. A portion of this excess carbon is dissolved in the liquid pig iron. The amount dissolved tends to approach the saturation point of carbon in liquid iron, as regulated by thermo-chemical conditions existing in the furnace.

The amount of silicon in pig iron is predominately controlled by the basicity of the slag and the temperatures that are maintained during reduction, assuming that the required carbon for the reduction of silicon is within the overall system. Practically all of the phosphorous that is in the furnace burden will be found in the pig iron.

The sulphur in the burden is distributed in four ways. Some of the sulphur is lost in the exhaust gas from the preheating shafts. An additional sulphur fraction is lost by volatilization during the smelting operation and is carried away by the furnace gases. Sulphur that remains after these two losses is distributed between and contained in the slag and metal. The final sulphur analysis of the pig iron is regulated primarily - assuming a pig iron of uniform analysis in respect to other elements - by the basicity, volume and temperature of the slag in contact with the pig iron in the furnace. When smelting pig iron of the analysis normally used for steelmaking purposes - about 1% silicon - the percentage sulphur in the slag is normally about 20 times the percentage sulphur in the metal. Although this distribution ratio is half, or even less, than that expected in blast furnace practice, it is sufficient for normal sulphur contents in the final pig iron. The poorer sulphur elimination in electric furnace smelting is partly offset by the fact that less sulphur needs to be eliminated since electric smelting uses less carbon per ton of production and practically all carbonaceous materials employed in smelting contain some sulphur.

The principal reason that the Elkem furnace is not as efficient a desulphurizer as the blast furnace is that the former does not maintain as high a reduction potential as that normally existing in a blast furnace, as indicated by (1) the smaller amount of excess carbon in contact with slag and metal and (2) by the iron oxide content of the slag which will run on the order of 1/2% in the Elkem and only 1/5th of 1% in the blast furnace. Actually the approximate 1/2% of FeO in the slag indicates a slight removal from equilibrium conditions as there is about 1% silicon in the metal, as well as some excess carbon in contact with slag and metal. Both of these factors are expected to lower the FeO content of the slag by reducing it to metallic iron.

By limiting the amount of excess carbon in the furnace (beyond that required for ore reduction) it is possible to make pig iron with carbon content far below the carbon solubility saturation point. This can only be done, however, by limiting the degree of completion of reduction of the iron ore. Thus the manufacture of low carbon metal will result in higher iron oxide contents in the slag with an attendant increased loss of iron units. As these iron units, in the form of oxides, increase in the slag, the reduction potential of the whole system is decreased. There is a radical change in the sulphur distribution between slag and metal. It thus becomes almost impossible for the furnace to maintain control of sulphur when attempting to manufacture low carbon pig iron.

The Elkem furnace should be considered as a pig iron producing furnace and not as a low carbon or semi-steel production unit.

The Elkem system of smelting with preheating and partial prereduction is a relatively efficient thermal system. The vertical shaft preheaters with the countercurrent flow of gases to materials, operates similar to a cupola or a blast furnace which have long been recognized as thermally efficient units.

The carbon monoxide that is formed at very high temperatures in the vicinity of the submerged arc is relieved of a great part of its sensible heat as it filters upward through the furnace burden. This escaping gas also reacts to a fair degree with the iron ore in the burden in a gaseous to solid reaction (in direct reduction) similar to that obtained in the stack of a blast furnace. With furnace conditions approaching thermal equilibrium, which should be realized in a large scale continuous commercial operation, the escaping furnace gases will approximate the temperature of the preheated burden. These gases therefore will contain the sensible heat related to a temperature somewhat less than 1800°F. The latent heat of this gas is used in the preheating and prereduction operation accomplished in the vertical shafts above the smelting furnace.

The amount of heat used or required in the vertical shaft furnace is dependent upon the degree of preheat and prereduction desired. The preferred or most economical degree of preheat and prereduction for any individual group of raw materials can only be established by operating experience in the commercial plant. Factors that will determine the optimum extent of prereduction in the shafts will be the smoothness of furnace operation and the relative costs of different fuels. It is obvious that the greater the amount of ore prereduction, the greater will be the productive capacity of the smelting furnace. Practically all heat consumed in the smelting furnace proper is secured from electrical energy. The maximum rate of production is therefore a function of the unit electrical consumption and the capacity of the furnace's electrical installation. Since the unit electrical consumption is controlled by the degree of preheating and prereduction, the degree of pretreatment controls the maximum rate of production.

Higher degrees of prereduction can be obtained if the vertical shafts are fired with an auxiliary fuel, such as fuel oil, in addition to the carbon monoxide gas that is recovered from the smelting furnace.

The Elkem Process is fairly immune from serious breakdowns and is quite flexible even in the event of certain equipment failures. A few hours a year of routine preventative maintenance is sufficient for the electrical switchgear that is associated with the smelting furnace. The biggest probability of failure is in the mechanical equipment that feeds raw materials to the furnace. However the furnaces have surge bin capacity above the preheating shafts so that it is possible to have delays in charging of up to 6 hours without affecting the furnace operation. The next most probable mechanical failure is in the pellet preparation equipment. Three days of pellet storage provide good insurance against breakdown of the pellet making equipment. Another item which, because of its nature, requires maintenance is the gas cleaning and handling equipment. The gas scrubbers must be periodically cleaned but this eventuality is foreseen by having an extra scrubber and the proper valving in the furnace gas system. If the gas circulation system does break down the operator will have two options, either to run the shaft furnace as a non-pretreating unit (cold with a totally unreduced charge) or to maintain the preheating operation by firing the vertical shafts totally with oil.

Pig iron production costs have been predicated on a five year life for the furnace lining. This is considered the minimum for a correctly designed furnace; under reasonable operating conditions one should experience a lining life about 10 years.

The first iron smelting Elkem furnace with a capacity of 5000 KW was put into operation in 1928. As operating experience was gained and installations became larger, furnace sizes were increased. In April 1955, three 20,000 KW furnaces were installed at Mo-i-Rana, Norway and subsequently enlarged; they are now operating with a power input of 25,000 KW. A battery of 9 similarly sized furnaces has been installed in Venezuela; two of which are operating at present.

In search of ways and means of increasing production, lowering costs and improving the efficiency of the smelting units, Elkem began work in 1955 on methods of preheating and achieving partial reduction of the burden before charging it into the smelter. A rotary kiln - the first attempt - produced some improvement but the benefits gained were not as good as Elkem desired to achieve. Later attempts to improve the operation resulted in modifying a portion of the vertical charging chute into a combustion chamber wherein the recycled gas is burned to preheat and partially prereduce the furnace burden immediately before it is charged into the smelting furnace.

Power consumption on the Mo-i-Rana furnaces, operating on a 100% sinter burden, is presently averaging about 2050 KWH per M.T. of pig iron. It is estimated that with preheat and prereduction, power consumption will drop to around 1380 KWH per ton and result in an approximate 50% increase in production with the same equipment and labor force. However since the new process utilizes a pellet burden, the rather extensive sinter installation at Mo-i-Rana would -- if the new process were adopted -- be idle. Even so, the evident advantages of prereduction over the usual electric smelting has prompted the conversion of one of the nominal 200 M.T. per day furnaces at Mo-i-Rana to a prereduction unit.

At the present time, there are about 50 Elkem iron smelting units installed and operating in various parts of the world. The problem of scaling up the results from tests in small pilot plant units is less serious in the Elkem than in other processes. Furnace design parameters, problems in charging, refractory life, etc. have been established in long commercial operation of these furnaces. The Mo-i-Rana furnaces are now operating at a power input of 25,000 KW - not too far below the 33,000 KW installation planned for Julian.

It can also be expected that by the time Julian is ready to go ahead with this project, actual production data and experience will be available from Mo-i-Rana and a new installation in Portugal which will be using the Elkem shaft preheating prereduction process for pretreatment of electric furnace feed.

Based on tests performed on Julian concentrates and on the thirty or more years experience in electric smelting, we believe the Elkem units with preheat shafts to be well suited for the production of pig iron at Julian.

ELEKTROKEMISK TESTING PROGRAM

Elkem divided their testing program into two separate sections. The first tests were made to evaluate the suitability of Julian ore concentrates for making pellets and to determine whether the pellets so made were susceptible to prereduction upon preheating. The work that was done is covered in Elkem's preliminary report No. 2734, which showed:

1. There is no difference in behavior between the Wabush and Julian concentrates which were examined, although both ores required additional grinding to develop a grain size distribution suitable for pelletizing.
2. Both 3% and 5% Portland cement, as a binder, produced sufficient mechanical strength in the pellets. Pellets made with sulphite lye were not as strong as those made with Portland cement - further testing would be required before planning to use sulphite lye as a binder in a commercial installation.
3. The rate of reduction of iron in the pellets, upon preheating, was found to be higher than the reduction rate of sinter pellets and found to be normal for unsintered pellets made from other hematitic ores.
4. The Nova Scotia coal had favorable coking properties and thus produced good strength in the fired pellets. The sulphur content of the coal sample processed by Elkem was 2.28%. Coke made from this coal still contained the same percentage of sulphur. Because of this high sulphur both the coal and the coke are considered metallurgically undesirable.

The second section of the Elkem tests covered Pilot Plant smelting of Julian concentrates at their Fiskaa Works Research Station. This work was carried out in February of this year. The procedure and a portion of the smelting tests were observed by the following:-

Mr. W. H. Roxburgh, Vice President Engineering, Canadian Javelin, Ltd.

Mr. Fred Gover, Deputy Minister of Mines, Province of Newfoundland

Mr. William Dailey, Pickands-Mather & Company

Dr. R. R. Rogers, Department of Mines & Technical Surveys, Ottawa

Mr. Gregg M. Moga, Consulting Engineer, New York

Mr. D. A. Sutch, President, Ramseyer & Miller, Inc., New York

Elkem's formal report covering this test was completed shortly before the date of this writing, and is appended to this report. The smelting tests proved that the Julian concentrates will smelt without any difficulties (other than those associated with normal operations) when using the Elkem scheme of pelletizing, preheating and/or prereduction and smelting.

The data from these tests is the basis for the development of production and capital costs that are included in this report. The writers have had considerable experience in correlating Elkem pilot plant data with actual production data. This experience was used in developing the costs of pig iron and the plant to produce it.

The Nova Scotia coal that was used in the Elkem pilot plant test contained 2.8% sulphur. If the sulphur cannot be reduced to the order of 1% it will probably prove advisable to purchase other coal with sulphur content more suitable for metallurgical smelting.

Summing up the Conclusions reached thus far we find:

1. The manufacture of pig iron from Julian concentrates will increase the returned value of the Julian ore deposit; will boost the economy of Newfoundland by providing the means of livelihood for hundreds of families; and will nucleate the further industrialization of this area.

2. The blast furnace - since it requires large quantities of high grade metallurgical coking coal which is not available in Labrador and which would have to be imported at high prices - cannot be considered an economic smelting unit in this area. Additionally, a blast furnace installation, complete with coke plant, requires a huge capital investment.

3. The so-called "direct reduction processes" operating with gas or oil as fuel are uneconomic in Labrador because these fuels are not locally available at advantageous prices. Moreover, these processes are low production units and mostly in the pilot plant stage of development.

4. The electric smelting process with preheating and/or prereduction is recommended for the manufacture of pig iron from Julian concentrates because electric power is the only source of locally available energy. Coal, coke, gas and fuel oil must be brought in to Labrador and thus are relatively expensive.

5. Pilot plant tests of the two available processes for electric smelting with prereduction were studied - the Strategic-Udy process and the Elektrokemisk. The tests indicate that Julian concentrates are amenable to commercial smelting by both processes.

6. The Elkem process is preferable because of better thermal efficiency, more economical control of sulphur, better expected availability and most important - a lower cost pig iron. Elektrokemisk should have fewer problems in scaling pilot plant tests up to commercial operation because of their experience in the operation

and maintenance of over 50 electric furnace installations in the past 30 years, in all parts of the world.

7. The sulphur content of the Nova Scotia coals (2.85%) is too high for an economical operation. Unless lower sulphur coal is available from Nova Scotia it appears to be economically advisable to look for other sources for at least part of the carbonaceous requirements.

In accordance with Javelin's request, Elektrokemisk proposes 3 - 40,000 KVA smelters to produce 500,000 gross tons (550,000 N.T.) of pig iron. The three furnaces, in normal operation, will, in our opinion, be capable of producing at a rate of 1800 N.T. a day - equivalent to 600,000 N.T. a year based on a 330 day year. The next section of this report discusses the layout, equipment, capital and production costs for a plant with an annual production of 600,000 net tons of pig iron by the Elkem process.

PLANT SITE

The Julian iron ore deposit is located in Labrador about 220 miles north of Seven Islands near the Quebec-Labrador border. It is situated on an irregularly shaped peninsula at the north end of Wabush Lake near its juction with Julienne Lake. The Wabush and Carol concentrating plants at the other end of Wabush Lake, and their respective townsites, are about 20 miles south of the ore deposit. The Quebec, North Shore and Labrador Railroad spur to Wabush Lake serving the Wabush and Carol developments runs within 10 miles of the Julian property.

The area is practically undeveloped. The addition of a working force of several hundred, and their families, will require the development of a town with the necessary utility services and municipal functions. It may be preferable to expand one of the presently established towns at the lower end of Wabush Lake that is within easy commuting distance of the Julian properties to provide the housing facilities and services required to attract and keep a satisfied work force.

The estimates presented in this report cover only electric smelting facilities. The necessary communication, railroad, road and townsite facilities for the development would be established in connection with mining and concentrate production facilities which must precede building of the electric smelting plant. An allowance has been included for extension of these facilities within the immediate area of the plant to serve the smelter.

The concentrating plant will be located in the vicinity of the deposit. The smelter location used in this report is also at the Julian deposit. Other locations have been discussed but no evaluation of the various locations has been undertaken in connection with this report.

