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23 G (148).

Proposal for the Japanese Steel Industry re Iron Ore Pellets & Soft Iron Piglets

CANADIAN JAVELIN LIMITED

23 G-(148).

~~CONFIDENT~~

Index

(A) General Statement

GENERAL STATEMENT

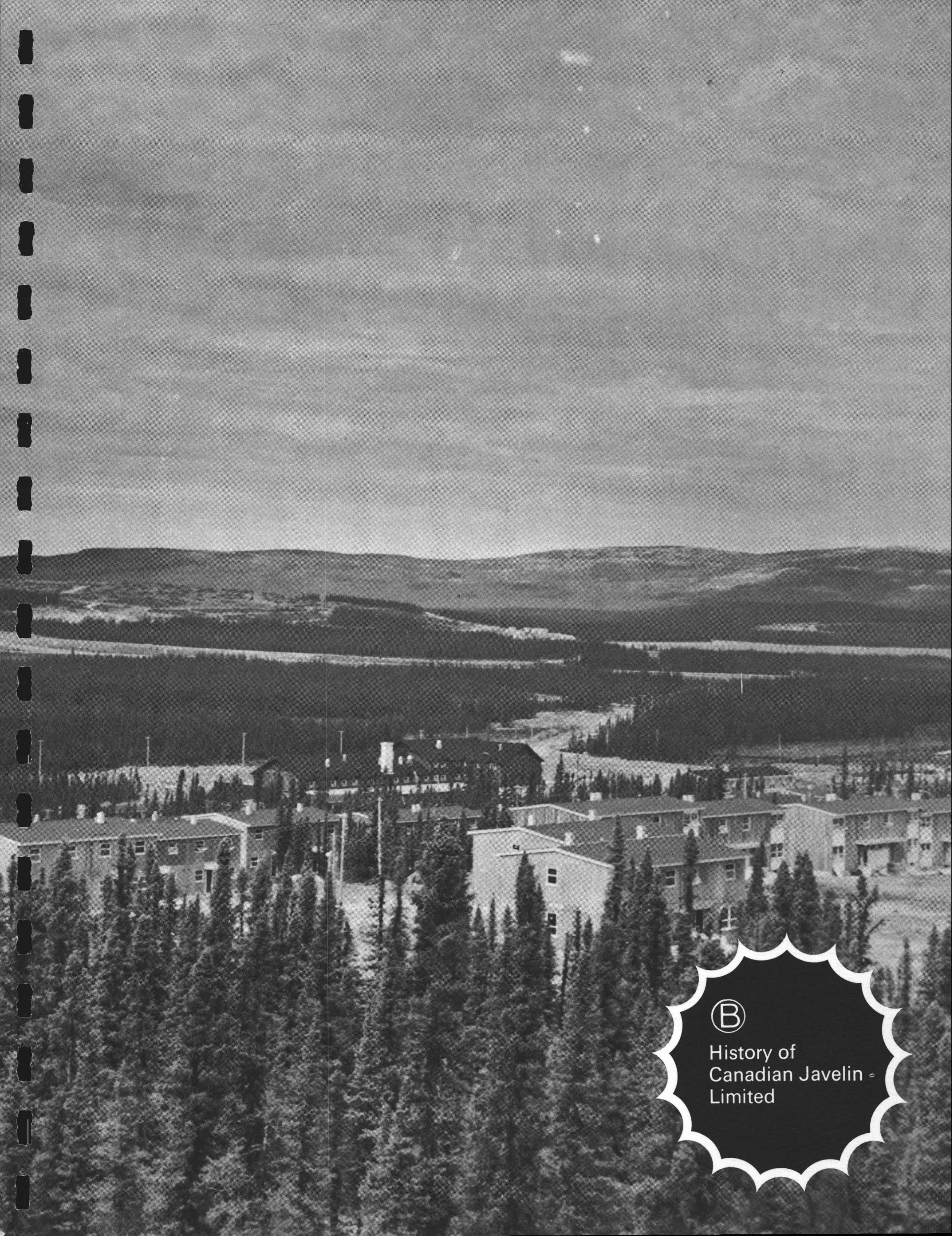
Canadian Javelin Limited and its subsidiary companies Jubilee Iron Corporation and Julian Iron Corporation own or control extensive deposits of concentrating type iron ore located in Eastern Canada approximately two hundred miles North of the St. Lawrence River iron ore shipping ports of Seven Islands and Port Cartier. The basis of this presentation is an offer by Canadian Javelin Limited to sell to the Japanese Steel Industry iron ore pellets and metallic iron melting stock in the form of "soft iron piglets" to be produced from these deposits.

The Japanese Steel Industry is a major competitive force in World Steel Markets and its position has been attained by the use of competitively priced raw materials, the maintenance of a high rate of production and expansion and the use of modern methods of production. In order to maintain its present position and to expand its share of the world market, the Industry must have an assured source of supply of high quality raw materials in large tonnages. At the present time the Industry depends largely on raw materials from areas of political and economic instability. A source of supply in Canada is, we submit, economically sound for many reasons one of which is the favourable political and economic history of that country which is a very important element in any long term arrangement for the purchase of raw materials.

Canadian Javelin Limited can supply large tonnages of these high quality raw materials to the Japanese Steel Industry at competitive prices on a long term basis and on acceptable terms and conditions of payment from the iron ore deposits owned or controlled by it and its subsidiaries. These deposits have uncommitted ore reserves in excess of 670,000,000 of concentrating type ore and approximately 290,000,000 tons of high quality iron ore concentrates are available through the processing of these reserves. This proposal anticipates the production of approximately 150,000,000 tons of these concentrates during a period of 24 years for further processing and sale to the Japanese Steel Industry as 58,400,000 tons of iron ore pellets and 58,400,000 tons of soft iron piglets.

It is recognized that a basic factor in world trade is reciprocity and it is a feature of the proposal now put forward by Canadian Javelin Limited that it will undertake to purchase from Japanese sources the steel products and machinery required for construction of plants and related facilities necessary to carry out the terms of the contracts with the Japanese Steel Industry. It is also proposed that all cargo vessels required to transport the products to Japan will be built in Japanese shipyards and it is felt that these conditions will not only enable the respective Governments of Japan and Canada to assist in finalizing the proposed contracts but will encourage them to do so.

Canadian Javelin Limited has prepared this proposal bearing in mind the policies and requirements of the Japanese Steel Industry in respect to supplies of basic raw materials and looks forward to a long association with the Japanese Steel Industry under the terms of the proposal.



Ⓑ
History of
Canadian Javelin
Limited

HISTORY OF CANADIAN JAVELIN LIMITED

Canadian Javelin Limited, hereinafter referred to as "the Company" was incorporated under Letters Patent issued by The Secretary of State of Canada and dated the 28th day of June, 1951 for the purpose of acquiring a foundry business carried on by Javelin Foundry and Machine Works Limited at Joliette in the Province of Quebec. The Company also acquired with the foundry business options on certain mining claims in the Province of Quebec.

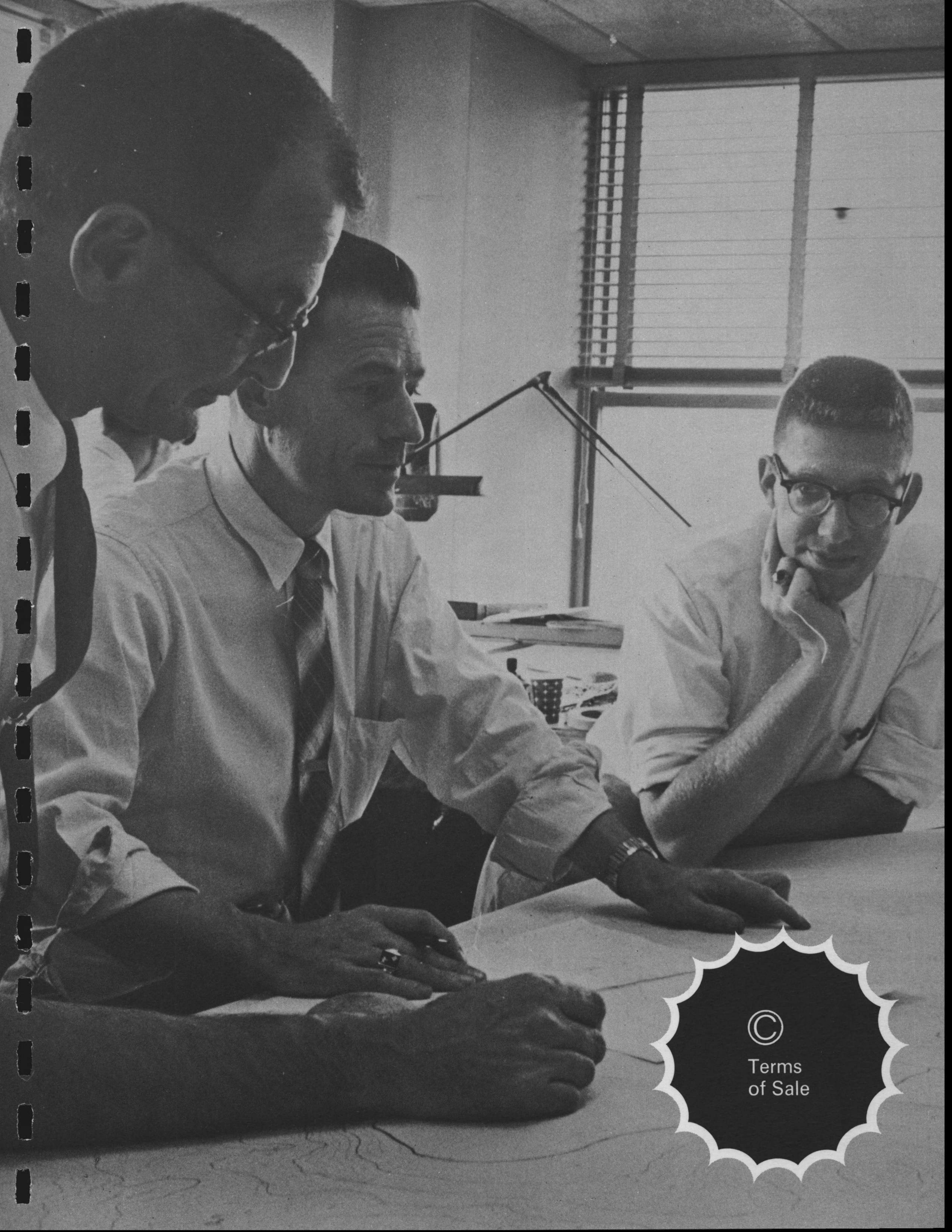
The Company is now a public company and has in excess of 18,000 shareholders, the majority of whom are resident in Canada and the United States. It has a capital structure of 12,000,000 common shares of which approximately 5,000,000 are issued and outstanding and fully paid.

The Company owns or controls extensive mining properties in the Western Hemisphere but it is essentially an iron ore company and is engaged principally in the holding, exploring and developing of iron ore properties in the Provinces of Newfoundland and Quebec.

The principal iron ore mining property of the Company is located near Wabush Lake in the Province of Newfoundland and covers an area of 5.6 square miles which property is under a long term lease that extends until the year 2055 as does a further lease of iron ore properties near Julien Lake in the Province of Newfoundland. The Company through Jubilee Iron Corporation which it controls has also acquired iron ore mining properties in the Province of Quebec.

The Company has an agreement with Pickands-Mather & Co. of Cleveland, Ohio pursuant to the provisions of which that company can be requested to manage the iron ore mining operations of the Company at any of its present locations.

The Company is a partner with the Government of Newfoundland in the Newfoundland and Labrador Corporation Limited which controls approximately 20,000,000 acres of mineral land and 10,000 square miles of standing commercial timber in the Province of Newfoundland.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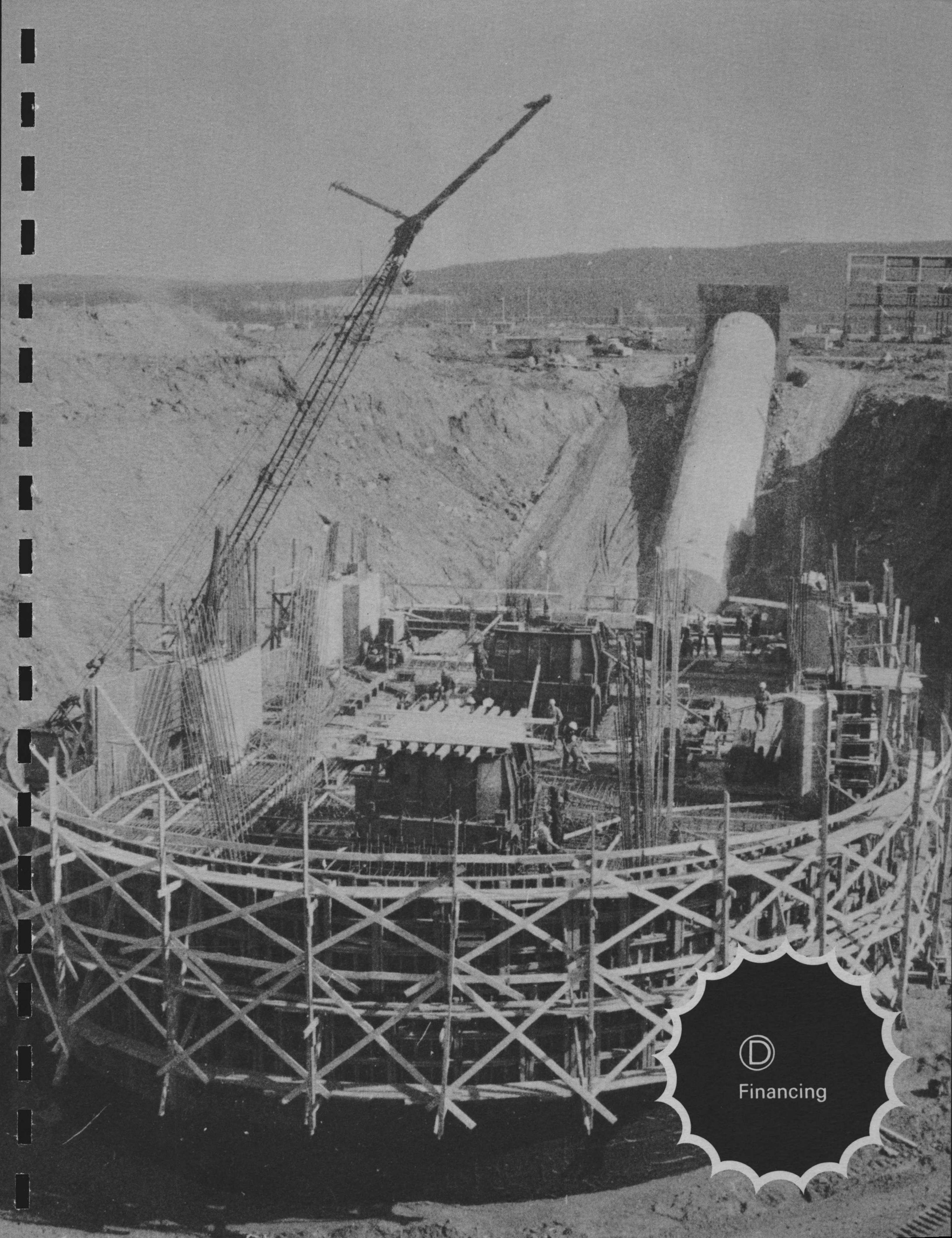
Terms
of Sale

TERMS OF SALE

Canadian Javelin Limited agrees to sell to the Japanese Steel Industry, Iron Ore Pellets in the maximum tonnage of 1,850,000 metric tons per year, 10% more or less, for a period of twenty years and Soft Iron Piglets or direct Iron Melting Stock to the maximum tonnage of 3,100,000 metric tons per year, 10% more or less, for a period of twenty years. The Japanese agents acting for Canadian Javelin Limited in Japan are Nichimen Co. Ltd. and Ataka & Co. Ltd.

The said contracts provide for the purchase and delivery of the products in accordance with the schedules set forth therein and while Canadian Javelin is prepared to make delivery in accordance with these schedules, it is a condition precedent to each contract as expressed therein that the Japanese Steel Industry shall purchase and accept delivery of an equivalent number of tons of either product in any one year up to the maximum tonnage of Iron Ore Pellets contracted for. Canadian Javelin Limited is offering to the Japanese Steel Industry both iron ore pellets and soft iron piglets at favorable competitive prices throughout the term of the respective contracts which prices have been calculated after taking into consideration volume of ore concentrate production, the ratio between production of iron ore pellets and soft iron piglets to meet delivery schedules, capital investment in plant, equipment and transportation costs relevant to the production and delivery of both products in the quantities offered. The quoted price per ton of each product is inter-dependent and therefore Canadian Javelin Limited is unable for economic reasons to make delivery of one product at the price quoted without effecting delivery of a similar number of tons of the other product.

It will be noted that the terms and conditions do not require any capital investment by the Japanese Steel Industry and the contracts provide for credit terms of nine months. These terms are such that under normal conditions the Japanese Steel Industry will not be required to make payment for these raw materials until after the finished steel has been sold.



D Financing

FINANCING

As it has not been the practice of Canadian and United States financial institutions to finance projects such as that proposed where the product is being sold to a foreign consumer, it is necessary to obtain credit financing from the Government of Canada.

Discussions have already taken place in this respect and it is believed the required financing can be obtained to enable Canadian Javelin Limited to extend credit to the Japanese Steel Industry for a period of 9 months. Such credit arrangements would be the equivalent of a very substantial loan to the Japanese Steel Industry.

It will be understood that the proposed credit arrangements can not be completed until the Japanese Steel Industry expresses its intention to enter into the proposed contracts with Canadian Javelin Limited by executing the same and for this reason the terms of the contracts provide that Canadian Javelin Limited shall have 6 months from the date of execution thereof by the Japanese Steel Industry to complete the proposed credit arrangements.

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Location & Description of Ore Deposits

LOCATION AND DESCRIPTION OF ORE DEPOSITS

This proposal is based on production of high quality iron ore concentrates from two iron ore deposits as follows:-

(i) Julian Deposit (see location Map, page 12).

Canadian Javelin Limited owns this deposit through its wholly owned subsidiary Julian Iron Corporation.

This property is situated in Labrador-Newfoundland at the North end of Wabush Lake, about 12 miles north of the Wabush Carol area where large concentrating and pelletizing plants are in operation by Iron Ore Company of Canada and Wabush Mines Limited.

Access to the property is by road from Wabush. Railway transportation and electric power with adequate capacity to serve the needs of the property are available through short extensions to existing facilities in the area. Scheduled airline service from Montreal is in operation to Wabush and all other necessary facilities are readily available in the area. The property is approximately 268 rail miles from the modern iron ore loading facilities at Pointe Noire (Seven Islands) which are available for handling of products from the property.

The deposit consists of a hill of concentrating type iron ore forming the body of a peninsula surrounded on three sides by shallow waters of Wabush and Julian Lakes. The deposit trends North Easterly through this peninsula and extends into the lakes on either side. Within the peninsula it has a length of approximately 6,000 feet and widths varying from 1,800 feet to 3,400 feet. The ore is essentially a uniform friable mass of a coarsely-crystalline mixture of quartz and iron oxide ore minerals.

A surface plan and typical cross sections of the Julian orebody are shown on pages 13 and 14.

The deposit has been explored by trenching and diamond drilling to depths exceeding 800 feet and on the basis of this work ore reserves have been calculated at 500,000,000 tons containing 34.2% iron with only traces of harmful impurities. Metallurgical tests have shown that the ore minerals can be readily separated from the quartz through grinding and gravity concentration to give a recovery of 42% by weight as a high grade specular hematite iron ore concentrate with an average analysis of 65.5% iron and 5% silica.

(ii) Jubilee Property (see location Map page 12)

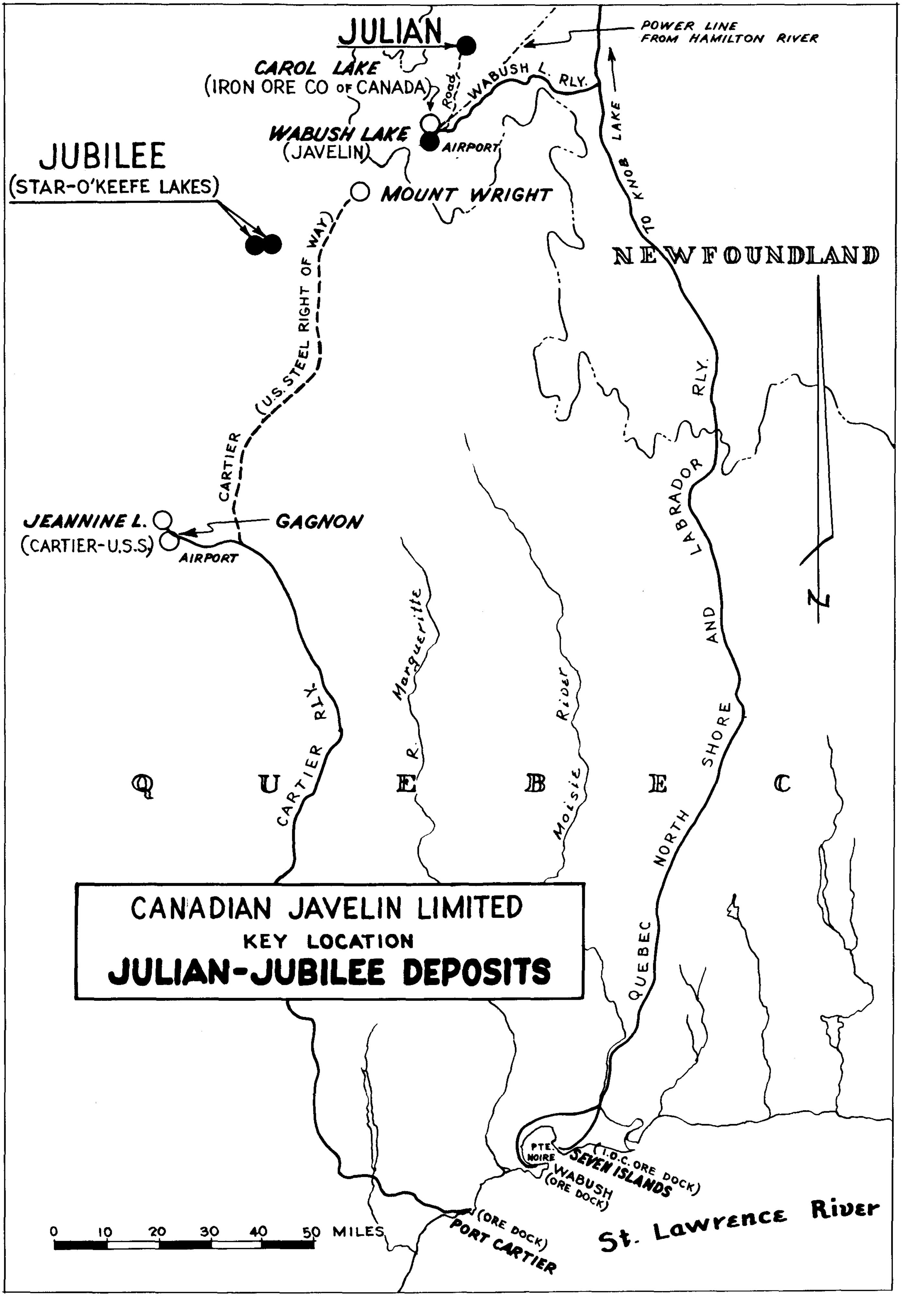
The Star and O'Keefe deposits of Jubilee Iron Corporation are controlled by Canadian Javelin Limited through operating management and lease agreements. Canadian Javelin Limited has a controlling interest in Jubilee Iron Corporation.