Placing the plant adjacent to the mine and concentrator has certain advantages. Concentrates can be transported by conveyor directly to the smelter, thus eliminating the need for storing large quantities of ore at the smelting plant. The concentrating and smelting plants can share the cost and make common use of the railroad spur, roads, water supply, repair and maintenance facilities, etc. The transmission line from the Hamilton Falls Hydroelectric Power Development - about 90 miles away - would serve the two plants, in addition to others along the line, with the possibility of obtaining more favorable rates for the larger block of power required (about 150,000 KVA).

The iron smelting plant will provide employment for about 250 workers with a yearly payroll of around $2,000,000. The addition of steelmaking facilities could double these figures. In planning the long term economic development of the Province it would appear desirable for the Government of the Province of Newfoundland to lend encouragement and aid to the project and encourage location of the plant at the mine site in Labrador.

A perusal of the topographical maps available to us indicates that there is a reasonably level area of adequate size to build both the concentrating and iron smelting plants near the Julian Deposit. A preliminary layout indicates that space is also available for the addition of steelmaking facilities should they be desired.

The development of the plant's layout and capital cost is based on constructing both the ore concentrator and the iron smelting plant at Julienne Lake. The two plants could be placed adjacent to each other which would advantageously permit the conveying of concentrates from the concentrator loadout station directly to the iron plant.

Except for possibly a surge capacity of several hundred tons, no storage of concentrates need be provided at the iron smelting plant. Water supply for both plants will come from Wabush Lake through a common intake and pumping plant. Water will be pumped to a high level tank situated near both plants and flow by gravity to the various departments.

PLANT LAYOUT

The plant layout provides for a capacity to produce 600,000 net tons (550,000 gross tons) of pig iron a year with provisions to add steelmaking facilities later at minimum capital expense and without interruption to pig iron production. Plant facilities will be generously sized so that they can be easily and economically expanded to take care of larger requirements in the future.

The three main departments of the pig iron plant are: Raw Material Handling, Smelting and Pig Casting. The Raw Material Handling Department receives and stores raw materials and is responsible for the movement of materials to the Electric Furnace Smelting Plant. At the Smelter, the raw materials, in controlled quantities, are preheated and partially reduced (some of the oxygen in the ore is removed) before entering the smelting furnace which uses electrically generated heat to enable the carbonaceous material in the coal and/or coke to complete the removal of oxygen from the iron ore and to melt the resultant product - molten pig iron. Fluxing materials, which have been introduced to remove impurities in the ore, form a slag which is subsequently wasted. The Pig Casting Department converts the molten pig iron into pigs.

Besides the main production departments, the plant will have auxiliary sections for maintenance and repair facilities, boiler house, garage and firehouse, electric power and water distribution systems, general office, etc. These facilities are grouped around the plant site to serve the initial ironmaking installation efficiently and yet are easily expandable in the event additional facilities are added at some later date.

It is expected that all raw materials, except iron ore concentrates, will be delivered by railroad. Bulk material, such as coal, coke, limestone, etc. will arrive in bottom dump hopper cars and be unloaded into a track hopper. The unloading plant will be arranged to receive and handle bulk material delivered by truck with equal facility. The track hoppers - more than one may be required - are covered by a shed large enough to contain at least four railroad cars for the thawing of frozen materials during the winter. The cars - both empty and full - are shifted by a trackmobile, a device with two sets of wheels adapted to travel on the ground as well as on tracks. A car shake-out, installed at the track hopper, assists in unloading bulk materials.

Storage at the plant site, for a least one month's supply of all materials of consumption, except concentrates, must be provided to assure uninterrupted operation during such periods as the normal flow of shipments is curtailed due to severity of the weather, breakdowns, strikes, etc. Each material must be stored independently with stacking and reclaiming facilities, under roof, with provisions for thawing, if necessary.

Bulk materials - except cement - are transported throughout the operation by belt conveyors which are totally enclosed in galleries. Vibrating feeders attached to the underside of the track hoppers withdraw the dumped materials from the hopper, depositing them onto a belt conveyor which carries the materials to their respective storage buildings where they are piled by traveling trippers or stacking conveyors.

As materials are consumed and the surge capacity at each operation is depleted, the supply must be periodically replenished from the storage areas. A bulldozer operating along the edges of the storage pile will push material into an underground hopper; or withdrawal can be accomplished through gates in a tunnel beneath the storage pile. In either case, a belt conveyor is used to carry the material to the next operation.

Since it is proposed to establish the smelting plant adjacent to the concentrator, no large amount of ore storage is contemplated. An overhead conveyor from the concentrate loadout station will carry ore concentrates to the limited capacity ore storage bins at the smelting plant.

The Elkem iron smelter proposed for this installation incorporates a series of vertical shafts above the furnace, through which the charge materials pass countercurrent to the upward flow of combustion gases. In the process, the charge is heated and partially reduced before entering the electric smelter. The charge is prepared in the form of pellets which gives a more efficient distribution of the burden in the furnace as well as providing the voids necessary for intimate contact of gases and materials.

The pellets are a mixture of ore and coal with cement as a binder. The formation of pellets - small balls from 1/2" to 1" in size - requires the use of finely ground material. The coal and ore concentrate must be ground to such a fineness that about 80% passes through a 200 mesh sieve and about 20% is minus 300 mesh. The major portion of Julian-Wabush concentrates is somewhere between 25 and 50 mesh, consequently the ore and coal will have to be ground fine before use.

Concentrates will first be brought by conveyor to the regrind plant and placed into bins that provide about one day's storage. Concentrates are fed to a series of ball mills in circuit with classifiers. The ball mills wet grind and the classifiers separate the coarse from the fine. Coarse material is recycled back to the ball mills, while the fine material is dewatered and conveyed to the smelter building where it is deposited into bins.

Raw coal is delivered by railroad car; dumped into a track hopper; removed by a mechanical feeder and conveyed to storage. It is reclaimed from storage - by bulldozer - and conveyed on belting to a coal preparation area in the smelter building. One coal preparation area serves the three smelters. The coal handling equipment consists principally of bins for one or more kinds of coal; a coal crushing and screening facility with provisions for closed-circuit operation; a set of bins for storing crushed coal, and conveyors to carry the crushed product to the mixer-pelletizing installations at each furnace.

Cement will be delivered in bulk; airlifted to storage silos and thence to bins in the smelter building.

Although one coal preparation area and one ore regrind plant serve the entire smelting plant, each Elkem smelting furnace will have its own set of feed bins, mixers, pelletizing drums and charging equipment. Crushed coal, ground ore and cement are withdrawn from their bins, weighed to obtain the desired proportions and conveyed to a rotary mixer where they are thoroughly and intimately dispersed. The mixture is then conveyed to revolving drums, which by their rotation and inclination, cause the moist material to agglomerate into small pellet balls. The wet (green) balls have insufficient strength at this time to be used as furnace charge, so they are conveyed to a storage area and allowed to harden in air for about three or four days. Any undersized or broken pellets are recycled to the charging end of the pelletizing drum.

Each Elkem furnace has its own set of charging bins containing the various materials required to make up the furnace burden. Pellets are reclaimed from their hardening and storage area by a mechanical payloader. Each scoopful is dropped through a hopper onto a belt conveyor which carries the pellets to the furnace charging bins. En route, they are screened to remove fines which may have been produced during handling. The fines are returned to the pelletizing drum and serve as "seed" material in the formation of new pellets.

Coke, limestone, manganese ore and other additives are reclaimed from storage as required and conveyed to the furnace charging bins adjacent to and above each smelter.

The three 40,000 KVA electric smelters proposed in this report are rated by Elektrokemisk to produce in excess of 500,000 gross tons (550,000 N.T.) pig iron per year. It is our opinion that each furnace, in normal operation, can produce about 600 net tons a day (25 N.T/hour) and during an operating year of 330 days the three smelters will turn out about 600,000 net tons of pig iron.

In order to keep the size of ladles, cranes and handling facilities to reasonable sizes each tap would be limited to 50/60 tons. This would result in about 10 tappings a day, making it mandatory for the furnace to be designed with two tap holes. The Elkem furnace taps both slag and metal from the same tap hole. The slag and metal are then separated outside the furnace.

The Elkem furnace is essentially a cylindrical vessel with a heavy steel plate shell, refractory lined inside and externally cooled by water sprays. The refractory brick roof is supported by water-cooled girders. Water-cooled glands in the top of the roof permit the entry of the electrodes; other water-cooled openings in the roof are provided for the furnace charging chutes and gas off-takes.

The charge material fills the inside of the furnace so that the electrodes are in contact with the charge material for almost the entire height of the furnace. Heat is generated by submerged arcs and the resistance of the charge. A number of charging chutes enter the roof of the furnace so that the material is distributed uniformly around the electrodes. The furnace is kept relatively full - almost to roof level.

The furnace electrodes are of the Soderberg self-baking type, three for each furnace. They are suspended from above and slipped downward as the electrode is consumed. The electrode is made by filling steel sheet cylinders with specially processed carbon paste and as the electrode is consumed, new cylinders are welded to the tops of the old ones forming a continuous electrode. The heat from the furnace bakes and hardens the carbon paste as it descends into the furnace.

Three phase electric power for smelting is derived from special furnace transformers - one for each furnace. These transformers, rated at 40,000 KVA step down the primary high voltage current received from the power company's system to the low-voltage high-amperage current used in the furnace. This power is distributed to each electrode by heavy copper bus bars that connect the secondary taps of the transformer to a clamp in contact with the electrode.

In the Elkem charging method the pellets, coke, limestone and manganese ore are withdrawn from bins, weighed to insure the proper proportions and conveyed to the top of the furnace. The material is then directed into a number of vertical shafts which lead into the furnace. As the material moves downward through the shafts it is in contact with a stream of burnt and burning gas so that all the materials are heated and the ore partially reduced. The hot material continues its downward movement into the top of the furnace.

The gas for this operation is obtained by recirculating the gas evolved during the reduction process in the electric smelter. After cleaning, it is burnt in a chamber attached to the base of the shafts; the products of combustion enter the shaft. The exhaust gas, as it leaves the top of the shaft, contains some CO and the distillate gases from the coal. A portion of the shaft exhaust gas is recirculated and mixed with the new fuel gas coming from the electric furnace. Provision is made for burning additional fuel - fuel oil - in the combustion chamber.

The heat generated by the submerged arcs and the resistance of the charge to the passage of electric current supplies the thermal energy necessary to complete the reduction of the iron ore to metallic iron and for melting the metal and slag. The oxygen in the ore combines with the carbon in the coal and coke and passes out of the furnace, principally as CO gas. Some carbon dissolves in the iron. Most other impurities in the ore, coal and coke are fluxed by limestone and are passed into the slag.

Once every two and one-half to three hours, the molten metal and slag are removed from the furnace. Two tap holes will be necessary to permit the cleaning, relining, resurfacing and drying of one set of tapping spouts (runners) while the other set is being used. The tap hole is opened by either an electric arc or an oxygen lance. The molten iron flows down a refractory lined trough into a ladle, which after filling is taken by an overhead electric traveling crane to the pouring station of the pig casting machine. The molten slag is granulated by playing a stream of water on the slag in the runner after it comes out of the furnace. The water carries the granulated slag through a trough to a deep pit outside the smelter building. The slag-water slurry is pumped to low-lying areas outside the plant and wasted.

Gas is evacuated from the furnace through exhaust ports in the roof. The gas is cooled by water sprays, cleaned of its dust by passing through a wet scrubber, subjected to pressure regulation and then used as fuel in the prereduction shafts.

The three Elkem furnaces are housed in a building of about 140,000 sq.ft. composed of four bays. The central portion, about 130 ft. high, contains the smelters, charging chutes and electrode control mechanisms. The raw material bins and pellet storage are located on one side of the central portion; the other side is the tapping bay served by two 125 ton cranes.

The pig casting machines are located with their filling end in the tapping hall so that hot metal can be transported to them by the overhead cranes. The pig casting machines, probably two in number, will extend out from the tapping bays with the discharge end above a railroad track so that solidified pigs can be discharged into gondola cars.

The tapping bay will be so arranged that it can be extended for steelmaking operations in the future. The cranes which transport the hot metal to the pig casting machine will, with the introduction of steelmaking, also carry hot metal to a stationary hot metal mixer where it can be stored for subsequent use in steelmaking.

It is contemplated at this time that the molten metal will be refined to steel in basic oxygen furnaces situated in a bay adjacent to the tapping aisle. The molten steel will be cast into billets by a continuous casting process. The combination of basic oxygen steelmaking and continuous casting is a rather new concept but each process has been proven in many installations throughout the world. A plant, utilizing this combination of processes, is now under construction in Chimbote, Peru. Continuous casting offers lower capital and operating costs than is generally possible with conventional ingot mold, soaking pit and primary mill practice.

Under continuous casting practice the molten steel from the convertors is poured into a refractory lined vessel, called a tundish, which is over the top of the casting machine. As the liquid steel is released from the tundish it flows through water cooled molds; the steel solidifies and is drawn downward continuously in billet form. As the metal progresses downward, and while still hot, it is cut into desired lengths which are then placed horizontally on cooling beds. After cooling and inspection the cast material is ready for shipment as billets.

CAPITAL COST

An estimate of the capital cost of installing a plant to produce 600,000 net tons (550,000 gross tons) of pig iron from Julian-Wabush concentrates by the Elektrokemisk method is given on the next page. A detailed breakdown of the estimate is given in a separate Appendix.

The cost figures were developed on the assumption that the smelting plant is located adjacent to the concentrator and will share in common some of the plant's general facilities such as water supply, railroad and road access, etc. Various equipment costs as well as installation and construction costs were obtained from equipment manufacturers. Valuable cost data was obtained from the reports made to Canadian Javelin Ltd. by Kilborn Engineering Ltd. of Toronto who made preliminary estimates for the mining and concentrating plant as well as for the smelting operation. Preliminary estimates of the cost of the Elektrokemisk equipment were obtained by Mr. D. A. Sutch during his visit to Norway to observe the Elkem smelting tests in February and from subsequent figures furnished by Elektrokemisk's New York Office.