These two adjoining deposits are located approximately 200 miles North of Port Cartier on the St. Lawrence River and 18 miles West of the right of way of the Quebec Cartier railway extension from Lac Jeanine to Mount Wright. They are about 60 miles North of Gagnon, Quebec and 40 miles West of Wabush, Labrador, at which points scheduled air line service is available to Montreal.

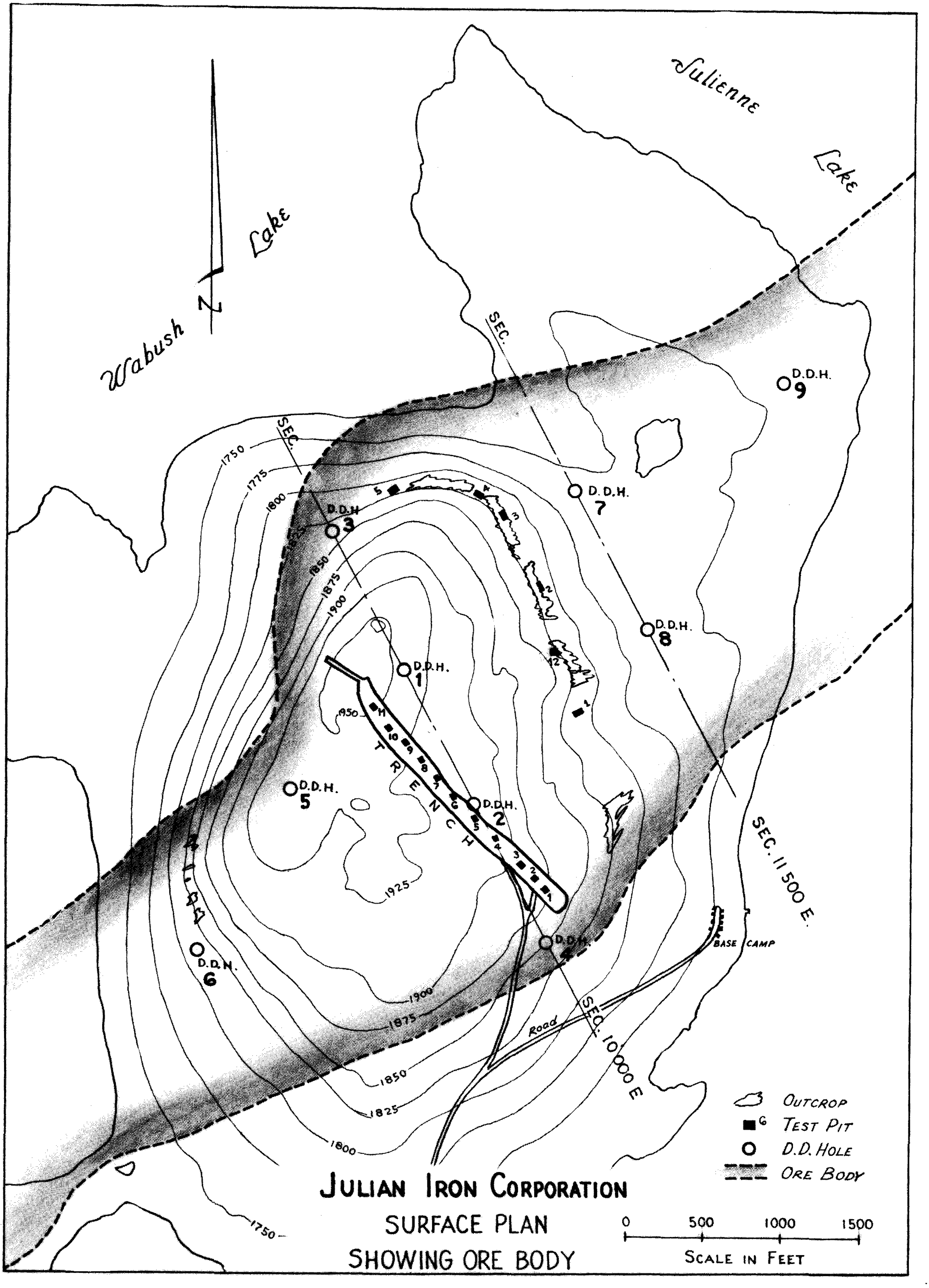
The Jubilee holdings cover two deposits lying less than 1 mile apart. These deposits have been explored by surface surveys, trenching and sampling and diamond drilling to depths of about 700 feet and on the basis of this work approximately 175,000,000 tons of ore suitable for open pit mining have been outlined in the deposits with an average analysis of 35% iron and only traces of harmful impurities.

These two deposits are similar in character being massive bodies of a friable crystalline mixture of quartz and specular hematite. Widths vary from 200 feet to 800 feet. Both ore bodies are well suited to low cost open pit mining methods. Concentration studies on representative samples from these ore bodies gave a recovery of 45% by weight as concentrates containing 67% iron and 3.44% silica with only traces of harmful impurities.

Both the Julian and Jubilee deposits are located in established iron mining areas where, with short extensions to existing services all necessary facilities are available for production and transportation of products to St. Lawrence River ports for shipment.

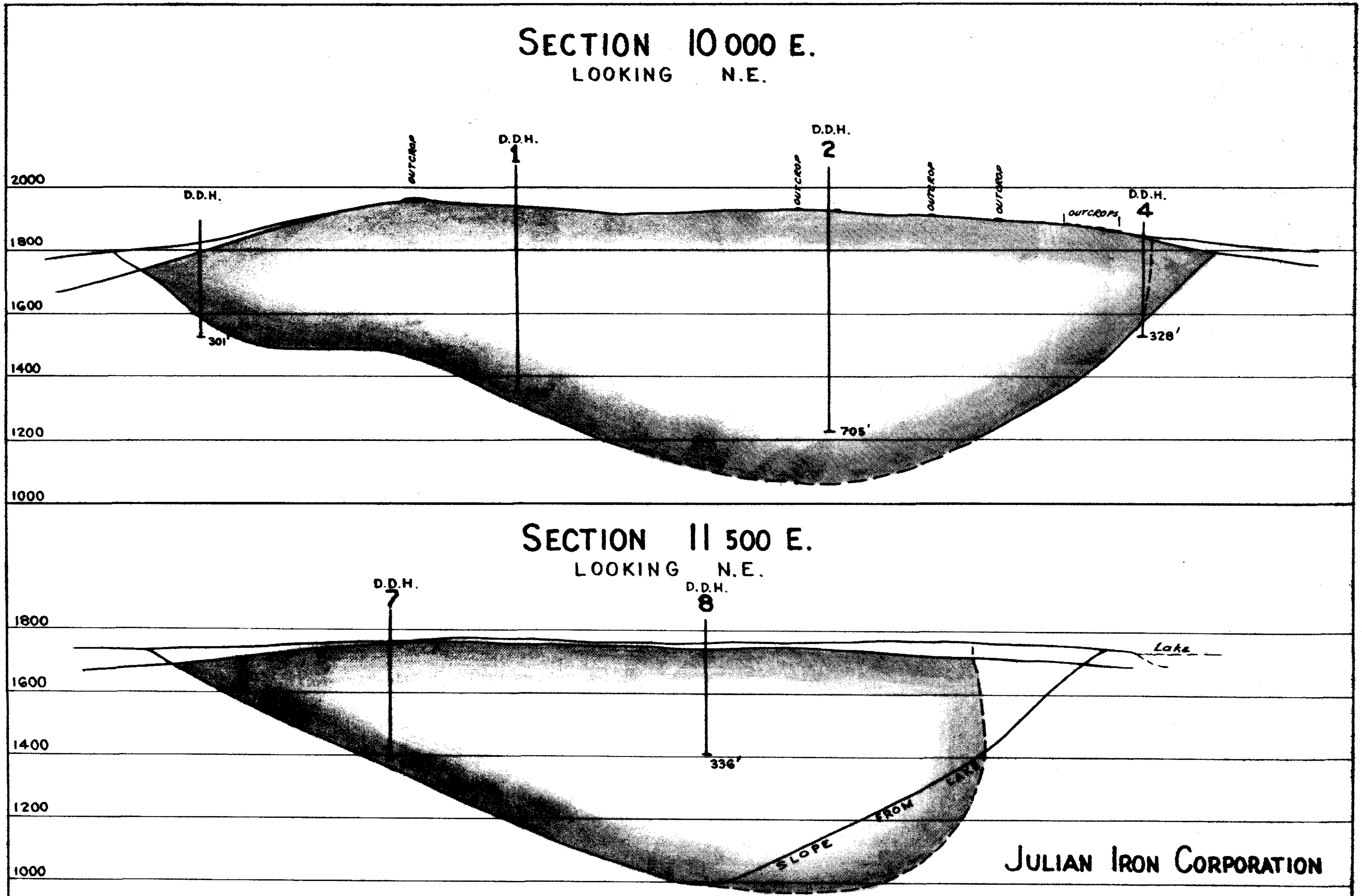


JULIAN
CAROL LAKE
(IRON ORE CO OF CANADA)
Road
WABUSH L. RLY.
POWER LINE
FROM HAMILTON RIVER
WABUSH LAKE
(JAVELIN)
AIRPORT
JUBILEE
(STAR-O'KEEFE LAKES)
MOUNT WRIGHT
TO KNOB LAKE
NEWFOUNDLAND
CARTIER (U.S. STEEL RIGHT OF WAY)
QUEBEC NORTH SHORE AND LABRADOR RLY.
N
JEANNINE L.
(CARTIER-U.S.S.)
AIRPORT
GAGNON
CARTIER RLY.
R. Marguerite
Moisie River
QUEBEC
CANADIAN JAVELIN LIMITED
KEY LOCATION
JULIAN-JUBILEE DEPOSITS
PTE. NOIRE
SEVEN ISLANDS
(I.O.C. ORE DOCK)
WABUSH
(ORE DOCK)
(ORE DOCK)
PORT CARTIER
St. Lawrence River
0 10 20 30 40 50 MILES



JULIAN IRON CORPORATION

SURFACE PLAN
SHOWING ORE BODY



TYPICAL CROSS-SECTION OF JULIAN ORE BODY LOOKING N.E.

Ⓕ Production Plans & Technical Information

PRODUCTION PLANS and TECHNICAL INFORMATION

All engineering and tests necessary for an immediate start on construction of production facilities have been completed. These reports and studies are in Canadian Javelin files for reference.

The production schedule under the terms of this proposal will require the simultaneous construction of two mining and processing plants - One at Julian having a capacity of 5,000,000 tons of concentrate a year and a second at Jubilee having a capacity of 2,000,000 tons per year. These two plants will have similar flow sheets and equipment.

Production from the Julian plant will be shipped over the Wabush Lake - Q.N.S. & L. Railway system for loading on ocean vessels at Pointe Noire dock at Seven Islands and from the Jubilee plant over the Quebec Cartier Railway to docks at Port Cartier.

Open pit mining methods will be used at both properties using large power shovels and heavy duty trucks, hauling to large primary crushers which will reduce the mine run ore to -12" size.

A simplified flow sheet for the concentration, pelletizing and reduction plants is shown on page 17.

After primary crushing the ore will be ground to -20 mesh in wet autogenous mills followed by concentration in two stages of

Humphreys spirals. This concentrate will then be ground to -325 mesh in wet ball mills followed by removal of liberated silica in a "column flotation" circuit. This low silica concentrate will be filtered and fed to pelletizing equipment. These green pellets will go either to pelletizing hardening equipment or to a direct Reduction plant for production of "soft iron piglets."

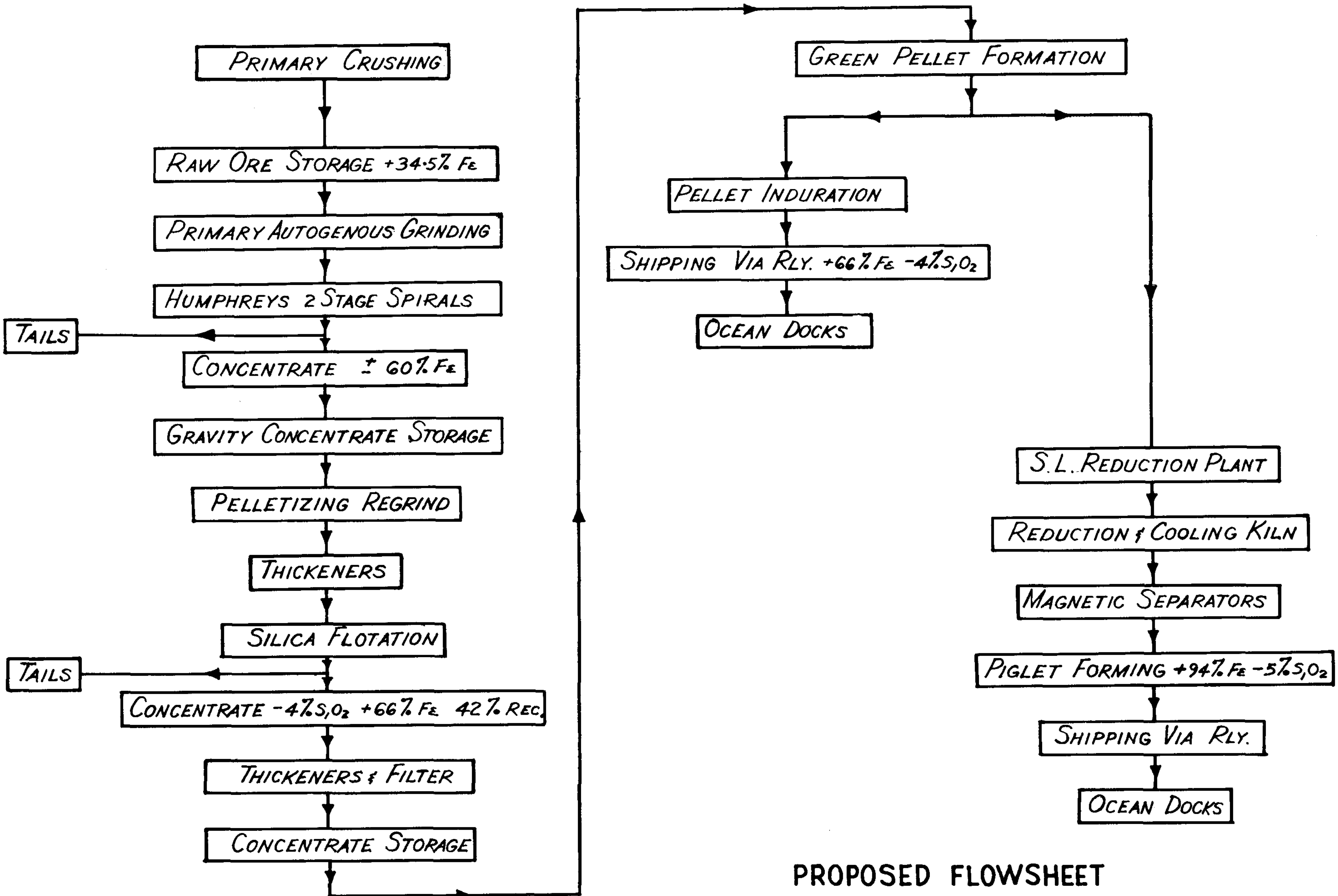
A feature of this flow sheet which is unique in the area is the addition of "silica flotation" following the pelletizing regrind ball mills. This addition has been made for two purposes:

(1) To improve overall recovery of iron in the concentration plant.

(2) To give a uniformly high quality product.

Pellet tests have been completed for Dravo-Lurgi pellet induration equipment similar to that presently in use in the other plants in the Labrador Quebec area. These tests, which have been correlated with the commercial production results, are the basis for the high physical quality guarantees proposed in the sales agreement. An installation using this equipment would carry a guarantee by Dravo Corporation that the product meets these specifications.

Canadian Javelin has had preliminary discussions with a number of technical groups concerning the use of pelletizing equipment and it is Javelin's intention to have tests conducted of the several available processes on which to base a comparative study of the economics



PROPOSED FLOWSHEET
JULIAN & JUBILEE PRODUCTION PLANTS

of each process. Javelin will consider proposals from Japan concerning pelletizing processes developed in that country.

From the proposed flow sheet concentrates and pellets having the following chemical composition will be produced.

	Concentrates %	Pellets %
Iron	66.5 to 69.5	66 to 68.5
Silica	2.0 to 4.5	2 to 4.5
Phosphorus	0.02	0.02
Sulfur	0.02	0.02
Manganese	0.3	0.3
Lime + Magnesia + Alumina	0.1	0.5

Traces of other elements.

The minimum physical quality of these pellets will exceed the contract guarantees.

The guarantees under which these pellets are sold make them the highest quality blast furnace feed available in large quantities in world markets.

Pelletizing processes are well known to the steel industry and therefore details of these processes as applied to Javelin ores have been omitted from this presentation.

Soft Iron Piglets are a technically advanced raw material for the iron and steel industry. A detailed presentation of Javelin's plans for production of this product, together with technical details of the process, are presented as Schedule C "Memorandum re Soft Iron Piglets" attached to this presentation.

Canadian Javelin has carried out extensive engineering studies relating to the technical aspect of this proposal and has engaged and worked closely with the following consultants:-

(1) Behre Dolbear & Company
Consulting Mining Engineers and Geologists
New York, U.S.A.

(2) Ford, Bacon & Davis, Incorporated
Engineers,
New York, U.S.A.

(3) Pickands Mather & Company
Management Engineers,
Cleveland, Ohio.

(4) Humphreys Engineering Company,
Denver, Colorado.

(5) Dravo Corporation
Pittsburgh, Pennsylvania.

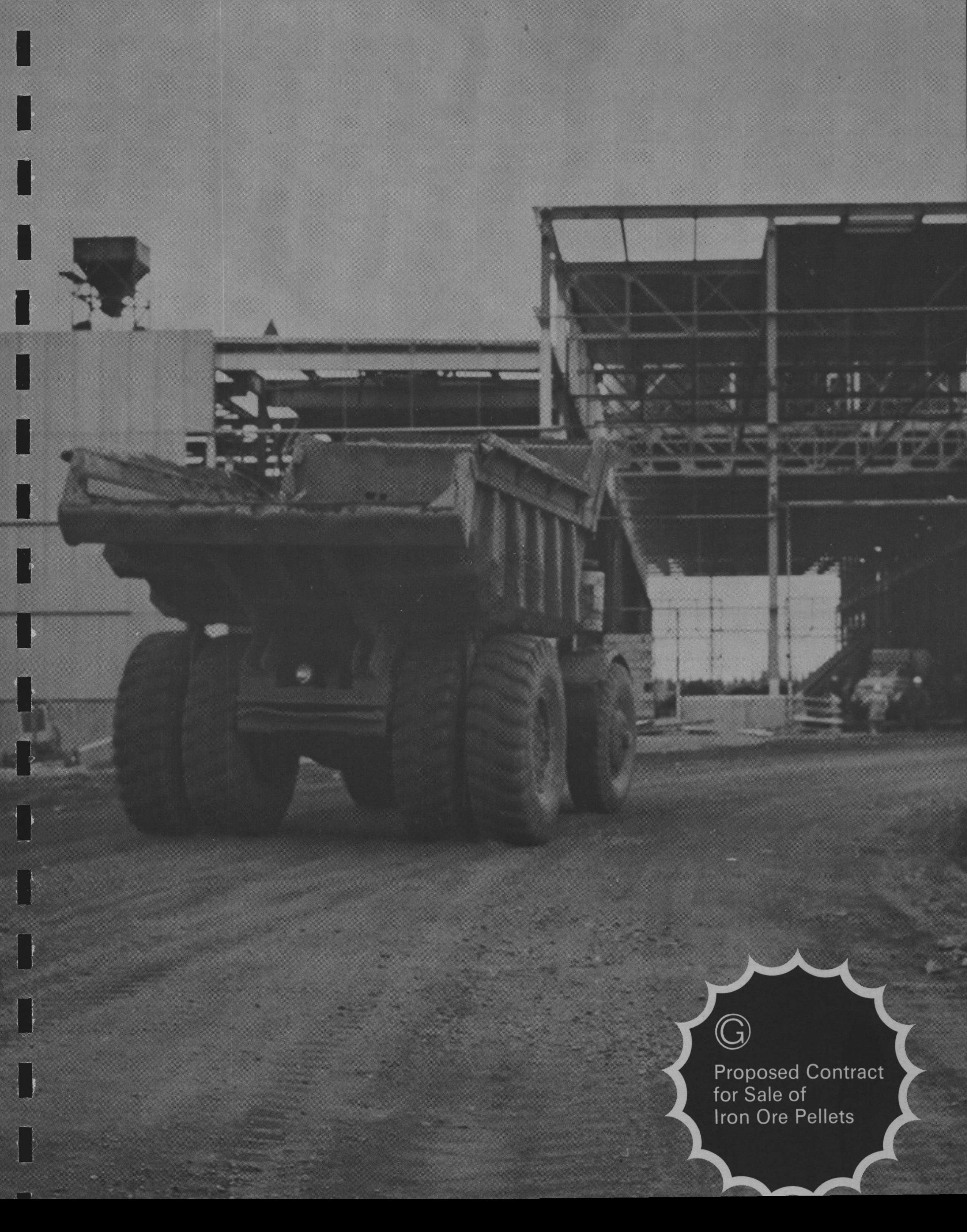
(6) Elektrokemisk A/S
Oslo, Norway.

(7) Lakefield Research of Canada Limited
Lakefield, Ontario.
Canada.

(8) Hains Engineering Company Limited
Consulting and Contracting Engineers
(Canadian Representatives of the
Lurgi Companies, Frankfurt/Main)
Toronto, Ontario.

(9) Kilborn Engineering Limited
Consulting Engineers,
Toronto, Ontario.

(10) Ramseyer & Miller, Inc.
Consultants to the
Iron and Steel Industry
New York.



Proposed Contract for Sale of Iron Ore Pellets

SCHEDULE "A"

JAVELIN - JAPANESE - IRON ORE PELLET SALES CONTRACT

BETWEEN:

JAVELIN EXPORT COMPANY LIMITED, a Corporation incorporated under the Laws of Nassau, in the Bahamas and having an office in Nassau in the Bahamas, hereinafter called "the Seller"

THE PARTY OF THE FIRST PART

- and -

hereinafter called "the Purchasers"

THE PARTY OF THE SECOND PART

- and -

CANADIAN JAVELIN LIMITED, a Corporation incorporated under the Laws of Canada and having its head office in the City of St. John's in the Province of Newfoundland on behalf of itself and acting as Managing Agent and Lessor on behalf of Jubilee Iron Corporation for its iron ore properties, hereinafter called the "Owner".