The cost of customs duty for machinery, equipment and supplies entering Canada from either the U. S. or European sources has not been included.

JULIAN IRON & STEEL

ESTIMATE OF CAPITAL COST

600,000 NT Pig Iron Capacity by ELKEM Process

	U.S. $
Site Works	760,000
Raw Material Handling	3,492,000
Prereduction & Smelting	15,930,000
Pig Casting	550,000
Electric Power Distribution	2,368,000
Boiler House	249,000
Machine Shop	760,000
Brick Storage	200,000
Garage	296,000
Firehouse	44,000
Office	200,000
Miscellaneous	329,000
Freight	1,000,000
Contingencies	1,200,000
Engineering & Supervision	2,000,000
Total Cost	29,378,000

In general the estimates have been developed on the basis of our knowledge of other metallurgical installations. However, much judgement had to be exercised since the plant site has not yet been selected nor have any detailed layout plans been prepared. A much more detailed and accurate estimate will have to wait until layout plans have been developed, sizes of buildings established and specifications written for the equipment. However, the figures presented herein are considered to be a reliable estimate on which to judge and evaluate the project.

A brief description of the factors taken into account for each item in the estimate is presented below.

Site Works

The estimate for the cost of site preparation including the installation of the necessary utilities is based entirely on information and maps from Canadian Javelin. We have not visited the site nor made an inspection of the area.

Grading About 100 acres of fairly level land should be allotted for the installation of the smelting plant. This should suffice for the enlargement of the plant to twice its initial capacity and for the addition of steelmaking facilities.

The sum of $50,000 has been allotted for rough grading and leveling the site to plant grade. No calculations of the cut and fill required have been made but if the ground is fairly level

$50,000 should be adequate for grading approximately 100 acres.

Water Supply The two plants - concentrating and smelting - will share the cost of a water intake and pump house on Wabush Lake. Water will be pumped from the lake to a high level tank or reservoir; from here it will flow by gravity to the points of usage. In some cases, where higher pressure is desired for particular functions, small pumping stations will be installed. The cost of the water supply system includes the plant water distribution piping for process, cooling and potable water.

Sewage Disposal This item includes not only the disposal of sanitary wastes but also the removal of process and cooling water. It is not intended to recycle any of this water since Wabush Lake presents an unlimited supply of good quality water. Waste water run-off generally will be directed into one of the lakes, possibly Julienne Lake.

Fencing A fence, for the complete encirclement of the plant area amounting to about 8,000 linear feet, is included in the capital cost estimate.

Roads This item is for approximately 5,000 feet of roads within the plant area itself. No part of the 24 mile long road to the Wabush Lake townsite is included.

Railroad Trackage An allowance for about 12,000 feet of railroad trackage within the plant site, to adequately serve each departme and to bring in raw materials and ship finished products from the plant to the railroad spur, has been made. No part of the connection to the Wabush Lake Railroad is included herein.

Raw Material Handling

Since all material except ore concentrates will arrive by rail from Seven Islands, sufficient storage at the plant for at least 4 week's supply of materials has been provided.

Because of the possible severe weather during the winter months all material will be stored under cover. Adequate heating and thawing facilities must be provided. All conveyors and their maintenance walkways will be enclosed in galleries and heated.

Iron Ore The cost of facilities for handling iron ore includes the installation of an overhead conveyor from the concentrator to the smelting plant. The Elkem process requires grinding and screening installations to reduce the "as received" coarse concentrates and coal to the fineness required for pelletizing. The cost of this item including the ball mills, classifiers, filters, conveyors, building and material handling equipment is included in this item. Also included is the cost of the conveyor from the crushing building to the bins at the smelter.

Coal and Coke All bulk materials arriving by rail will be unloaded through an under-track hopper. The track hopper will be located in an enclosure with the necessary equipment for thawing frozen shipments. Material from the track hopper is deposited through feeders onto belt conveyors which carry it to their respective storage areas. Each storage area will be enclosed. These materials will be reclaimed through a hopper, probably by bulldozer, and brought by conveyor to the smelting plant.

However, coal for the Elkem process must be ground, consequently it is sent by conveyor to a separate crushing installation included in the smelting building when it is reclaimed from storage. The estimate for coal storage includes a 175' x 275' building, the track hopper and stacking and reclaiming equipment.

Miscellaneous Materials Limestone is received, stored and reclaimed in a manner similar to coal. The building enclosing the limestone storage will be about 160' x 160'.

The Elkem process requires cement for pelletizing. This material is received in bulk and airlifted to silos placed adjacent to the smelter building. Cement is withdrawn as needed and airlifted to the cement bins in the storage plant.

The cost of equipment for handling miscellaneous raw materials such as manganese ore, fluxes, etc. is lumped into one item called additives for smelting and includes the costs of all equipment from the track hopper through the enclosed storage facilities and reclaiming to the smelter operation.

Prereduction and Smelting

The Elkem installation is designed to operate with three 40,000 KVA electric furnaces. Each furnace has its own complement of bins, mixing and pelletizing equipment, furnace charging equipment, conveyors and electrical substation. One coal crushing installation will serve all three furnaces. It is intended to make all operations as automatic as possible to reduce labor costs - an item for instrumentation is therefore included.

The capital cost estimate includes a complement of hot metal ladles and overhead electric traveling cranes to carry hot metal either to pig casting machines or to the steel plant. Slag will be granulated with water and flumed to outside pits from where it will be pumped to low lying areas adjacent to the plant site.

Pig Casting

The pig casting installation will include two 50 ton/hour machines housed in a building 200 ft. long. Its head end will project into the smelter tapping bay. The tail end will discharge pigs into railroad cars. The installation will be complete with liming and ladle tilting facilities.

Electrical

It is assumed that electric power will be received at 230 KV. The plant will have to build a 150,000 KVA substation to reduce the incoming voltage to that required for utilization. The cost of electric power distribution includes the substation equipment plus the various departmental substations as well as feeders to the electric furnaces and to plant substations. A single line diagram of the electrical system for both Elkem and Strategic Plants is included in the Appendices.

General Plant Facilities

To take care of the plant's heating requirements a boiler house with three 150 HP boilers has been foreseen. A machine shop for maintenance and repair facilities is also provided. There is a possibility that the cost of some of these facilities may be shared with the concentrating plant.

A storage building for refractories is required. An office building approximately 150' x 60', necessary to take care of the plant's supervisory personnel and records, is provided. A garage 80' x 180' with equipment necessary to serve automotive equipment with fuel, grease and lubrication and minor repairs is provided. A small firehouse 40' x 40' with possibly one pumper may be required to take care of the fire fighting needs of the plant.

Under miscellaneous we have provided trucks and other mobile equipment normally required in a plant of this type and size. It is foreseen that the railroad company will supply switching service within the plant. However, for general movement of materials within the plant one trackmobile and two railroad cars are provided. It is not known at this time whether the boilers will be oil or coal-fired, however, we shall need fuel oil as an auxiliary fuel for the Elkem preheating shafts; consequently a fuel oil storage installation is included.

Freight has been estimated roughly on the basis of 10% of the cost of the shipped equipment.

Approximately 4-1/2% of the cost of the plant has been added for contingencies. This may be somewhat on the low side because of the preliminary nature of the studies and estimates. The same might be true for engineering and supervision for which an allowance of about 7% has been included.

PRODUCTION COSTS

A 40,000 KVA Elkem smelter with preheat and prereduction of the charge can be expected to produce about 600 net tons of pig iron a day. Three such smelters operating 330 days a year - which should be easily realized - will produce about 600,000 net tons of pig iron a year. The estimated cost per ton of pig iron will be as follows:

Raw Materials	$14.61
Operating Costs	14.26
Cost per Net Ton	$28.87
Cost per Gross Ton	$32.33

A detailed breakdown of the costs is given on the next page.

Some cost data for the Elkem process was furnished by Elektrokemisk; the remainder was developed by us on the basis of our knowledge and experience of Elkem furnace operations in Peru, Norway and Venezuela. The cost estimates are believed to be accurate within plus or minus 5%. Since the raw material balance as well as other operating characteristics are based on tests performed on a pilot plant scale, slight variations from these indicated costs are to be expected in a 600,000 ton a year operation.

JULIAN IRON AND STEEL

PRODUCTION COSTS

600,000 N.T. Pig Iron Annually
by ELKEM Method

	Quantity Lbs	Unit Price N.T. (US $)	Cost N.T. (US $)
RAW MATERIALS			
Julian Concentrates - 65% Fe	2900	4.50	6.53
Pocahontas Coal	480	12.00	2.88
Coke	275	15.00	2.06
Limestone	155	5.00	.39
Mn Ore - 20% Mn	75	7.00	.26
Cement	110	31.00	1.71
Dolomite	255	5.00	.64
Bauxite	55	5.00	.14
COST OF RAW MATERIALS			14.61
OPERATING COSTS			
Operating Labor			2.28
Maintenance Labor			.24
Supervision			.18
Electric Power - Smelting 1250 KWH @ .004			5.00
- Auxiliary 200 KWH @ .004			.80
Electrodes - 11 lbs. @ .10			1.10
Misc. Fuel - Prereduction 10 gals @ .09			.90
- Ladles, Coal Drying, etc.			.25
Materials for Maintenance & Repair			.75
Ore Grinding Supplier			.40
Tools, Supplies & Lubricants			.50
Water			.10
Steam			.05
O_2 and C_2H_2			.10
Reserve for Relining			.30
Refractory Expense - Ladles, Runners, Etc.			.25
Laboratory			.15
General Plant Expense			.41
Cost of Pigging			.50
COST ABOVE RAW MATERIALS			14.26
TOTAL COST PIG IRON PER NET TON			28.87
TOTAL COST PIG IRON PER GROSS TON			32.33

Raw Materials

The input of raw materials is based on producing a basic pig iron from Julian concentrates with the following analysis:

	Julian Concentrates	Basic Pig
Fe	65.0%	94.5%
SiO_2	6.0	-
Si	-	1.0/1.25
Al_2O_3	0.6	-
CaO	0.3	-
MgO	0.2	-
S	.01	.045
P	.01	.02
Mn	.11	.62
C	-	3.8/4.2

Generally about 2% has been added to the calculated quantities to take care of unaccountable losses in material handling, gas washer dust, etc.

Julian concentrates are charged to the operation at $5 per long ton ($4.50 per net ton) at the concentrator loadout station.

The burden calculations were developed using imported Pocahontas coal with a fixed carbon content of 78% and Dosco coke assumed at 91% fixed carbon. The coal is taken at $12.00 per ton delivered at Julian - including freight from Seven Islands; coke at $15.00 per ton. Variations in the proportions of coal, fluxes and coke which may develop under actual operating practices, may alter the cost figures to some extent. Moreover, it may be possible to obtain coal from the Maritime Provinces at less cost - provided the sulphur content is not excessive.

At the time of this writing, a source of supply for limestone, dolomite, bauxite and manganese ore had not been investigated, but it was indicated that these materials can be produced in the area at prices close to those used in the cost calculations. The cost of cement - $31.00 per net ton bulk includes delivery and reloading on cars at Seven Islands, as well as railroad freight to Julienne Lake.

Labor Costs

The average wage rate for operating labor, $2.75 per hour, is based on current union wage contracts in the area and to which about 30% is added to include fringe benefits.

A summary of the projected labor force for the Elkem plant is as follows:

	Number	Weekly Payroll	Cost/Ton	Cost/Ton with added Fringe Benefits
Operating Labor	187	$20,570	$1.72	$2.28
Maintenance Labor	20	2,200	.18	.24
Supervision	7	1,630	.14	.18
General Plant	30	3,690	.31	.41
	244	$28,090		

A more detailed breakdown of the labor force for operating an Elkem smelting plant of 600,000 net ton capacity is given on the following page.

Electric power for smelting is taken at what we consider to be a reasonable figure of 1250 KWH per ton. Power consumption for smelting, as well as electrode consumption, depends on many factors - the composition of the burden and the amount of pre-reduction achieved prior to the smelter are amoung the most important. We have not taken the worst nor the best of the figures obtained in the short pilot plant test runs. On the contrary, we have tried to establish a figure which we feel is practical and achievable in a normal operation. In addition to power for the electric furnaces, operation of conveyors, cranes, motors, lighting, etc. in the smelting plant will consume an additional 200 KWH per ton.