THE PARTY OF THE THIRD PART

WHEREAS the Seller is the Sales Agent for the Owner who owns iron ore deposits in the said Province of Quebec and in the Province of Newfoundland, Canada.

AND WHEREAS the Purchasers constitute the basic pig iron producers of the steel industry in Japan.

NOW THEREFORE THIS AGREEMENT WITNESSETH that the Seller agrees to sell to the Purchasers and the Purchasers agree to purchase from the Seller iron ore pellets (hereinafter called "the product") of the specifications, in the quantities, at the price, and subject to the terms, conditions and covenants by the parties hereto hereinafter set forth:-

1. SPECIFICATIONS

(a) Chemical Analysis

Iron	66.00% average
Silica	4.00%
Phosphorus	0.02% maximum
Sulfur	0.02% maximum
Alumina + Lime + Magnesia	0.05% maximum

Only traces of other harmful elements with a guaranteed minimum of 65% Iron and maximum of 5.5% Silica.

(b) Physical Characteristics

The iron ore pellets will have the following physical characteristics:-

(i) Size on discharge - 80% in the 3/8" x 5/8" size range - 15% maximum fines under 1/8" in size;

(ii) Strength - Minimum average compression strength of pellets in 3/8" x 5/8" size range - 500 pounds per pellet;

(iii) ASTM Coke Tumble Test - 7% maximum fines under 1/8" in a 25 pound sample of the 3/8" x 5/8" size pellets after 200 revolutions.

(c) Should the quality of the product regarding chemical composition or physical properties not correspond to the above description or should the product not have the properties agreed as to stability and smelting characteristics, the Purchasers are not obliged to pay the contract price but an agreement shall be arrived at on a new price which will be in accordance with the actual quality of the product delivered.

2. SAMPLING AND ANALYSIS

(a) Sampling and analysis shall be effected at the port of discharge by one of the following methods:-

(i) Independent - Seller and Purchasers shall mutually agree upon a representative who shall act for both parties and at the joint expense of both parties;

(ii) Joint - The product shall be sampled by representatives of the Seller and the Purchasers conjointly during the discharge of vessels. Analysis for iron to be exchanged on an agreed date in the usual manner and each party shall pay the cost of his representative. Differences of up to half per cent in iron to be equally divided and in the event the difference in iron exceeds the agreed percentage, reserved sealed samples shall be sent by Seller and Purchasers to a mutually agreed referee chemist whose analysis shall be final and binding on the parties hereto. The cost of the referee's analysis shall be borne by the party whose result is least in accord with the result of the referee chemist.

3. SHIPMENTS

(a) The Seller shall ship to the Purchasers the product on the following schedule subject always to a variation of 10% and to such further variations as are normal in an industry of the nature of that carried on by the Seller:-

(i)	1967	1 million tons
(ii)	1968 - 1988	1.85 million tons

(b) The above production schedule shall be subject to such modifications as may become necessary due to delivery of equipment purchased in Japan for the production and other facilities of the Seller as provided in Section 12 of this agreement.

(c) Delivery shall be made in approximately equal monthly shipments, subject to seasonal adjustments, to Japanese ports as named by the Purchasers at least 14 days prior to departure of vessels.

(d) The Seller will advise the Purchasers by cable of the departure of each vessel stating in such cable the quality and quantity loaded and the total price of the shipment F.O.B. port. Vessels shall be consigned to Purchasers' agent at sea port of discharge.

4. LOADING AND UNLOADING

(a) It is agreed that the vessels will be discharged at a rate of 2,000 tons per hour. Provided that it is further agreed as port facilities are improved and the rate of capacity of discharge is increased, the said rate of 2,000 tons per hour will be increased proportionately to the rate of capacity.

(b) Vessels demurrage to be $2,000.00 (U.S.) per day and dispatch to be $500.00 (U.S.) per day.

(c) The Japanese Steel Industry undertakes to use its best efforts to ensure that the Japanese Government shall accord the vessels transporting the product the same treatment as if they were under Japanese registry as to all port and terminal charges. Terminal charges shall, for the purpose of this paragraph, include any charges incurred by the vessels in lightening, in discharging into lighters, barges, etc. as well as any demurrage on any lighters, barges, etc. and any dockage fees at discharging points. Port charges are normal expenses incurred and include all charges normally incurred by a vessel on arriving at a destination i.e. pilots, tugs, etc.

5. PRICE

(a) The Price shall be the Canadian dollar equivalent as at this date of $11.12 U.S. funds per metric ton F.O.B. Lower St. Lawrence ports of Seven Islands or Port Cartier with a guaranteed freight rate of $5.00 U.S. funds per metric ton for delivery in vessels of 50,000 to 60,000 capacity to Japanese sea ports.

(b) The aforementioned price and freight rate shall be subject to the following adjustments:-

(i) Where average iron analysis of a cargo exceeds the guaranteed minimum of 65%, a premium calculated in the Canadian dollar equivalent as at this date of $ U.S. 0.22 per "metric ton iron unit" shall be added to the Lower St. Lawrence price per metric ton in respect to such excess.

(ii) The price of the iron ore pellets at Lower St. Lawrence ports as quoted in (a) and (b) (i) above shall be subject to escalation downwards and upwards based on average weighted world market prices for iron ore pellets. The average world market price is defined as the arithmetic mean of :-

(a) The price of iron ore pellets of similar quality delivered from Sweden to world markets calculated in U.S. Dollar equivalent

(b) The standard "Lake Erie" price in the United States for iron ore pellets of similar quality.

(iii) The vessel freight rate of $U.S. 5.00 per metric ton shall be subject to adjustment for increases and decreases from the date hereof in the cost of operation of vessels including, but not limited to, changes in cost of fuel, wages, taxes, canal tolls, duties, port and terminal charges.

(iv) The price of iron ore pellets shall also be subject to adjustments for increase or decrease in the cost of materials, wages, transportation and taxes incurred by the Seller.

6 PAYMENT

(a) F.A.S. Japan.

(b) Purchasers shall pay sea freight upon the arrival of vessels at sea port of discharge.

(c) Purchasers shall pay product value by promissory notes in favor of the Seller at the times and on the terms hereinafter set forth:-

(i) A note shall be issued by the Purchasers within 2 days of receipt of notice by them pursuant to clause 3 (d) hereof with respect to each shipment and such note shall be delivered to the Owners or their nominees as advised in the said notice.

(ii) Each of such notes shall be dated as at the date of departure of the respective shipment from the loading port as advised by the Seller persuant to clause 3 (d) hereof and shall be in an amount based on the bill of lading weight and in accordance with the invoice relevant to the shipment and shall become due and payable 10 calendar months after date with interest from date at the current Canadian bank interest rate at date.

(iii) Each of such notes shall be payable in U.S. Dollars or Canadian Dollar equivalent.

(iv) Such notes shall be subject to adjustment on account of variations from specifications in weight and quantity 30 days after arrival of the respective shipment at the port of discharge or as may be agreed between the parties hereto.

7. WEIGHING

Weight to be ascertained at port of discharge unless otherwise agreed and the Seller to have the option to appoint a checkweigher and in the event cargoes are not weighed the Purchasers shall make payment based on the bill of lading weight.

8. INSURANCE

Insurance to be effected by the Seller for the account of the Purchasers with premiums at competitive rates to be billed by the Insurer or its agent directly to the Purchasers. Such insurance shall be applicable at the time of completion of loading of each shipment and in the event of loss of cargo the Purchasers undertake to pay the Seller on the basis of the bill of lading weight and invoiced quality.

9. TAX

In the event that any additional duty or tax or increase in any existing duty or tax in the country of destination shall be imposed during the term of this contract resulting in an increase in the cost of the ore to be delivered under the contract, the same shall be paid by the Purchasers.

10. ARBITRATION

(a) Any dispute or difference of opinion between the parties hereto as to the quality of the product under this contract shall be dealt with pursuant to clause 2 of this contract.

(b) If at any time during the continuance of this contract any dispute, difference or question arises between the parties hereto with reference to this contract, other than with reference to the quality of this product, and upon which the parties cannot agree then every such dispute, difference or question shall be referred to three arbitrators, one to be appointed by the Seller, one to be appointed by the Purchasers and the two arbitrators so appointed shall appoint the third arbitrator. The arbitrators shall have the power to decide the dispute, difference or question referred to them and their decision or the decision of the majority of them shall be final and binding upon the parties hereto, their executors, administrators, successors and assigns.

11. FORCE MAJEURE

The parties hereto shall not be liable for any loss, damage or delay caused by an Act of God, the Queen's or public enemies, the authority of law, quarantine, riots, strikes, perils of navigation, defect or inherent vice or for conditions beyond their control including war or the anticipated imminence thereof between any nations and in the event of any such occurrence preventing or delaying the performance of this contract, delivery or receipt may be suspended during the continuance of any such event or occurrence and the contract period of delivery be correspondingly extended. Provided that shipments already on the way and vessels already loading or immediately ready to load will still be accepted by the Purchasers if they have been given notice thereof in accordance with the terms hereof by the Seller and if the Seller did not have knowledge of such event or occurrence.

12. OPTIONS

The Purchasers shall have the option to purchase an additional 1 million tons of the product per year from the Seller on the terms and conditions hereinbefore set forth provided the Purchasers shall give to the Seller sufficient advance notice to enable it to make the necessary arrangements for increased production. Provided further, however, that the Purchasers shall notify the Seller in writing prior to the First day of January, 1972, that they exercise such option to take an additional 1 million tons of the product per year for the balance of the term hereof subject to the Seller making the necessary arrangements for increased production and in the event that such notice is not received by the Seller on or before the First day of January, 1972, the said option shall lapse and be of no force or effect.

13. SPECIAL COVENANTS

(a) The Owner covenants to purchase it's requirements of the steel necessary to install its facilities in Canada required as a result of this contract from the Japanese Steel Industry at competitive prices.

(b) The Owner covenants that it will order, as required, ore/oil carriers to be constructed in Japanese shipyards designated by the Purchasers. Provided always that the said carriers may be ordered by the Owner and delivered to the Owner at such time or times as are necessary in order to enable it and the Seller to complete the terms of this contract.

(c) The Owner covenants that when possible, subject to availability and competitive prices, it will purchase from Japanese sources equipment and material required in the installation of the facilities resulting from this contract including steel requirements and ships as hereinbefore specified, machinery, electronic controls and miscellaneous electrical equipment.

14. LICENCES

The Purchasers undertake and guarantee to obtain such licences as may be required by Japan.

15. GUARANTEE

The Owner in consideration of the covenants and commitments herein set forth on behalf of the Purchasers, hereby guarantees the performance of all the covenants and commitments imposed by this contract on the Seller during the term hereof.

16. GOVERNING LAW

This contract shall be governed by the Laws of the Province of Newfoundland, Canada.

17. NOTICES

Any notice required to be given by either party to the other under the terms hereof shall be in writing and may be delivered personally or mailed by registered post in a properly stamped envelope addressed to the party to be notified at the address hereinafter set forth:-

Javelin Export Company Limited	- Address - Box 5273, M.S. Nassau, Bahamas.
Japanese Steel Industry	- Address -
Canadian Javelin Limited	- Address - Javelin House, Water Street, St. John's Newfoundland.

18. SPECIAL CONDITION AS TO SALES

Notwithstanding anything in this contract contained, subject to a further agreement between the parties as to price, the Seller shall not be obliged hereunder to sell and deliver to the Purchasers at any time during the term hereof any number of tons of the pelletized product in excess of the number of tons of soft iron piglets sold and delivered to the Japanese Steel Industry pursuant to the terms of a contract between the Seller, the Owner and the Purchasers of even date.

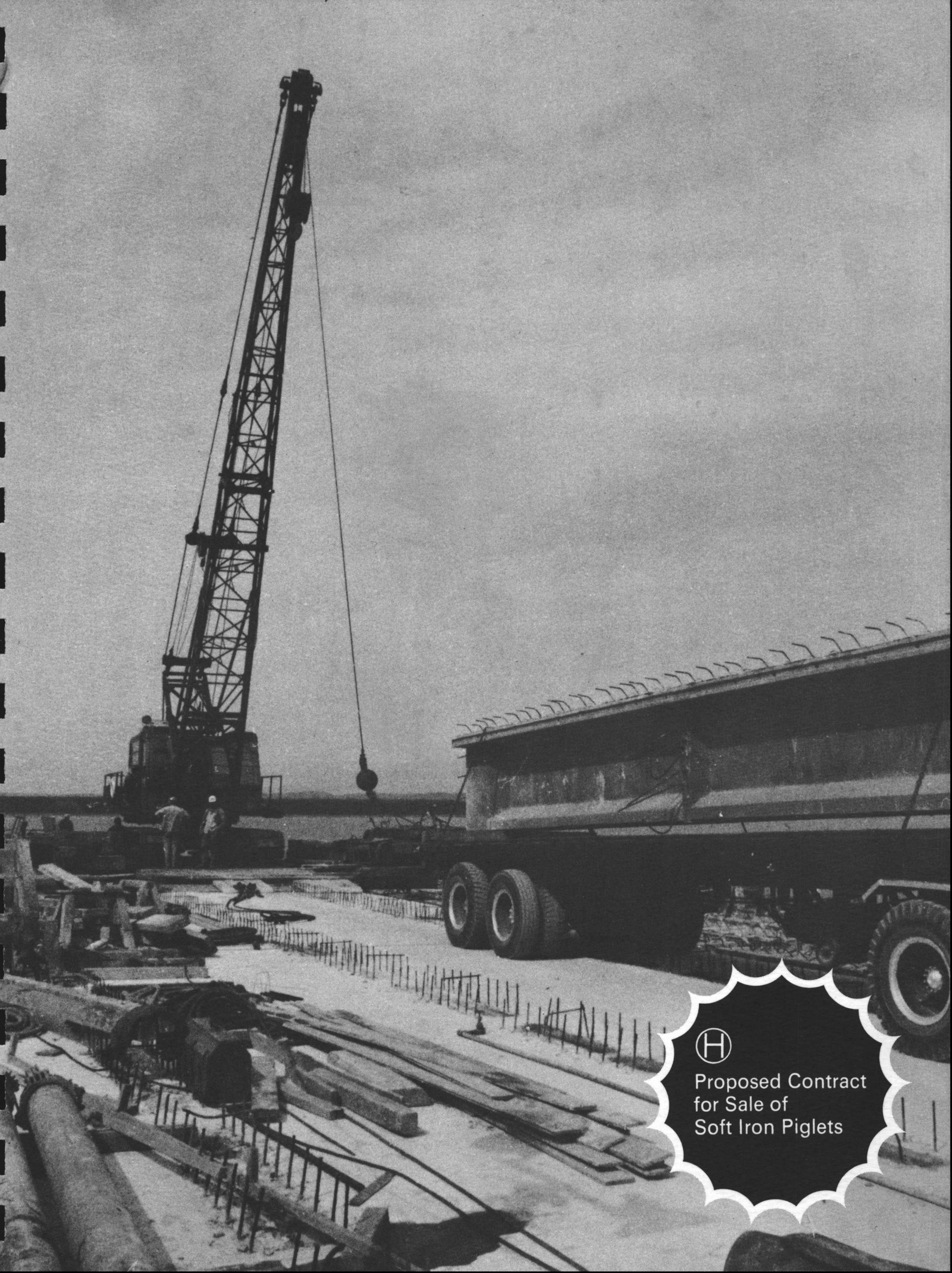
19. CONDITION PRECEDENT

It is agreed between the parties hereto that this contract when executed shall constitute a binding agreement of purchase and sale of the product subject only to the Seller or the Owner completing the necessary credit arrangements to carry out the terms of this contract and they shall have six (6) months from the date of execution hereof to make such credit arrangements and shall notify the Purchasers in writing when the same have been made. Provided always that the Seller or the Owner shall use their best efforts to complete such arrangements as soon as possible and in the event that such notice is not given within six (6) months from the date hereof this contract shall be void and of no force or effect.

20. This agreement shall be binding upon the respective heirs, administrators, successors and assigns of the parties hereto.

IN WITNESS WHEREOF the parties hereto have hereunto affixed their respective corporate seals under the hands of their officers duly authorized in that behalf this day of , 1964.

CANADIAN JAVELIN LIMITED	JAVELIN EXPORT COMPANY LIMITED
per ______________	per ______________
per ______________	per ______________
	(JAPANESE IRON & STEEL PRODUCERS)
	per ______________
	per ______________



Proposed Contract for Sale of Soft Iron Piglets

SCHEDULE "B"

JAVELIN - JAPANESE - SOFT IRON PIGLET SALES CONTRACT

BETWEEN:

JAVELIN EXPORT COMPANY LIMITED, a Corporation incorporated under the Laws of Nassau, in the Bahamas and having an office in Nassau in the Bahamas, hereinafter called "the Seller"

THE PARTY OF THE FIRST PART

- and -

hereinafter called "the Purchasers"

THE PARTY OF THE SECOND PART

- and -

CANADIAN JAVELIN LIMITED, a Corporation incorporated under the Laws of Canada and having its head office in the City of St. John's in the Province of Newfoundland on behalf of itself and acting as Managing Agent and Lessor on behalf of Jubilee Iron Corporation for its iron ore properties, hereinafter called "the Owner".

THE PARTY OF THE THIRD PART

WHEREAS the Seller is the Sales Agent for the Owner who owns iron ore deposits in the said Province of Quebec and in the Province of Newfoundland, Canada.

AND WHEREAS the Purchasers constitute the basic pig iron producers of the steel industry in Japan.

NOW THEREFORE THIS AGREEMENT WITNESSETH That the Seller agrees to sell to the Purchasers and the Purchasers agree to purchase from the Seller soft iron piglets (hereinafter called "the Product") of the specifications, in the quantities, at the price, and subject to the terms, conditions and covenants by the parties hereto hereinafter set forth:-

1. SPECIFICATIONS

(a) Chemical Analysis

Iron (total)	94.00% minimum
Manganese	0.50% maximum
Silica	5.50% maximum
Magnesia + Lime + Alumina	1.00% maximum
Sulfur	0.02% maximum
Phosphorus	0.02% maximum
Other Elements	Traces
Reduction of total iron to metallic iron	95.00% minimum

(b) Physical Characteristics

The product will be shipped as a "soft iron piglet" made from reduced iron pellets. The size and shape of these piglets within the capacity of the forming machinery will be arranged by agreement with the Purchasers to suit end use of the product, but will be such as to allow loading, shipping and discharge using iron ore loading and discharge facilities without penalty for excessive degradation in handling.

(c) Should the quality of the product regarding chemical composition or physical properties not correspond to the above description or should the product not have the properties agreed as to stability and smelting characteristics, the Purchasers are not obliged to pay the contract price but an agreement shall be arrived at on a new price which will be in accordance with the actual quality of the product delivered.

2. SAMPLING AND ANALYSIS

(a) Sampling and analysis shall be effected at the port of discharge by one of the following methods:-

(i) Independent - Seller and Purchasers shall mutually agree upon a representative who shall act for both parties and at the joint expense of both parties;

(ii) Joint - The product shall be sampled by representatives of the Seller and the Purchasers conjointly during the discharge of vessels. Analysis for iron to be exchanged on an agreed date in the usual manner and each party shall pay the cost of his representative. Differences of up to half per cent in iron to be equally divided and in the event the difference in iron exceeds the agreed percentage, reserved sealed samples shall be sent by Seller and Purchasers to a mutually agreed referee chemist whoseanalysis shall be final and binding on the parties hereto. The cost of the referee's analysis shall be borne by the party whose result is least in accord with the result of the referee chemist.

3. SHIPMENTS

(a) The Seller shall ship to the Purchasers the product on the following schedule subject always to a variation of 10% and to such further variations as are normal in an industry of the nature of that carried on by the Seller:-

(i)	1968	1 million tons
(ii)	1969	2 million tons
(iii)	1970-1990	3.10 million tons in each year

(b) Delivery shall be made in approximately equal monthly shipments subject to seasonal adjustments to Japanese ports as named by the Purchasers at least 14 days prior to departure of vessels.

(c) The Seller will advise the Purchasers by cable of the departure of each vessel stating in such cable the quality and quantity loaded and the total price of the shipment F.O.B. port. Vessels shall be consigned to Purchasers' agent at sea port of discharge.

4. LOADING AND UNLOADING

(a) It is agreed that the vessels will be discharged at a rate of 2,000 tons per hour. Provided that it is further agreed as port facilities are improved and the rate of capacity of discharge is increased, the said rate of 2,000 tons per hour will be increased proportionately to the rate of capacity.

(b) Vessels demurrage to be $2,000.00 (U.S.) per day and dispatch to be $500.00 (U.S.) per day.

(c) The Japanese Steel Industry undertakes to use its best efforts to ensure that the Japanese Government shall accord the vessels transporting the product the same treatment as if they were under Japanese registry as to all port and terminal charges. Terminal charges shall, for the purpose of this paragraph, include any charges incurred by the vessels in lightening, in discharging into lighters, barges, etc. as well as any demurrage on any lighters,, barges, etc. and any dockage fees at discharging points. Port charges are normal expenses incurred and include all charges normally incurred by a vessel on arriving at a destination i. e. pilots, tugs, etc.

5. PRICE

(a) The price shall be the Canadian dollar equivalent as at this date of $33.00 U.S. funds per metric ton F.O.B. Lower St. Lawrence ports with a guaranteed freight rate of $5.00 U.S. funds per metric ton for delivery to Japanese sea ports in vessels of 50,000 to 60,000 tons capacity.

(b) The aforementioned price and freight rate shall be subject to the following adjustments:-

(i) Where average iron analysis of a cargo exceeds the guaranteed minimum of 94% a premium shall be added to the Lower St. Lawrence price quoted above and payable in respect to the tonnage in the cargo which shall be calculated on the basis of the Canadian dollar equivalent as at this date of $U.S. 0.40 for each 1% (or part thereof) by which the average iron analysis exceeds 94%

(ii) The F.O.B. price at Lower St. Lawrence ports quoted in (a) and (b) above shall be subject to adjustments for increases or decreases in the cost of production and transportation incurred by the Seller which shall include, but are not limited to, material, wages, supplies, transportation and taxes.

(iii) The vessel freight rate of $U.S. 5.00 per metric ton shall be subject to adjustment for increases and decreases from the date hereof in the cost of operation of vessels including, but not limited to, changes in cost of fuel, wages, taxes, canal tolls, duties, port and terminal charges.

6. PAYMENT

(a) F.A.S. Japan

(b) Purchasers shall pay sea freight upon the arrival of vessels at sea port of discharge.

(c) Purchasers shall pay product value by promissory notes in favor of the Seller at the times and on the terms hereinafter set forth:-

(i) A note shall be issued by the Purchasers within 2 days of receipt of notice by them pursuant to clause 3 (c) hereof with respect to each shipment and such note shall be delivered to the Owner or its nominees as advised in the said notice.

(ii) Each of such notes shall be dated as at the date of departure of the respective shipment from the loading port as advised by the Seller pursuant to clause 3 (c) hereof and shall be in an amount based on the bill of lading weight and in accordance with the invoice relevant to the shipment and shall become due and payable 10 calendar months after date with interest from date at the current Canadian bank interest rate at date.