JULIAN IRON & STEEL

ELKEM SMELTING

LABOR FORCE

WEEKLY PAYROLL

1. OPERATING LABOR

Raw Material Handling

1 Foreman
4 Ore Grinding
2 Track Hopper
2 Reclaimer
2 Clean-up Labor
11

Pelletizing

4 Foremen
4 Coal Crusher
12 Material Feed
12 Pelletizer Control
4 Storage
12 Reclaim from Storage
12 Top of Bins
60

Smelting

4 Foremen
12 Furnace Charging
8 Preheat Burner
12 Electrode Make-up
12 Furnace Control
20 Furnace Helpers
12 Tapping
12 Slag Handling
92

Casting

8 Crane Operators
16 Pig Casting Machines
24

187 employees x 40 hrs. each x $2.75 per hour = $20,570

		WEEKLY PAYROLL
2. **MAINTENANCE LABOR**		
4 Electricians		
1 Master Mechanic		
1 Pipe Fitter		
4 Welders		
4 Machinists		
2 Brick Layers		
4 General Labor		
20 employees x 40 hrs. each x $2.75 per hour =		$2,200
3. **SUPERVISION**		
1 General Superintendent		500
4 General Foremen	250	1,000
1 Clerk	50	50
1 Timekeeper	80	80
7		1,630
4. **GENERAL PLANT**		
3 Secretaries	70	210
3 Clerks	80	240
1 Phone Operator	60	60
3 Watchmen	50	150
3 Janitors	80	240
3 Engineers	250	750
4 Metallurgists-Chemists	250	1,000
1 Labor Relations	150	150
3 Storeroom Clerks	80	240
1 Instrument Man	100	100
2 Mobile Equipment	110	220
3 Boiler House	110	330
30		3,690

SUMMARY

Employees		Weekly Payroll				
Operating	187	$20,570				
Maintenance	20	2,200				
Supervision	7	1,630				
General Plant	30	3,690				
	244	$28,090	x	52	=	$1,460,680

Fringe Benefits (approx.) = 539,320

Annual Payroll $2,000,000

The cost of electric power used in the estimate is 4 mills per kwh. We expect that the actual price may be somewhat less since 4-mill power is relatively expensive for electro-metallurgical industries. The 4 mills used might be compared with 1.4 mills, the cost of electrical energy at Mo-i-Rana; 2.25 mills which is the approximate cost of electrical energy if this load were connected to the Bonneville Power System, or 3.065 mills if this load were connected to Portland General Electric Company - a private utility operating in the Northwest area of the U. S. In general, the electro-alloy industry in the U. S., which uses from 2 to 3 times as much electrical current per ton of finished product as that foreseen herein, and on the other hand which sells their production at 2 to 4 times the cost of pig iron - considers power rates over 3 mills per kwh as being unsatisfactory for their industry.

Electrode consumption is taken at 11 lbs. on the basis of Elkem test data. The cost of electrodes at 10 cents per lb. includes the steel casing as well as carbon paste. Auxiliary fuel for the Elkem preheating shafts is estimates at 10 gallons per ton of metal based on preliminary heat calculations. The cost of a U. S. gallon of fuel oil delivered at Julienne Lake is assumed to be 9 cents.

Materials and supplies for ore grinding and pelletizing are estimated at 40 cents per ton of pig iron, which includes grinding balls, liners, retainers, etc. Besides the consumption of refractory materials in the day-to-day operation in relining ladles, runners, etc. a reserve of 30 cents per ton of pig iron is established to accrue for the cost of relining the smelting furnaces - once each five years.

It is to be noted that no provision is made in these estimates for royalty payments, if any.

STEELMAKING

It is quite logical at this time to explore the possibilities of making steel, as well as iron, either in conjunction with the initial operation or at some later date. This thought merits serious consideration not only because of its impact on the economy of the Province but also because the added value of manufactured steel will surely enhance the profit potential of the entire project. Accordingly, a brief study was made of the processes and economics of carrying the project one step further - to steelmaking.

Although no market survey for steel products has been made - it is somewhat premature at this time - the basis for our study and the discussion which follows is limited to an installation to produce 250,000 net tons of billets a year. It is not contemplated in this study to carry the operation further to finished steel products such as bar and rod, plate and sheet, pipe or structurals. This will be left for a further expansion of operations in the future. Thus the plant would have saleable products of 300,000 gross tons of pig iron and 250,000 net tons of billets.

Of the various steelmaking processes in normal use - the open hearth, electric furnace, and basic oxygen furnace, we would select the oxygen steelmaking process as most suitable for the following reasons:

1. The open hearth furnace, for most efficient operation, requires the use of about 40 to 50% scrap; it can however operate with as little as 30% and as high as 100% scrap. Such quantities of scrap are not easily procurable or economically available in Eastern Canada. Besides the open hearth is fired with fuel oil - an expensive commodity in Labrador. Moreover, the appreciably higher investment required for a small open hearth plant in comparison with an oxygen steel-making installation of the same capacity precludes further consideration of the open hearth.

2. While the electric furnace uses electrical energy which is available locally and relatively cheap, a good operation requires at least 50% of its charge in the form of scrap. A successful operation of this type is established in Peru, where charges containing as high as 60% hot metal and only 40% scrap are being converted to steel in electric furnaces. However, this is not practical for Julian because of the scarcity of scrap. Practically the only scrap available to a plant at Julienne Lake is that generated at its own works and at adjacent mining operations - which are negligible. Any other scrap would have to be shipped to Seven Islands and transshipped by rail to Julienne Lake.

3. The basic oxygen furnace can operate at full efficiency on 100% molten iron. When the stream of high purity oxygen impinges on the bath of molten metal in the vessel, high temperatures are generated because of the exothermic reactions involved. Control of temperature is obtained by the addition of coolants, usually in the form of scrap or iron ore. Scrap generated in the plant or procured locally will be augmented by ore concentrates up to about 25% of the charge for use as coolants. For the plant under consideration, an additional 15,000 tons of concentrates a year will be consumed as coolants.

4. Additionally the basic oxygen furnace is flexible in adapting to most any operating schedule - it can work 24 hours a day, 7 days a week, or be shut down over weekends, if required. It is designed in a wide range of sizes from as low as 20 ton capacity to huge vessels of 300 tons, such as recently proposed for one of the larger steel companies. Besides, the basic oxygen plant requires the least capital investment per ton of annual capacity and gives the lowest operating costs.

Once the steelmaking process is completed and molten steel tapped from the furnace, normal practice is to cast it in ingot molds. The molds are stripped; the ingots are reheated and then rolled on a blooming mill to billet size.

Continuous casting, long used in non-ferrous industries and recently successfully applied to steel, substitutes a machine which accomplishes the same result in one operation. Molten metal, poured into a receptacle on top of the machine, flows into a copper mold where it solidifies and from which it is continuously extracted in solid form as a continuous billet and cut to length at the exit end. The product can be a slab or billet depending on the size and shape of the mold that is used.

The process bypasses the expenses involved in ingot mold preparation, stripping, transportation of ingots and molds, reheating and primary rolling; it consequently produces a lower cost billet. In addition, the yield from molten metal to cast billet is more favorable since there are no scale losses due to reheating, and cropping losses resulting from cutting the top and bottom ends of each ingot, do not occur. The investment for continuous casting is much less than that for the usual ingot practice since the molds, stripper cranes, reheat furnace and primary rolling mill are eliminated.

Consequently, for the reasons stated above, the basic oxygen steelmaking process followed by continuous casting is selected as the most efficient and economical installation for Julian.

The steelmaking units foreseen are two 30 net ton vessels - only one of which is in operation at any one time, while the other is being relined. While it is expected that a heat can be tapped in less than an hour, we have conservatively estimated production at the rate of 30 net tons per hour - somewhat over 250,000 net tons a year. Production can be doubled at slight additional capital expense by installing a third unit - two units would be operating at the same time; the third idle for relining.

The addition of steelmaking facilities increases the flexibility of the plant. Molten iron from the electric smelters can be taken either to pig casting or to the oxygen vessels depending upon whether pig iron or steel is required. In the event of a breakdown of either one of the facilities, the other is available for immediate service.

The steelmaking process begins when the ladle carrying molten iron is emptied into the mouth of the oxygen vessel. The vessel is turned upright to receive the required amount of ore and fluxes and then a jet of oxygen is directed onto the surface of the metal through a water-cooled lance suspended from above.

Oxygen is blown for about 15 to 20 minutes; the entire steelmaking cycle, tap to tap, runs about 45 minutes. The vessel is then turned down, its contents of steel poured into a ladle and the ladle taken away to the casting machine.

The casting machine is supported on an independent structure free of the building steel. It rises to a height of about five stories which allows the required time for cooling as the steel slowly descends. On top of the machine is a holding vessel - called a tundish - which receives the molten metal and allows it to flow down through a water-cooled copper mold where solidification starts. The solidified bar is pulled down through pinch rolls and is cut to length by oxyacetylene torch which travels with the bar. The cut bars pass to a cooling bed and when sufficiently cooled are stacked and ready for shipment.

CAPITAL COST - STEELMAKING

The capital cost for the additional equipment and structure required to produce 250,000 net tons of continuous cast billets by the Basic Oxygen Process is estimated at $13,371,000. A detailed breakdown of the costs is given in the Appendix and summarized below.

Site Works	$ 200,000
Raw Material Handling	836,000
Basic Oxygen Steel Plant	3,605,000
Continuous Casting	4,260,000
Oxygen Plant	1,450,000
Electrical	425,000
Miscellaneous	495,000
Freight	500,000
Contingencies	600,000
Engineering & Supervision	1,000,000
Total	$13,371,000

The cost of site works includes additions to roads and railroads, sewer and water piping. Raw material handling involves the receipt, conveying and storage of fluxes and additives required for steelmaking as well as a lime burning kiln and related equipment.

The Basic Oxygen Plant provides for two 30 net ton vessels complete with water-cooled hoods, fans, gas cleaning systems, oxygen lances and supports, instruments and refractories. It also includes auxiliary equipment such as an 800 ton hot metal mixer, ladles, slag pots and cars, overhead cranes, melter's office and laboratory, ladle relining, drying and stopper rod makeup as well as the building.

Two continuous casting machines are required for the operation to permit relining, repair and preparation work to proceed on one while the other is in operation.

The process requires high purity oxygen - approximately 1800 to 2000 cubic feet of 99.5% pure O_2 per ton of metal at a pressure of about 150 psi. We have included the cost of a 70-ton a day oxygen plant although many steel plants buy their oxygen on a long time basis from producers who set up their plant on the steel company's property.

The costs involved in the electrical department include additional substations, feeders, etc. Miscellaneous equipment includes additions of trucks, payloader, fork lifts, trackmobile, material handling equipment, etc. to that already acquired for the smelting plant. Freight, Contingencies and Engineering are estimated on the same basis as was used for the pig iron plant capital cost estimates.

PRODUCTION COST - STEELMAKING

The cost of producing continuous cast billets is estimated at $58.66 per net ton summarized as follows:

Cost of metallics	$34.84
Cost above	16.40
Cost of molten steel	$51.24
Yield loss less scrap credit	1.42
Cost of casting	6.00
Cost of billet - per net ton	$58.66

A detailed breakdown of the costs is given on the next page.

The metallic charge is based on a yield from charge to molten steel of 87%, and augmenting the scrap return from ladle skulls, pit scrap, etc. with ore as coolant. Hot metal is charged at the cost of pig iron less the cost of pigging - $28.37 per net ton. Scrap is credited to the casting operation and charged to steelmaking at the hot metal price - $28.37. The additions of various ferro-alloys will vary somewhat with hot metal analysis and steel specifications.

JULIAN IRON & STEEL

PRODUCTION COSTS

250,000 N.T. Continuous Cast Billets Annually

Steelmaking

Metallic Charge	Quantity	Price	Amount
Hot Metal	2126 lbs.	@ $ 28.37/ton	= $30.16
Scrap	80 lbs.	@ 28.37/ton	= 1.14
Fe Mn	16 lbs.	@ 250.00/ton	= 2.00
Fe Si	13 lbs.	@ 150.00/ton	= .98
Al	1.5 lbs.	@ 440.00/ton	= .33
Iron Ore	100 lbs.	@ 4.50/ton	= .23
Cost of Metallics			$34.84

Cost Above	
Operating Labor	5.60
Maintenance Labor	.50
Office & General Plant	.25
Supervision	.25
Electric Power - 100 kwh @ .004	.40
Miscellaneous Fuel	.30
Fluxes	1.50
Materials for Maintenance & Repair	.80
Tools, Supplies & Lubricants	.35
Refractories	2.50
Water & Steam	.10
Oxygen	1.65
Laboratory	.20
General Plant Expense	2.00
Cost Above	$16.40
Cost of Molten Steel	$51.24

Casting	
Molten Steel	51.24
5% Yield Loss	2.56
Less 4% Scrap Credit @ $28.37 per ton	- 1.14
Cost of Metal	$52.66
Casting Cost	6.00
Cost per Net Ton of Billets	$58.66

A yield of 95% from molten steel to finished billet is accounted for by scale losses, cuttings, etc. Approximately 4% of this can be recovered as scrap and is returned to steel-making.

APPENDICES

DISCUSSION OF STRATEGIC UDY

The Elkem system for smelting Julian concentrates was discussed in the main body of the report. The general concepts of the S-U and Elkem Processes follow the same general line of processing, i.e. preheating and/or partial prereduction of the burden followed by electric smelting.

Until 1961 Strategic-Udy had performed all of their work on a relatively small pilot plant scale. In 1961, Strategic-Udy installed a 10,000 KVA furnace and an 8' x 150' prereduction kiln. Although this equipment was planned for the production of ferrochrome, 4,000 tons of Hunner ore concentrates were processed at a rate of approximately 100 tons of metal per day.

Additionally a conventional (non-preheating) 200 gross ton per day Elkem furnace in Venezuela is being modified to adapt the furnace to the Strategic-Udy process.