(iii) Each of such notes shall be payable in U.S. Dollars or Canadian Dollar equivalent.

(iv) Such notes shall be subject to adjustment on account of variations from specifications in weight and quantity 30 days after arrival of the respective shipment at the port of discharge or as may be agreed between the parties hereto.

7. WEIGHING

Weight to be ascertained at port of discharge unless otherwise agreed and the Seller to have the option to appoint a checkweigher and in the event cargoes are not weighed the Purchasers shall make payment based on the bill of lading weight.

8. INSURANCE

Insurance to be effected by the Seller for the account of the Purchasers with premiums at competitive rates to be billed by the Insurer or its agent directly to the Purchasers. Such insurance shall be applicable at the time of completion of loading of each shipment and in the event of loss of cargo the Purchasers undertake to pay the Seller on the basis of the bill of lading weight and invoiced quality.

9. TAX

In the event that any additional duty or tax or increase in any existing duty or tax in the country of destination shall be imposed during the term of this contract resulting in an increase in the cost of the ore to be delivered under the contract, the same shall be paid by the Purchasers.

10. ARBITRATION

(a) Any dispute or difference of opinion between the parties hereto as to the quality of the product under this contract shall be dealt with pursuant to clause 2 of this contract.

(b) If at any time during the continuance of this contract any dispute, difference or question arises between the parties hereto with reference to this contract, other than with reference to the quality of this product, and upon which the parties cannot agree then every such dispute, difference or question shall be referred to three arbitrators, one to be appointed by the Seller, one to be appointed by the Purchasers and the two arbitrators so appointed shall appoint the third arbitrator. The arbitrators shall have the power to decide the dispute, difference or question referred to them and their decision or the decision of the majority of them shall be final and binding upon the parties hereto, their executors, administrators, successors and assigns.

11. FORCE MAJEURE

The parties hereto shall not be liable for any loss, damage or delay caused by an Act of God, the Queen's or public enemies, the authority of law, quarantine, riots, strikes, perils of navigation, defect or inherent vice or for conditions beyond their control including war or the anticipated imminence thereof between any nations and in the event of any such occurrence preventing or delaying the performance of this contract, delivery or receipt may be suspended during the continuance of any such event or occurrence and the contract period of delivery be correspondingly extended. Provided that shipment already on the way and vessels already loading or immediately ready to load will still be accepted by the Purchasers if they have been given notice thereof in accordance with the terms hereof by the Seller and if the Seller did not have knowledge of such event or occurrence.

12. OPTIONS

The Purchasers shall have the option to purchase an additional 1 million tons of the product per year from the Seller on the terms and conditions hereinbefore set forth provided the Purchasers shall give to the Seller sufficient advance notice to enable it to make the necessary arrangements for increased production. Provided further, however, that the Purchasers shall notify the Seller in writing prior to the First day of January, 1972, that they exercise such option to take an additional 1 million tons of the product per year for the balance of the term hereof subject to the Seller making the necessary arrangements for increased production and in the event that such notice is not received by the Seller on or before the First day of January, 1972, the said option shall lapse and be of no force or effect.

13. SPECIAL COVENANTS

(a) The Owner covenants to purchase its requirements of the steel necessary to install its facilities in Canada required as a result of this contract from the Japanese Steel Industry at competitive prices.

(b) The Owner covenants that it will order, as required, ore/oil carriers to be constructed in Japanese shipyards designated by the Purchasers. Provided always that the said carriers may be ordered by the Owner and delivered to the Owner at such time or times as are necessary in order to enable it and the Seller to complete the terms of this contract.

(c) The Owner covenants that when possible, subject to availability and competitive prices, it will purchase from Japanese sources equipment and material required in the installation of the facilities resulting from this contract including steel requirements and ships as hereinbefore specified, electronic controls and miscellaneous electrical equipment.

14. LICENCES

The Purchasers undertake and guarantee to obtain such licences as may be required by Japan.

15. GUARANTEE

The Owner, in consideration of the covenants and commitments herein set forth on behalf of the Purchasers, hereby guarantees the performance of all the covenants and commitments imposed by this contract on the Seller during the term hereof.

16. GOVERNING LAW

This contract shall be governed by the Laws of the Province of Newfoundland, Canada.

17. NOTICES

Any notice required to be given by either party to the other under the terms hereof shall be in writing and may be delivered personally or mailed by registered post in a properly stamped envelope addressed to the party to be notified at the address hereinafter set forth:-

Javelin Export Company Limited - Address -

Box 5273, M.S.
Nassau,
Bahamas.

Japanese Steel Industry - Address -

Canadian Javelin Limited - Address -
Javelin House,
Water Street,
St. John's,
Newfoundland.

18. SPECIAL CONDITION AS TO SALES

Notwithstanding anything in this contract contained, subject to a further agreement between the parties as to price, the Seller shall not be obliged hereunder to sell and deliver to the Purchasers at any time during the term hereof any number of tons of the soft iron piglets less than the number of tons of iron ore pellets sold and delivered to the Japanese Steel Industry pursuant to the terms of a contract between the Seller, the Owner and the Purchasers of even date. Delivery of each product will be made in approximately equal monthly installments as provided in Section 3 of the aforesaid contracts.

19. CONDITION PRECEDENT

It is agreed between the parties hereto that this contract when executed shall constitute a binding agreement of purchase and sale of the product subject only to the Seller or the Owner completing the necessary credit arrangements to carry out the terms of this contract and they shall have six (6) months from the date of execution hereof to make such credit arrangements and shall notify the Purchasers in writing when the same have been made. Provided always that the Seller or the Owner shall use their best efforts to complete such arrangements as soon as possible and in the event that such notice is not given within six (6) months from the date hereof this contract shall be void and of no force or effect.

20. This agreement shall be binding upon the respective heirs, administrators, successors and assigns of the parties hereto.

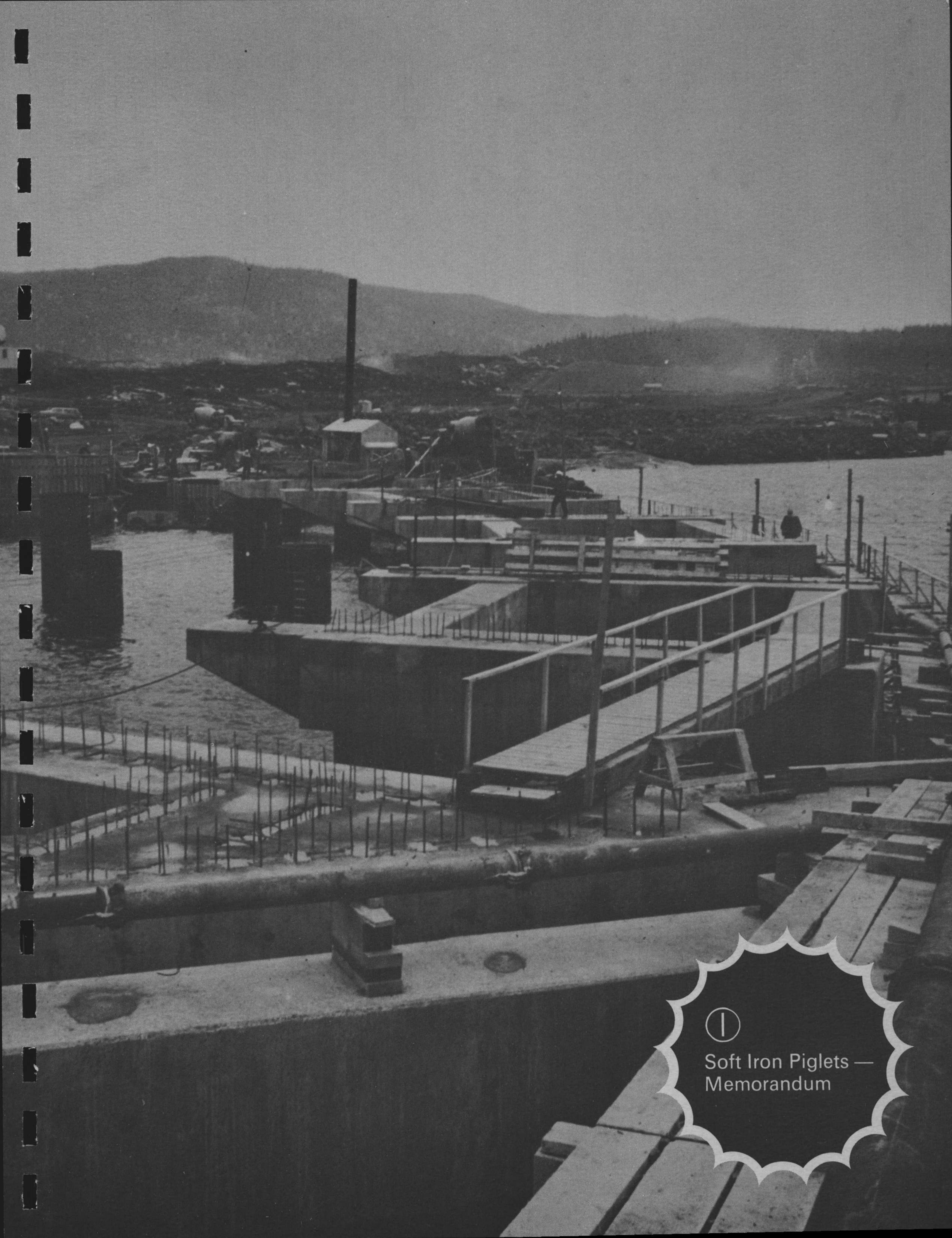
IN WITNESS WHEREOF the parties hereto have hereunto affixed their respective corporate seals under the hands of their officers duly authorized in that behalf this day of , 1964.

CANADIAN JAVELIN LIMITED	JAVELIN EXPORT COMPANY LTD.
per ____________________	per ____________________
per ____________________	per ____________________

(JAPANESE PIG IRON PRODUCERS)

per ____________________

per ____________________



1 Soft Iron Piglets — Memorandum

SCHEDULE "C"

MEMORANDUM

re

SOFT IRON PIGLETS

CANADIAN JAVELIN LIMITED

December 1963

Memorandum

re

Soft Iron Piglets

This memorandum outlines Canadian Javelin's proposal for commercial production of a high quality metallic iron melting stock for use in iron and steel making processes in the form of "Soft Iron Piglets."

1. Raw Material

Canadian Javelin has available some 300,000,000 tons of high grade iron ore concentrate from its Julian and Jubilee orebodies in Labrador and New Quebec. These properties can be developed to produce 7,500,000 tons of this concentrate annually for further processing to produce premium quality iron ore pellets and/or a high quality metallic iron melting stock using a suitable direct reduction process.

For production of Soft Iron Piglets from these concentrates Javelin proposes to use a direct reduction process. Following a careful study of available direct reduction processes Canadian Javelin considers the Stelco Lurgi process one of the suitable methods presently available for commercial production of a metallic iron melting stock from its concentrates. Although this memorandum is based on the use of this process Canadian Javelin reserves the right to use any economically feasible direct reduction process for the production of the reduced iron melting stock used to produce soft iron piglets of the chemical and physical characteristics outlined in this memorandum.

Technical details of the Stelco Lurgi process are presented in paragraph 5 of this memorandum. The reduced iron ore pellets from this process would be compressed into Soft Iron Piglets having a physical characteristics and shape which would allow the product to be shipped in ore carriers using iron ore bulk loading and discharge facilities.

2. Quantity

Allocation of Canadian Javelin's concentrate production, between production of soft iron piglets and iron ore pellets, will be made on the basis of sales commitments for these products. Processing of all of the projected annual production of 7,500,000 tons of concentrate for compressed iron melting stock would result in production of some 5,000,000 tons annually of this product for a period of forty years.