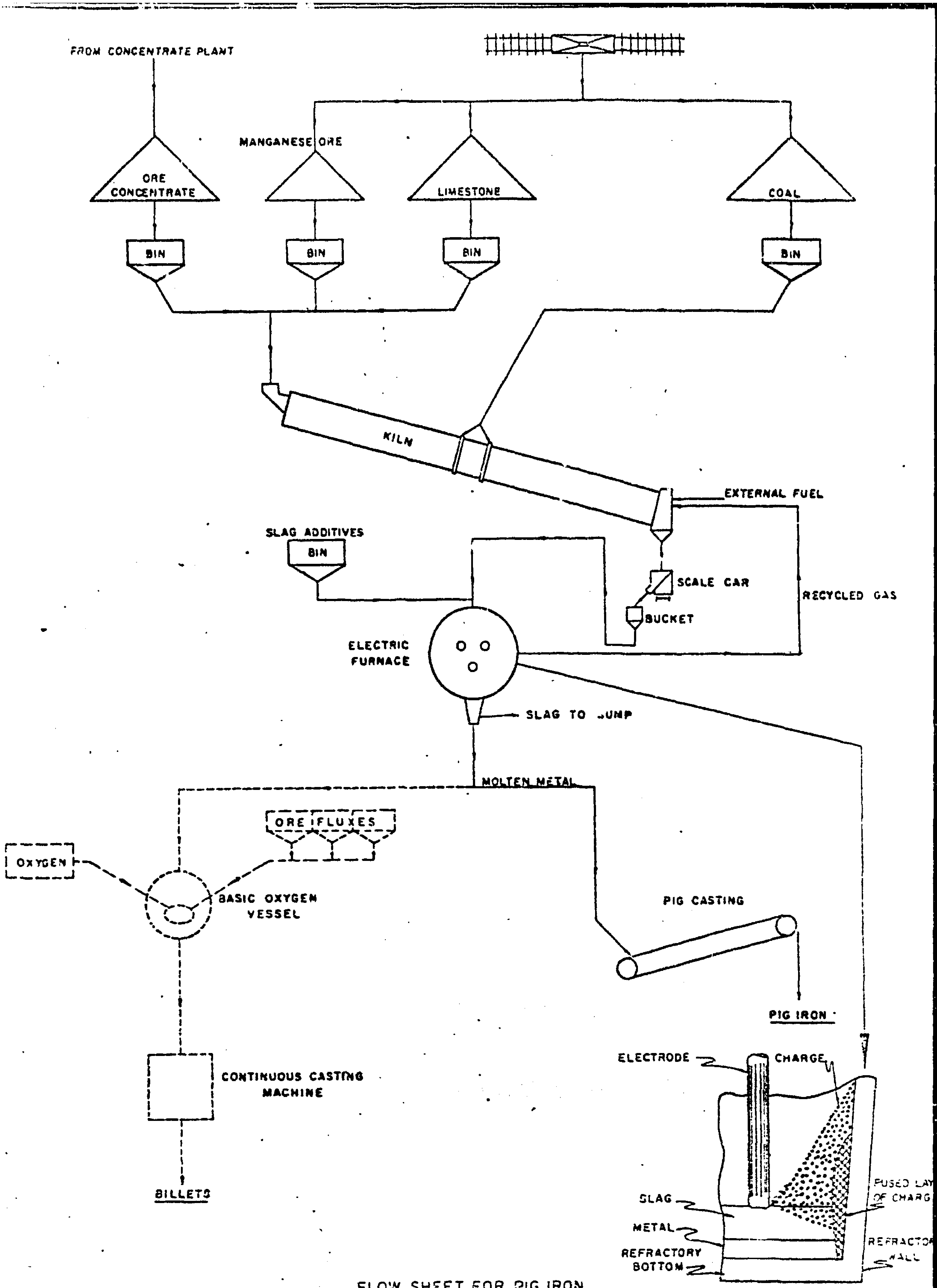
The question of Strategic-Udy being able to apply the experience gained from the operation of this Venezuelan furnace to the larger furnace foreseen herein (approximately 480 gross tons per day) is a question of timing. If Julian were to go ahead in the immediate future, Strategic-Udy would be required to base its design (as in Venezuela) on the present 100-ton per day plant at Niagara Falls. One can only speculate as to when -

1. The Venezuelan unit will be put into production.
2. When enough production experience will be gained to evaluate the improvements which should be designed in any later plant.

In all probability two to three years will be required before the Venezuelan installation supplies the experience that must be available for the design of a successful Strategic-Udy process plant, in the magnitude of 600,000 tons per year, that is to be built from the ground up.

The details of the process, mechanics of preheating, and/or prereduction and smelting are quite different when comparing the two processes. The Elkem Process requires finely ground ore, coal with coking qualities and cement to make the ore pellets that are used in the system.

The S-U Process (see flow sheet on next page) takes the ore or concentrate, as received, and commercial slack coal and pretreats these materials as received, together with the other burden items, in a fired rotary kiln. The kiln can be operated at almost any temperature up to the coalescent point of the material. As the materials are heated in contact with each other a series of reactions takes place. The more important reactions, all of which require heat, are removal of moisture or any water of crystallization, gasification of the volatile fraction in the



SECTION THROUGH FURNACE

FLOW SHEET FOR PIG IRON
USING IRON ORE CONCENTRATES
PREREDUCTION IN ROTARY KILN
SMELTING IN ELECTRIC FURNACE

coal, the calcination of carbonates and finally partial reduction of the iron ore, principally by converting Fe_2O_3 to FeO.

The burden that has been pretreated in the kiln is collected as it is discharged and then charged hot into an electric smelting furnace. The pretreated materials are charged into the furnace so that an annular cone is formed, following the natural angle of repose, around the sidewall of the furnace. A molten bath of slag is maintained between and around the electrodes - which are located in the central zone of the furnace - so that no substantial part of the raw charge comes in contact with the electrodes. As the bottom section of the charge mixes in with the slag layer and melts, it is replaced by additional material that is charged through ports in the roof.

The tips of the furnace electrodes are kept within the slag blanket so that there is a minimum of arcing from the electrodes to the metal bath beneath the slag and a maximum of resistance heating using the slag as the electrical resistance medium in the circuits between the electrodes. The 10,000 KVA Strategic-Udy furnace has been able to hold surprisingly high power factors under such an electrical system. The energy released by the electrical current between the electrodes melts the charged material, supplies the energy required for iron ore reduction, and superheats both the slag and metal so that they can be tapped and handled in liquid form.

Javelin concentrates for these concentrates are already very low in sulphur. Some of the sulphur contained in the coal is lost as the coal's volatile matter is gasified in the kiln. This removal is very similar to that performed in the Elkem preheating shafts. If the kiln and shaft are operated at the same temperature, the S-U can be expected to charge a greater amount of sulphur, per ton of product, into the smelting furnace because of higher unit coal and/or coke requirements.

Some of the sulphur charged into the furnace is lost as volatile material in the furnace gases, the remaining sulphur that has not been lost in either the kiln or the furnace gases resides in the slag and in the metal. In the discussion of the Elkem furnace it was pointed out that the desulphurizing power of the Elkem furnace was only about 50% of that expected of a blast furnace. The S-U Process maintains a still lower reduction potential than the Elkem so that the sulphur absorbing power of the S-U slag, when measured as the ratio of the sulphur content of the slag to sulphur content of the metal, approximates half that of the Elkem Process. In order to make up for this lower sulphur removing power it is necessary to run a higher slag volume in the open arc furnace. One can evaluate the differences in slag volume (approximately 600 lbs. and 925 lbs. per N.T. of iron) by comparing the amounts of fluxing material that have been used in developing the production costs of pig iron for the two respective processes.

The gas that is produced by the reaction between carbon and iron ore is principally carbon monoxide and escapes at a relatively high temperature - approximately 2500°F. This gas is first cooled, then cleaned and used as part of the fuel requirements of the rotary pretreating kiln, the balance of the fuel being supplied from burning a portion of the coal charged in the kiln and from fuel oil which is used as an auxiliary kiln fuel.

The mechanics of open bath smelting, as compared with submerged arc smelting, do not allow as high a reduction potential in the smelting zone. There are two reasons for this:

1. The process does not maintain a substantial amount of excess carbon above that required for the reduction of the iron and other elements - after making allowance for the carbon that is absorbed by the liquid metal.
2. Unreduced oxides are constantly entering and being dissolved in the slag blanket.

The net result of this low reduction potential can be noticed in the higher FeO content of the slag. These iron units are not recovered but are thrown away with the slag as waste. The S-U system is able to remove substantial amounts of sulphur from the iron ore being processed by virtue of an oxidizing zone in the front or charging end of the rotary kiln. This advantage, however, is of only minor importance in the case of smelting

Practically all of the phosphorous that is in the burden will enter into the finished pig iron. The silicon in the pig iron is controlled by the basicity of the slag and the operating temperature of the furnace. The carbon in the pig iron tends to approach the solubility limit, as related to the thermal chemical conditions that are established in the smelting zone, when excess carbon is available to the metal bath. By limiting the amount of carbon, S-U is able to make low carbon material with ease, but with an almost total loss of sulphur control and, as pointed out above, with additional iron loss because of higher iron contents in the slag.

As with the Elkem, we consider the S-U a pig iron making process - and not one for manufacturing so-called semi-steel.

The furnace gas that is produced by the action between oxides and carbon in the charge is essentially carbon monoxide. Since there are no oxides above the smelting zone, the gas escapes through ports in the furnace roof without further chemical reaction and at a relatively high temperature.

The thermal efficiency of the overall S-U process will be lower than that of the Elkem smelting system. The production cost developments indicate that Elkem requires a gross heat input of approximately 15,000,000 Btu; S-U approximates 18,500,000 Btu - both per net ton of iron after making allowance for 4% carbon in the metal. If allowances are made for using the furnace gases to heat the vertical shafts or the kilns respectively, the comparative gross energy requirements are approximately 13,700,000 and 15,800,000 Btu. One cannot expect the rotary kiln to have the same thermal efficiency as the Elkem vertical shaft furnace. Similarly pretreated kiln material must be handled hot from the kiln to the insulated charging chutes over the S-U furnace. Some heat losses here, however small, cannot be avoided.

Another point of greater heat loss for the S-U process is in the smelting furnace proper since it is impossible, under the S-U system, to use the sensible heat of the furnace gases to any appreciable degree.

One can expect the S-U furnace to have a relatively high availability although somewhat less than the Elkem furnace. The life of the furnace lining in the S-U smelting furnace, assuming the furnace parameters are of the proper design, will be highly dependent upon the skill and care that the operators use in charging raw materials. The raw materials are charged in such a manner that they provide a protection cover for the circumference of the furnace wall. Thus any carelessness in charging techniques can result in damage to the furnace wall refractories. Even with the best charging techniques one could only expect the S-U furnace lining to approach the same life as that expected in the Elkem system. The lower furnace roof temperature and the less deoxidizing atmosphere of the Elkem furnace should give this furnace superior roof life.

A continuous operation of the smelting furnace requires the continuous operation of the kiln. Any breakdown in the pretreating kiln, the material handling equipment between kiln and furnace or the charging equipment at the furnace proper is reflected very quickly in the furnace operation since it is impractical to have much surge capacity in the hot materials handling system and the S-U concept of smelting does not allow the continuation of furnace smelting operation once the raw material supply to the furnace is interrupted. Conversely it is impossible to continue operation of the kiln for any appreciable period of time once the preheated materials handling system or the furnace itself suffers a breakdown.

STRATEGIC UDY TESTS

Strategic Materials used Julian concentrates, a typical Pocahontas coal as their reductant, and commercial grades of lime, silica and spar as fluxes for their reduction tests.

The Julian specular hematite concentrates were smelted in January 1961 and all or parts of the demonstration were observed by:

Mr. W. H. Roxburgh, Vice President, Canadian Javelin Ltd.
Mr. K. M. Dewar, President, Kilborn Engineering
Mr. B. S. Crocker, Vice President, Kilborn Engineering
Mr. F. Schora, Arthur D. Little Company

The detailed analysis of these materials, together with certain other details related to the tests, are covered by Strategic-Udy Report - Project 1240-2.

The prime purpose of this work was to prove the feasibility and practicability of smelting Julian concentrates by the Strategic-Udy process. Included in a previous section of this report is a discussion of both the Strategic-Udy and Elkem processes as applicable to Julian ore. The Strategic-Udy flow sheet shows that the Strategic-Udy process utilizes a rotary kiln for preheating and prereducing the furnace burden material before it is charged into the electric smelting furnace. For the

Strategic-Udy tests on Julian concentrates, however, the raw materials -- ore, fluxes and reductant -- were charged cold, then smelted, in a 100 KVA furnace. By varying their operating procedure Strategic-Udy was able to produce low carbon (.64 to 2.5%) iron; a typical basic open hearth pig iron, and a typical foundry pig iron. A review of the various types of iron produced indicates that Strategic-Udy was able to keep the analysis of the reduced metal, with the exception of sulphur, within limitations generally expected of iron smelting operations. Thus one can conclude that under an established operation, all of the five elements normally considered in pig iron analysis -- carbon, manganese, silicon, sulphur and phosphorous, can be kept under control, although an estimate of the economics of sulphur control cannot be developed from the data given in Report 1240-2.

Another portion of the iron concentrate was treated in a small gas-fired batch rotary kiln. This test proved that Julian concentrates can be prereduced by coal in a kiln type furnace.

The Strategic-Udy laboratory work is considered to be sufficient to prove that Julian concentrates are amenable to reduction by the Strategic-Udy process.

The economic parameters in regard to smelting Julian ore indicated in Project Report 1240-2 are in our opinion not representative of what might be expected in a large scale commercial operation. They are scaled up or extrapolated from small laboratory sized tests which can differ a great deal from actual operating conditions in a commercial plant. The economic data in this report was developed primarily from a later Strategic Udy report prepared after smelting 4000 tons of a generally similar Hunner iron ore concentrate in a 10,000 KVA furnace. The Hunner concentrate, which differs from Julian principally in regard to silica content, was preheated and prereduced in an 8 ft. diameter x 150 ft. long rotary kiln and then charged hot into the 10,000 KVA electric smelting furnace. This test is considered a better basis for developing the over-all economics of smelting Julian concentrates by the S-U process.

STRATEGIC UDY PROCESS

The Strategic-Udy process, like Elkem, utilizes an electric smelting furnace to complete the reduction of a preheated and partially reduced charge and produce a molten pig iron. In the Elkem, preheat and partial reduction are accomplished in vertical shafts above the smelter by the circulation of gas countercurrent to the flow of materials, In Strategic-Udy, a rotating kiln accomplishes a similar result.

The kiln makes use of materials as received; iron ore concentrates are fed into the kiln together with coal and limestone. The carbon in the coal, under the action of heat, combines with some of the oxygen in the ore, resulting in a heated, partially reduced mixture which is charged, hot, into the smelting furnace.

As far as plant layout is concerned, the two processes differ principally in material handling, pretreatment of the ore and design of the electric furnace. In the description of a projected Strategic-Udy plant which follows, these differences will be pointed out; otherwise the facilities are relatively similar for both processes.

The Strategic-Udy process makes use of a horizontal kiln to pretreat the raw materials before smelting. The kiln, a long cylindrical steel shell lined with refractory brick rotates at less than one half revolution per minute and is slightly inclined so that the charge materials move forward as the kiln revolves. Iron ore concentrate, limestone and manganese ore are fed in at the higher kiln end in controlled quantities. Coal is fed through specially designed feeders in two positions located near the center of the kiln. The lower, or discharge end of the kiln is fitted with a firing hood and fuel burners. Carbon monoxide gas, generated in the smelting operation, is cleaned and used as fuel; any deficiency in fuel requirements is made up by fuel oil.

It is our present estimate - arrived at in consultation with Strategic-Udy - that two kilns 14 ft. in diameter and 350 ft. long will be required for the plant's initial production requirements. Since no such large installation is operating anywhere, the future development of detail design and engineering may indicate that a larger number of smaller kilns are more desirable and efficient from an operating standpoint.

In a multiple kiln layout each material, coming from its main storage pile (iron ore comes directly from the adjacent concentrating plant) is deposited near the head end of the kilns in bins with sufficient capacity to provide from 4 to 8 hours continuous operation. The discharge from the bins is controlled by mechanical feeders which deposit the desired quantity of each material on conveyors leading to the kiln feeding chutes.

The upper end of the kiln is relatively cool. Ore and limestone are dried and heated in this section by the gases of combustion which are discharged to the atmosphere through a stack. It is not contemplated to provide dust and fume control equipment since its expense would not be warranted at Julienne Lake. Coal which enters at the center of the kiln becomes intimately mixed with the ore and limestone during the kiln's rotation. As the coal is heated by the burning fuel, most of the coal's volatile matter is driven off and burned. A portion of the coal combines with the oxygen in the ore and thus produces partially reduced material.

The hot metal discharges from the lower end of the kiln into a surge bin, thence to a scale car where its weight is recorded. The scale car dumps the material into a hopper which is lifted to the top of the smelter building, then carried by monorail to the furnace charging chutes. One monorail can be used to charge two furnaces while the entire sequence of charging operations is interlocked electrically. The material cannot be discharged from the kiln until the scale car is there to receive it, the scale car cannot dump into the lifting hopper until it is in position to receive it, etc.

Strategic-Udy has indicated that four 30,000 KVA Electric Smelting Furnaces are required for a production of 600,000 net tons of pig iron a year. Each furnace would produce about 20 tons of metal per hour or 480 tons per day. Tapping a furnace once every 2-1/2 to 3 hours would give a tapped weight of 50 to 60 tons. Although such a furnace has not yet been built, its general characteristics, except for size details, are fairly well established.

The furnace is cylindircally shaped with a heavy steel plate shell - externally water cooled and lined internally with refractory brick. The roof is flat, of brick construction, suspended from a superior supporting structure. It is pierced by openings for the entry of charge materials, for the electrodes and for the escape of gas.

In the Strategic-Udy method the furnace burden does not come in contact with the electrodes. The electrodes are submerged in a slag layer - the resistance of the slag to the passage of electric current generates the heat necessary for the process. The charge material, which assumes its natural angle of repose once it has fallen free below the roof of the furnace, forms into a triangular pattern with its base clear of the electrode. This requires a system of selective charging with sufficient openings in the furnace roof to permit a uniform distribution of material around the furnace side wall. Occasional probe holes in the top of the furnace aid in determining the uniformity of the charge distribution and help in guiding the order of charging the furnace. The larger the circular furnace becomes, the more difficult it is to procure uniform and proper distribution. This is one phase of the operation which requires further development. Perhaps a rectangular shaped furnace with six electrodes in line might offer means for better material distribution. Such a design might even be beneficial to refractory life, power and electrode consumption and possibly to simplification of tapping procedures.

The furnace electrodes are of the Soderberg self-baking type, three for each furnace. They are suspended from a hoisting structure at the top of the building, held by water cooled clamps and pass into the furnace through water cooled glands in the roof. In the furnace, they hang completely free except that the lower end is immersed in the slag which floats on top of the molten iron. The electrode is manufactured at the plant from carbon paste in a manner similar to that described for the Elkem process.

Transformers rated at 30,000 KVA supply the low voltage high amperage power for smelting, through a series of secondary bus bars. The heat generated by the resistance of the slag to the passage of electric current supplies the thermal energy necessary for the reduction of iron ore to metallic iron and for melting the slag and metal. The oxygen in the ore combines with the carbon in the coal and passes out of the furnace, principally as CO gas. Some carbon remains dissolved in the iron. Most other impurities in the ore and coal are fluxed by the limestone and pass into the slag.

Molten iron and slag are tapped every two and a half to three hours in a manner similar to that described for the Elkem installation. Similarly, slag is granulated and molten iron transported to the pig casting machines.

The gas evolved during the smelting operation - principally CO - is evacuated through ports in the roof, cleaned and recycled to the kiln.

The building for a Strategic-Udy smelter consists of four parallel bays. The kiln discharge occupies one bay approximately 30' wide by 400' long, the upper part of which contains bins for the additive materials. Adjacent to this is a bay 40' wide by 400' long in which the charge materials are hoisted to the top of the furnace building. An intermediate floor in this area contains the electrical equipment for the smelting furnaces. The electric furnaces are situated in a 70' wide by 400' long adjacent bay which has three operating levels above the ground floor. The first level is the furnace tapping floor, the second or operating floor is level with the roof of the furnace. The electrical control room and all instruments are stationed on the operating floor. The furnace operation is observed and controlled and adjusted at this level.

The third level is the charging floor where the materials are deposited into the open ends of the charging chutes. Electrodes are made up on the top level. Molten iron is tapped from the furnace into an adjacent bay 70' wide by 600' long which contains two 125 T overhead electric traveling cranes for transporting the hot metal. The entire structure is 220' wide and occupies about 98,000 sq.ft. of floor space.

CAPITAL COST

An estimate for installing a plant for an annual production of 600,000 net tons of pig iron by the Strategic-Udy method is summarized below. A detailed breakdown of the estimate is given on the following pages.

Site Works	$ 760,000
Raw Material Handling	1,925,000
Prereduction	2,587,000
Smelting	12,834,000
Pig Casting	550,000
Electrical	2,546,000
Boiler House	249,000
Machine Shop	760,000
Brick Storage	200,000
Office	200,000
Garage	296,000
Fire House	44,000
Miscellaneous	329,000
Freight	1,000,000
Contingencies	1,200,000
Engineering & Supervision	2,000,000
Total	$27,480,000

As noted in the Capital Cost section for the Elkem installation, the plant is assumed to be located adjacent to the concentrator and shares in common such general plant facilities as water supply, rail and road access, etc. The layout and the cost of major items of equipment were reviewed with representatives of Strategic and Koppers during discussions in our office. Costs of installation of general utilities were developed on the basis of data given in the Kilborn reports. Customs duty has not been included.

The items in the Capital Cost estimate generally follow the descriptions given previously for similar items in the Elkem installation except where they differ specifically for raw material handling, prereduction and smelting. Concentrates are conveyed directly from the concentrator to surge storage at the kiln feed bins and are used as received. Coal does not have to be crushed - it is reclaimed from storage and conveyed to the kiln feed bins. Limestone and additives are handled similarly in both installations.

The prereduction unit, as explained previously, consists of two kilns, complete with feeders, refractories, instruments and a building. The smelting installation is based around four 30,000 KVA electric smelters complete with electrical equipment, instruments, refractories, charging and gas cleaning equipment, complements of ladles and cranes and building.

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 NT Pig Iron Annually by Strategic-Udy Method

		COST U.S. $
1.	SITE WORKS	
	Grading	50,000
	Water Supply incl. Distribution	300,000
	Sewage Disposal	70,000
	Fencing	40,000
	Roads	50,000
	RR Trackage	250,000
		760,000
2.	RAW MATERIAL HANDLING	
	Iron Ore	330,000
	Coal	867,000
	Limestone	533,000
	Additives for Smelting	195,000
		1,925,000
3.	PREREDUCTION	
	2 - Prereduction Kilns	2,000,000
	Kiln Building	300,000
	Refractories	287,000
		2,587,000
4.	SMELTING	
	4 - 30,000 KVA Elec. Furn. with Transformers	6,000,000
	Furnace Charging System	300,000
	Gas Handling System	400,000
	Refractories	384,000
	Slag Handling	300,000
	8 - 50 T Hot Metal Ladles with Stands	80,000
	2 - 100/25 T Cranes	400,000
	Transformer Transfer Car & Hoist	30,000
	Electrode Casing Shop	40,000
	Building	4,900,000
		12,834,000

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 NT Pig Iron Annually by Strategic-Udy Method

		COST U.S. $
5.	PIG CASTING	
	2 - 50 T/Hr. Pig Casting Machines	400,000
	Ladle Tilter, etc.	60,000
	Building	90,000
		550,000
6.	ELECTRICAL	
	230 KV Outdoor Substation	1,403,000
	Furnace Feeders	238,000
	13.8 KV Feeders to Dept. Substations	125,000
	Dept. Substations	310,000
	Miscellaneous	470,000
		2,546,000
7.	BOILER HOUSE	
	Building	64,000
	Boiler	125,000
	Piping	60,000
		249,000
8.	MACHINE SHOP	
	Building	360,000
	Equipment	400,000
		760,000
9.	BRICK STORAGE	
	Building	157,000
	Equipment	43,000
		200,000
10.	OFFICE	
	Building	180,000
	Equipment	20,000
		200,000

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 MT Pig Iron Annually by Strategic-Udy Method

		COST U.S. $
11.	GARAGE	
	Building	216,000
	Equipment	80,000
		296,000
12.	FIRE HOUSE	
	Building	24,000
	Equipment	20,000
		44,000
13.	MISCELLANEOUS	
	1 - Trackmobile	10,000
	1 - Bulldozer	30,000
	2 - RR Cars @ 20,000	40,000
	1 - 100 T Track Scale	20,000
	1 - Fork Lift Truck	20,000
	2 - Dump Trucks @ 15,000	30,000
	1 - Station Wagon	4,000
	Misc. Material Handling & Storage Equipment	25,000
	Fuel Oil Tanks & Piping	150,000
		329,000
	Total	23,280,000
14.	FREIGHT	1,000,000
15.	CONTINGENCIES	1,200,000
16.	ENGINEERING & SUPERVISION	2,000,000
	TOTAL	27,480,000

PRODUCTION COSTS

The estimated cost of producing pig iron from Julian iron ore concentrates by the Strategic-Udy process is su [illegible] ed below. A detailed breakdown is given on the next page.

Cost of Raw Materials	$15.55
Operating Costs	15.25
Cost per Net Ton	$30.80
Cost per Gross Ton	$34.50

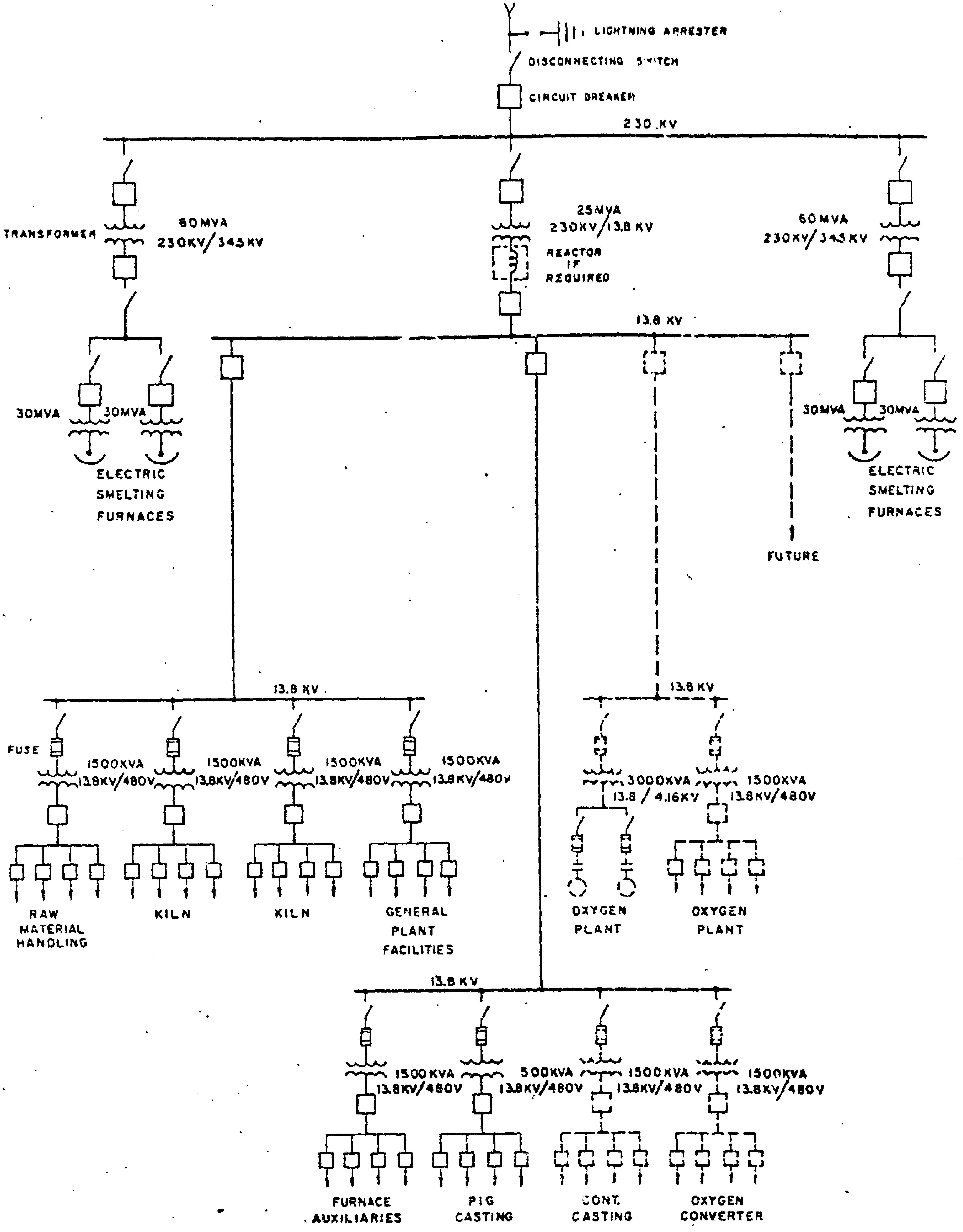
The quantities of raw materials required to produce a ton of pig iron were developed by drawing up a material balance using known and estimated analyses of the materials and from data given in the Strategic-Udy pilot plant tests. The calculated figures were increased approximately 2% to take into account unavoidable losses in material handling and dust. Although scaling up some of the operating costs from pilot plant test to operation at a 600,000 ton a year level may show some variations from those given in the estimate, it is believed to be accurate within plus or minus 5%. No provision for royalty payments has, however, been included.

JULIAN IRON & STEEL

PRODUCTION COSTS

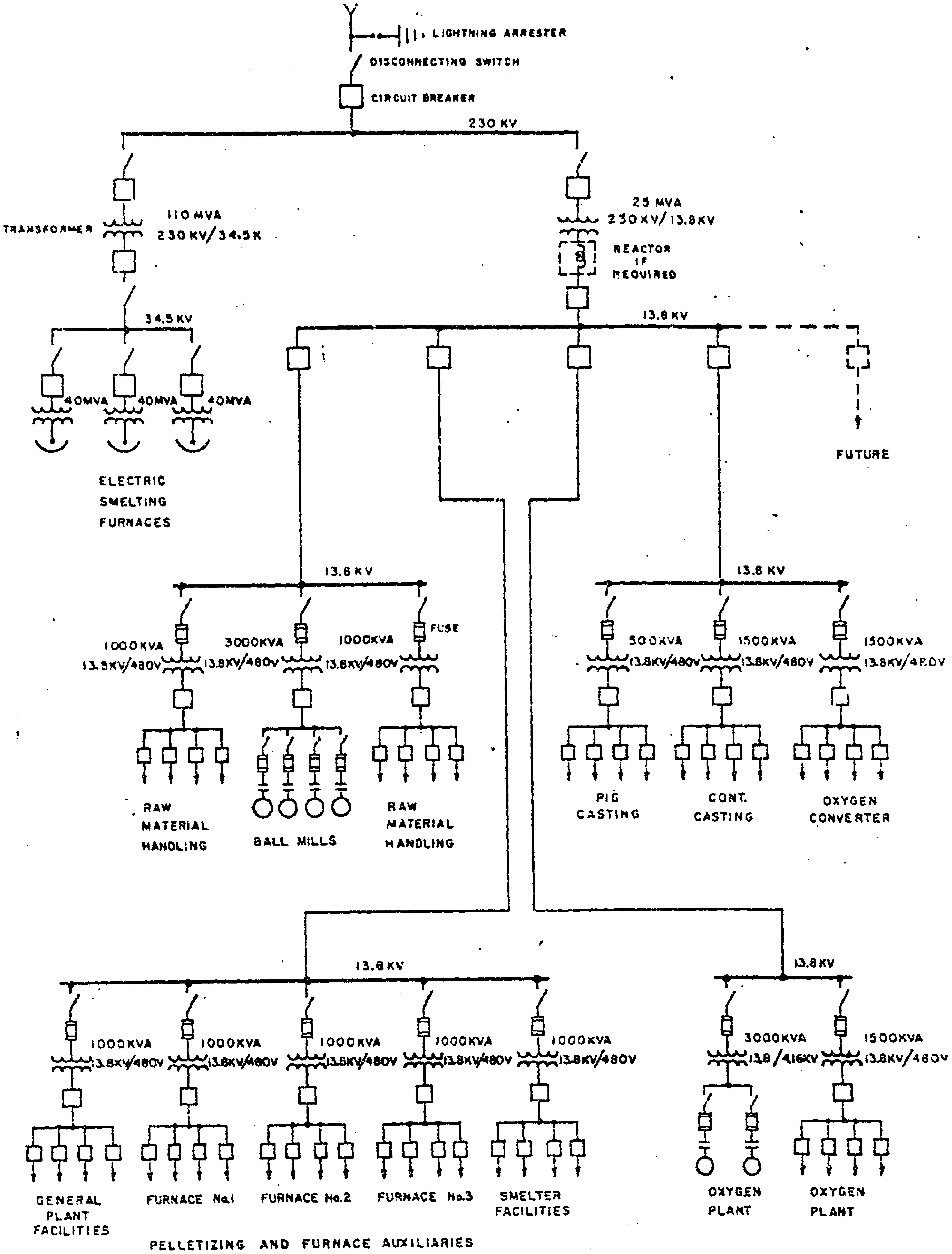
600,000 NT Pig Iron Annually
by Strategic-Udy Method

	Quantity lbs.	Unit Price N.T. (US $)	Cost N.T. (US $)
RAW MATERIALS			
Julian Concentrates - 65% Fe	2915	4.50	6.56
Pocahontas Coal	925	12.00	5.55
Dosco Coke	75	15.00	.56
Limestone	860	5.00	2.15
Mn Ore - 20% Mn	75	7.00	.26
Bauxite	55	5.00	.14
Quartz	130	5.00	.33
COST OF RAW MATERIALS			$15.55
OPERATING COSTS			
Operating Labor			2.87
Maintenance Labor			.24
Supervision			.18
Electric Power - Smelting 1250 KWH @ .004			5.00
Auxiliary 200 KWH @ .004			.80
Electrodes - 15 lbs. @ .10			1.50
Misc. Fuel - Prereduction 15 gals. @ .09			1.35
Ladles, etc.			.15
Materials for Maintenance & Repair			.75
Tools, Supplies & Lubricants			.50
Water			.05
Steam			.05
O_2 and C_2H_2			.10
Reserve for Relining			.40
Refractory Expense - Ladles, Runners, etc.			.25
Laboratory			.15
General Plant Expense			.41
Cost of Pigging			.50
COST ABOVE RAW MATERIALS			$15.25
TOTAL COST PIG IRON PER NET TON			$30.80
TOTAL COST PIG IRON PER GROSS TON			$34.50



PROPOSED SINGLE LINE DIAGRAM

STRATEGIC-UDY METHOD



PROPOSED SINGLE LINE DIAGRAM

ELKEM METHOD

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 NT Pig Iron Annually by Elkem Method

	COST U.S. $
1. **SITE WORKS**	
Grading	50,000
Water Supply incl. Distribution	300,000
Sewage Disposal	70,000
Fencing	40,000
Roads	50,000
RR Trackage	250,000
	760,000
2. **RAW MATERIAL HANDLING**	
Iron Ore	411,000
Coal	700,000
Coke	408,000
Limestone	289,000
Cement	244,000
Iron Ore Grinding	1,400,000
Additives for Smelting	40,000
	3,492,000
3. **PELLETIZING & SMELTING**	
Pelletizing & Smelting Equipment incl. 3 - 40,000 KVA Electric Furnaces	10,950,000
Pellet Hardening Storage	100,000
Instrumentation	500,000
Electrode Making	40,000
Slag Granulation	100,000
100 T Transformer Hoist & Transfer Car	50,000
2 - Payloaders @ 15,000	30,000
2 - 125/25 T OET Cranes	500,000
Building	3,660,000
	15,930,000

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 NT Pig Iron Annually by Elkem Method

	COST U.S. $
4. PIG CASTING	
2 - 50 T/Hr. Pig Casting Machines	400,000
Ladle Tilter, etc.	60,000
Building	90,000
	550,000
5. ELECTRICAL	
230 KV Outdoor Substation	1,242,000
Furnace Feeders	204,000
13.8 KV Feeders to Dept. Substations	125,000
Dept. Substations	327,000
Miscellaneous	470,000
	2,368,000
6. BOILER HOUSE	
Building	64,000
Boiler	125,000
Piping	60,000
	249,000
7. MACHINE SHOP	
Building	360,000
Equipment	400,000
	760,000
8. BRICK STORAGE	
Building	157,000
Equipment	43,000
	200,000
9. OFFICE	
Building	180,000
Equipment	20,000
	200,000

JULIAN IRON & STEEL

CAPITAL COSTS

600,000 NT Pig Iron Annually by Elkem Method

		COST U.S. $
10.	GARAGE	
	Building	216,000
	Equipment	80,000
		296,000
11.	FIRE HOUSE	
	Building	24,000
	Equipment	20,000
		44,000
12.	MISCELLANEOUS	
	1 - Bulldozer	30,000
	2 - RR Cars @ 20,000	40,000
	1 - Fork Lift Truck @ 20,000	20,000
	2 - Dump Trucks @ 15,000	30,000
	Misc. Material Handling & Storage Equipment	25,000
	Fuel Oil Tanks & Piping	150,000
	1 - Station Wagon	4,000
	1 - 100 T Track Scale	20,000
	1 - Trackmobile	10,000
		329,000
	Total	25,178,000
13.	FREIGHT	1,000,000
14.	CONTINGENCIES	1,200,000
15.	ENGINEERING & SUPERVISION	2,000,000
	TOTAL	29,378,000

JULIAN IRON & STEEL

ADDITIONAL CAPITAL INVESTMENT

FOR STEELMAKING

250,000 NT Continuous Cast Billets

	COST U.S. $
1. SITE WORKS	
Water Supply Distribution	100,000
Sewage Disposal	30,000
Roads	20,000
RR Trackage	50,000
	200,000
2. RAW MATERIAL HANDLING	
Bins & Conveyors for Additives	230,000
Lime Kiln	400,000
Lime Kiln Drive House	30,000
Lime Kiln Refractories	56,000
Lime Kiln Building	120,000
	836,000
3. BASIC OXYGEN STEELMAKING	
2 - 30 T Basic Oxygen Vessels	800,000
Hoods & Fans	200,000
Oxygen Lances, Hoists & Monorails	110,000
Meters & Controls	70,000
Refractories	60,000
Gas Cleaning System	200,000
1 - 800 T Hot Metal Mixer	550,000
5 - Steel Ladles	50,000
2 - Ladle Cars	50,000
10 - Slag Pots and Cars	150,000
2 - 50/10 T Cranes	250,000
Melter's Office & Laboratory	50,000
Ladle Relining & Drying	10,000
Stopper Rod Makeup	5,000
Building Addition	1,050,000
	3,605,000
4. CONTINUOUS CASTING	
2 - Continuous Casting Machines	2,000 000
4 - 10 T Cranes	160,000
Building	2,100,000
	4,260,000

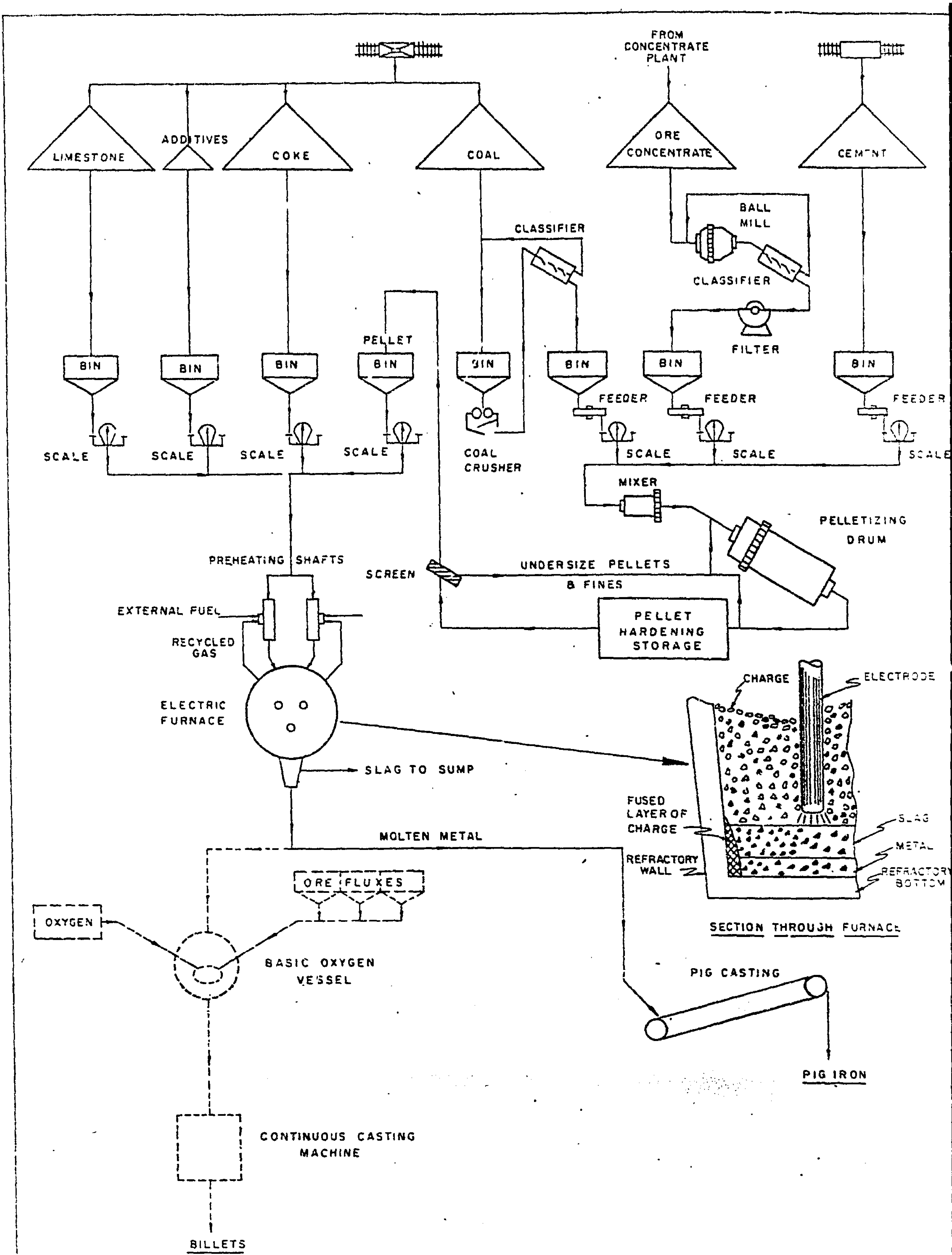
JULIAN IRON & STEEL

ADDITIONAL CAPITAL INVESTMENT

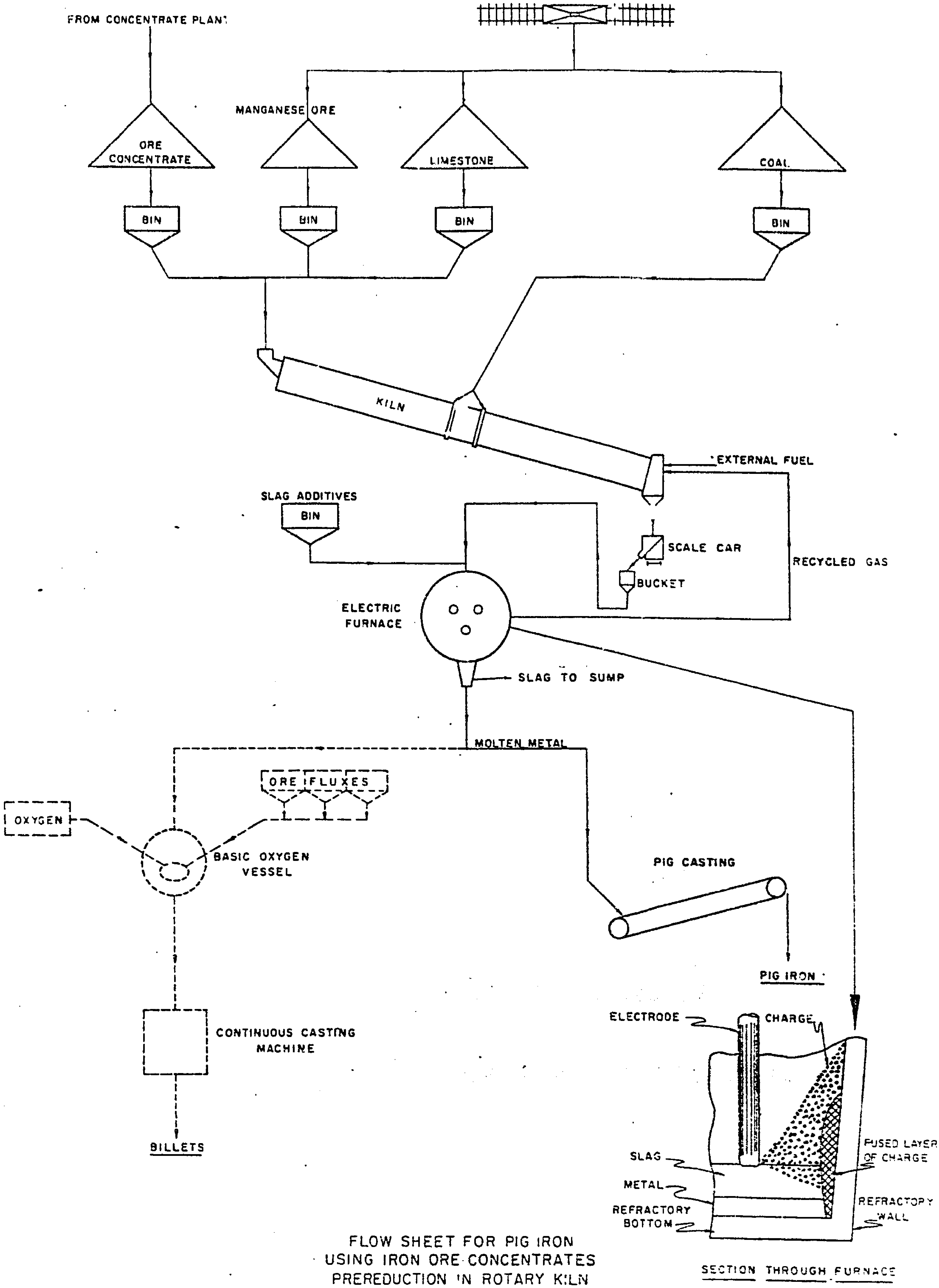
FOR STEELMAKING

250,000 NT Continuous Cast Billets

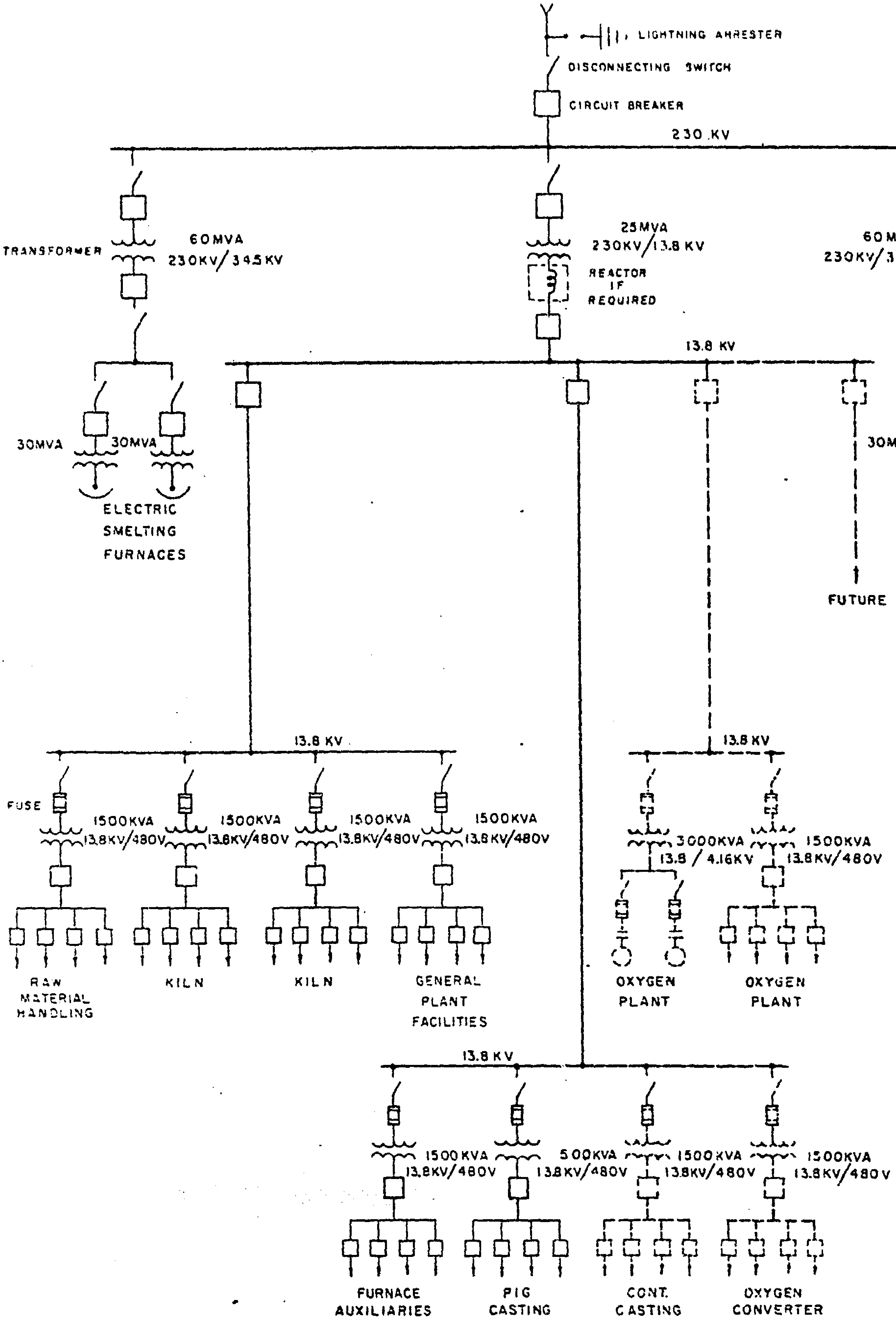
		COST U.S. $
5.	OXYGEN PLANT	
	Building	150,000
	70 T/Day Oxygen Plant	1,300,000
		1,450,000
6.	ELECTRICAL	
	230 KV Substation Addition	10,000
	13.8 KV Feeders to Dept. Substations	55,000
	Dept. Substations	155,000
	Miscellaneous	205,000
		425,000
7.	MISCELLANEOUS	
	1 - Trackmobile	10,000
	2 - RR Cars @ 20,000	40,000
	1 - Fork Lift Truck	20,000
	1 - Payloader	20,000
	2 - Dump Trucks @ 15,000	30,000
	Material Handling & Storage Equipment	25,000
	Pipe for Air, O_2, steam, etc.	200,000
	Additional Machine Shop & Repair Equipment	100,000
	Laboratory Equipment	50,000
		495,000
	Total	11,271,000
8.	FREIGHT	500,000
9.	CONTINGENCIES	600,000
10.	ENGINEERING & SUPERVISION	1,000,000
	TOTAL	13,371,000



FLOW SHEET FOR PIG IRON
USING CEMENT-IRON ORE PELLETS
PREHEATING & PREREDUCTION
ELEKTROKEMISK METHOD

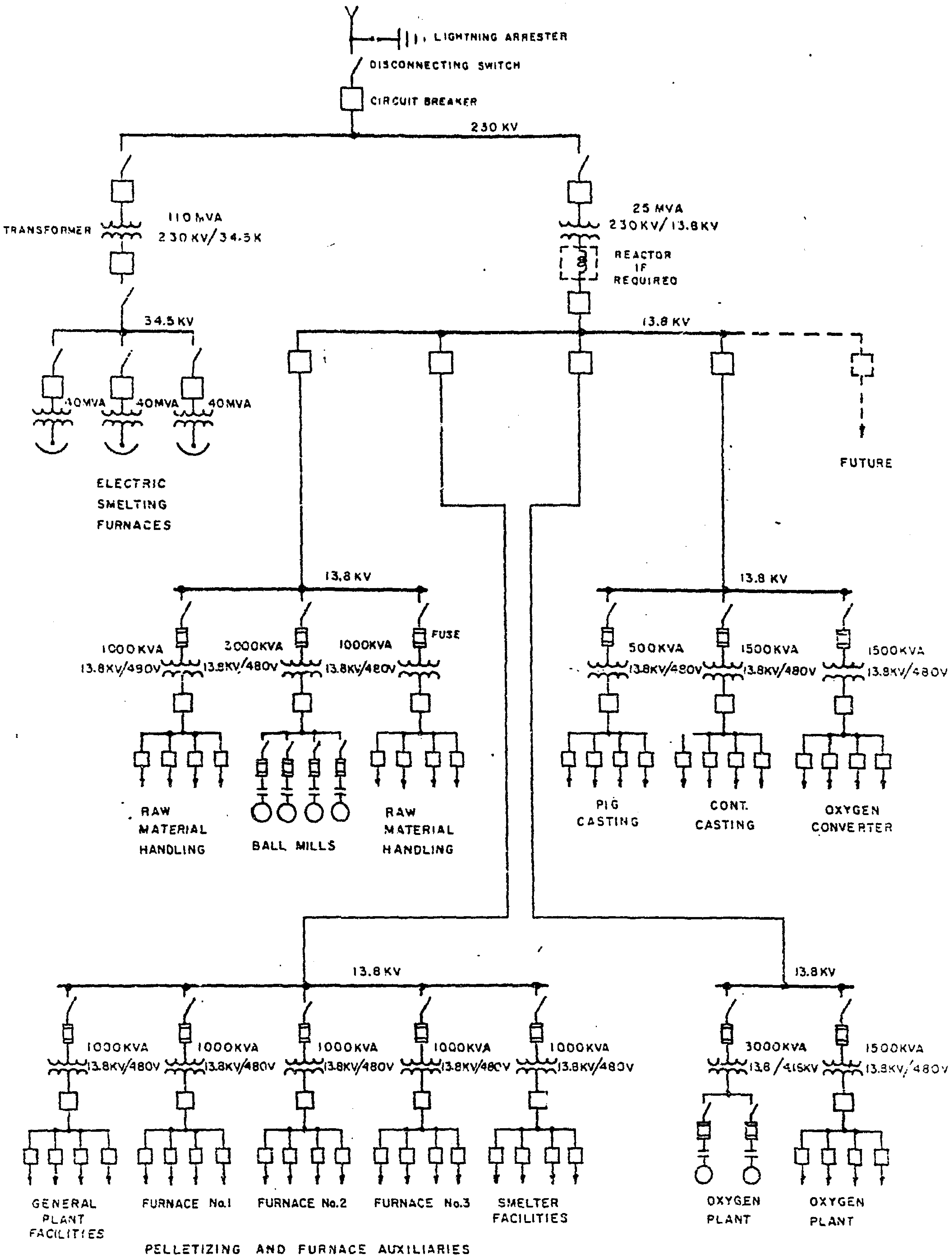


FLOW SHEET FOR PIG IRON
USING IRON ORE CONCENTRATES
PREREDUCTION IN ROTARY KILN
SMELTING IN ELECTRIC FURNACE
STPATEGIC–UDY METHOD



PROPOSED SINGLE LINE DIAGRAM

STRATEGIC-UDY METHOD



PROPOSED SINGLE LINE DIAGRAM

ELKEM METHOD