3. Quality

Canadian Javelin proposes to offer these Soft Iron Piglets for sale under the following quality guarantees

(a) Chemical Analysis:

Iron (total)	94% minimum
Manganese	0.5% maximum
Silica	5.5% maximum
Magnesia + Lime + Alumina	1.0% maximum
Sulfur	0.02% maximum
Phosphorus	0.02% maximum

Other Elements	Traces only
Reduction of total iron to metallic iron	95% minimum

(b) Physical Characteristics and Shape:

The reduced iron will be shipped in compressed form as a "soft iron piglet" made from reduced iron pellets. The size and shape of these piglets will be arranged by agreement with the purchaser to suit the end use of the melting stock and will be such as to allow loading, shipping and discharge facilities.

(c) Density and Compressive Strength:

To be arranged by agreement with the purchaser to suit end use of the Soft Iron Piglet and the requirements of loading, shipping and discharge without excessive degradation.

(d) Melting Characteristics:

The Soft Iron Piglets will have melting characteristics equivalent to or better than those of high grade steel scrap

'e) Product Standards and Tests:

"Soft Iron Piglets" are an advanced raw material for the iron and steel industry. Commercial standard and testing methods for the product have not been developed. Canadian Javelin will, with the cooperation of purchasers of its products, undertake to develop commercial standards and testing methods which will ensure the uniformity and high quality of its shipments.

4. Price and Delivery

Canadian Javelin would propose a stable price related to the price of good quality scrap for Soft Iron Piglets purchased under long term sales agreements. These long term sales agreements would also provide for periodical review and escalation upwards or downwards of the delivered price, based on fluctuations in cost of labor, fuel supplies, shipping and taxes.

Delivery schedules and details of pricing would be specified in sales contracts.

5. <u>The Stelco Lurgi Direct Reduction Process</u>

The Stelco Lurgi process was developed as a joint venture of the Steel Company of Canada and "Lurgi" of Frankfurt, Germany. It is available to Canadian Javelin for processing of its Julian and Jubilee ores under licence from the Stelco Lurgi group.

The details of the process and its development are covered in two technical reports attached to this memorandum as:

Appendix I — The SL Direct Reduction Process
D. J. Hains November, 1963.

Appendix II — Development of the SL Direct Reduction Process
J. G. Sibakin May 23, 1962.

The SL Direct Reduction Process, though applicable to most high quality iron ores, was developed specifically for processing of high purity iron ore concentrate from Canadian Javelin's Labrador properties. Development of the process was undertaken to meet the anticipated requirements of the Steel Company of Canada for an alternate method to blast furnace smelting for commercial processing of the large quantities of high purity iron ore concentrate it will have available, starting in late 1964, through its participation in the Wabush Mines development of Canadian Javelin's Wabush Lake orebody.

The concentrate from the Julian and Jubilee orebodies which Javelin proposes to use for production of Soft Iron Piglets is essentially the same as the Wabush concentrate and is therefore a preferred raw material feed for commercial Stelco Lurgi direct reduction plants.

A very recent development is the successful use of "green iron ore pellets" as feed for the SL reduction process. Continuous pilot plant runs have been completed in the Lurgi test plant and plans are now under way for larger scale tests.

The initial results from tests using this green pellet feed leave no doubt that both the Hamilton semi-commercial plant and later commercial installation will use green iron ore pellets as a process feed material. This development eliminates separate pellet induration equipment and will materially reduce capital expenditures and operating costs in commercial production plants.

Reports covering this new development are not yet available and will be presented in a later memorandum.

The results of commercial scale tests of SL reduced iron as a charge material for iron and steel making have been uniformly favorable. Details of some of these tests are in the reports attached to this memorandum.

APPENDIX I

To Memorandum Re

SOFT IRON PIGLETS

THE SL DIRECT REDUCTION PROCESS

by

D. J. HAINS

November 1963

December 1963

PRINTED IN CANADA

THE SL DIRECT REDUCTION PROCESS

by

D. J. HAINS

November, 1963.

THE SL DIRECT REDUCTION PROCESS

by

D. J. HAINS, President
HAINS ENGINEERING COMPANY LIMITED
Toronto, Ontario, Canada

I. Synopsis of Process

1. The SL Direct Reduction Process is the result of the co-operative efforts of The Steel Company of Canada Limited, Hamilton, Ontario, Canada, and the LURGI Gesellschaft fuer Chemie und Huettenwesen m. b. H., Frankfurt/Main, Germany. The "SL" trade name is derived from the first letters of the STELCO and LURGI trade names.

2. The process can use high-grade iron ores or iron concentrates which have been agglomerated into the form of pellets. The iron ore or the pellets are fed into a rotary kiln along with coal and dolomite. The coal is used as a reductant and as a source of supplemental heat. The dolomite serves as an interface and absorbs sulphur which may be driven off from the coal or the iron-bearing materials.

3. Due to the mechanical construction features of the SL kiln very high reaction temperatures are possible without fusion of the materials within the kiln. One of the features of the SL kiln is mantle burners. The burners are supplied with air and gas and the total mix is combusted in the kiln. The burners act as a source of heat and in addition enable the control of the temperature and the composition of the gas atmosphere within the kiln. The control so exercised is accurate and temperature profiles of plus or minus a few degrees centigrade are attainable over long periods of time. The reduced iron, commonly referred to as sponge iron, is discharged via a gastight chute from the reducing kiln into a rotary cooler where the sponge, unburnt char and dolomite are cooled and discharged via an airtight seal to a conveying system. The discharged product generally has a temperature of 65° C and is non-pyrophoric. By means of screening and dry magnetic separation, the non-magnetic products are separated from the magnetic products, namely sponge iron. The non-magnetic products can be further separated to recover the char and this char returned to the system.

II. Process History and Application

4. In 1958, The Steel Company of Canada Ltd. commenced a programme of investigating direct reduction processes and based on their survey of existing processes came to the conclusion that there were serious technical and economic shortcomings in the available processes. At this time, they contacted the LURGI Companies and it was determined that mutual interests existed. An agreement was entered into and trials commenced in the autumn of 1959, using the Lurgi pilot plant kiln in Frankfurt. The successful results of these preliminary tests warranted the building of a semi-industrial unit in Hamilton, Ontario, Canada, which started operation in the spring of 1961. The recent average production rate is approximately 100 net tons sponge per day.

5. The SL-sponge iron product produced since 1961 has been used:

a. in pilot blast furnace tests;
b. for electric furnace steel making;
c. as a coolant for oxygen steel making;
d. for cupola melting tests;
e. as a precipitant for copper solutions.

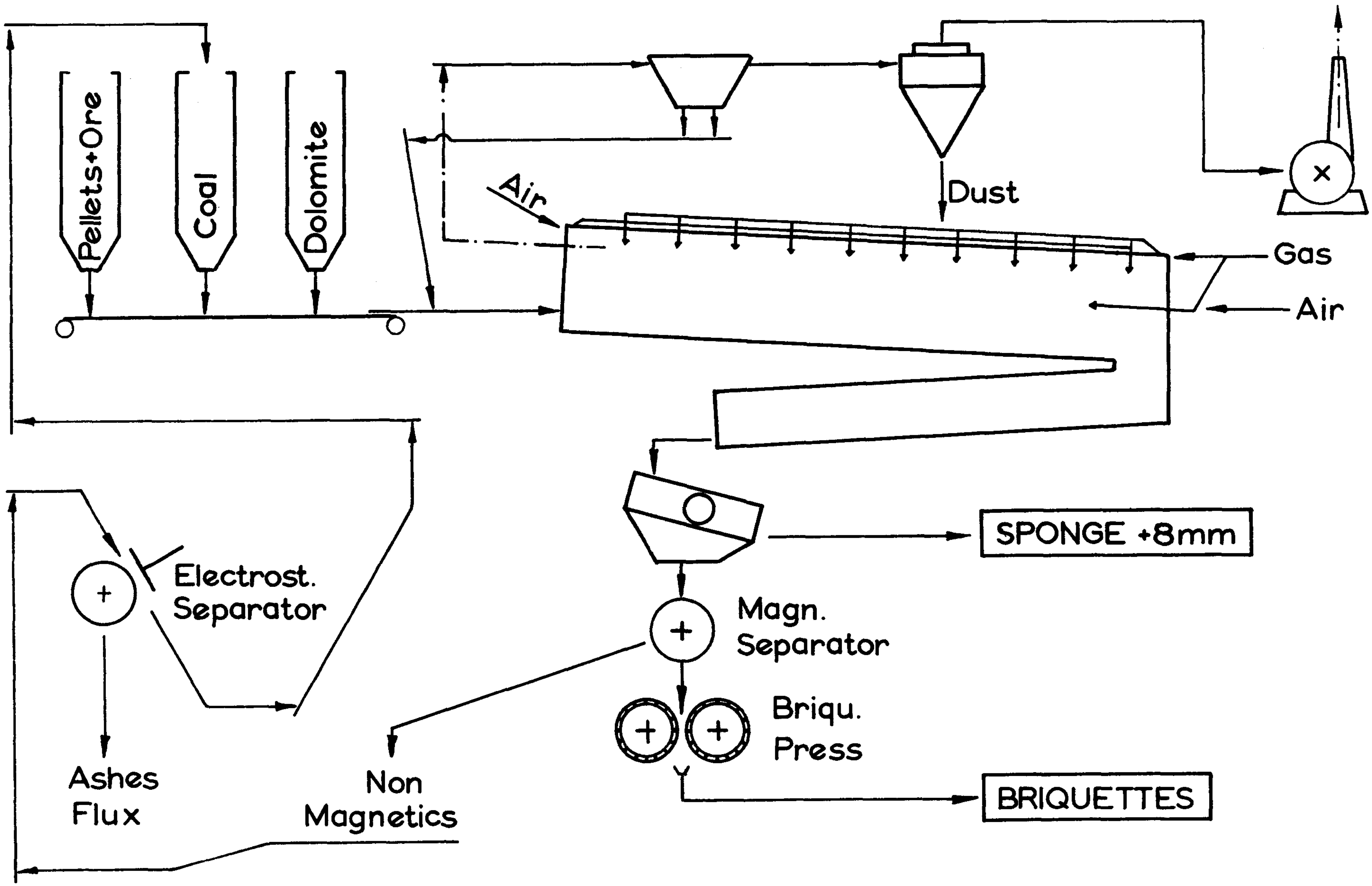
III. Raw Materials and their Preparation

6. Iron Ore

In the LURGI pilot plant in Frankfurt Brazilian ore and Venezuelan ore has been crushed and screened so that the $+\frac{1}{4}$" - $1\frac{1}{2}$" material was fed directly to the kiln. At the Steel Company of Canada in Hamilton the basic material, which has been used, is a magnetite ore which is crushed, ground and concentrated so that the concentrates contain approximately 66-68% Fe as Fe_3O_4. These concentrates are pelletized and indurated at the mine and the hardened pellets are transported to Hamilton for charging into the kiln. These pellets are screened to reject the $-\frac{1}{4}$"and +5/8". The quantity which has been rejected as over- and undersize has been very small, indicating good control of the pellet size at the mine.

7. Coal

The coal can vary from anthracite to lignite and should have non-coking characteristics. A desirable feature is to have the softening temperature of the ash of the coal as high as possible. The coal is usually crushed to -6.68 millimeters, the dolomite or limestone is usually crushed to -3.327 millimeters. These raw materials



SL-PROCESS

FIG. 1

are received and placed in storage bins and are discharged from the storage bins by means of weigh feeders which are programmed and can be individually adjusted from a remotely situated central control panel. The weighing devices are fully integrated so that the total weight and ratio of pellets to coal to dolomite is kept.

IV. Process Equipment

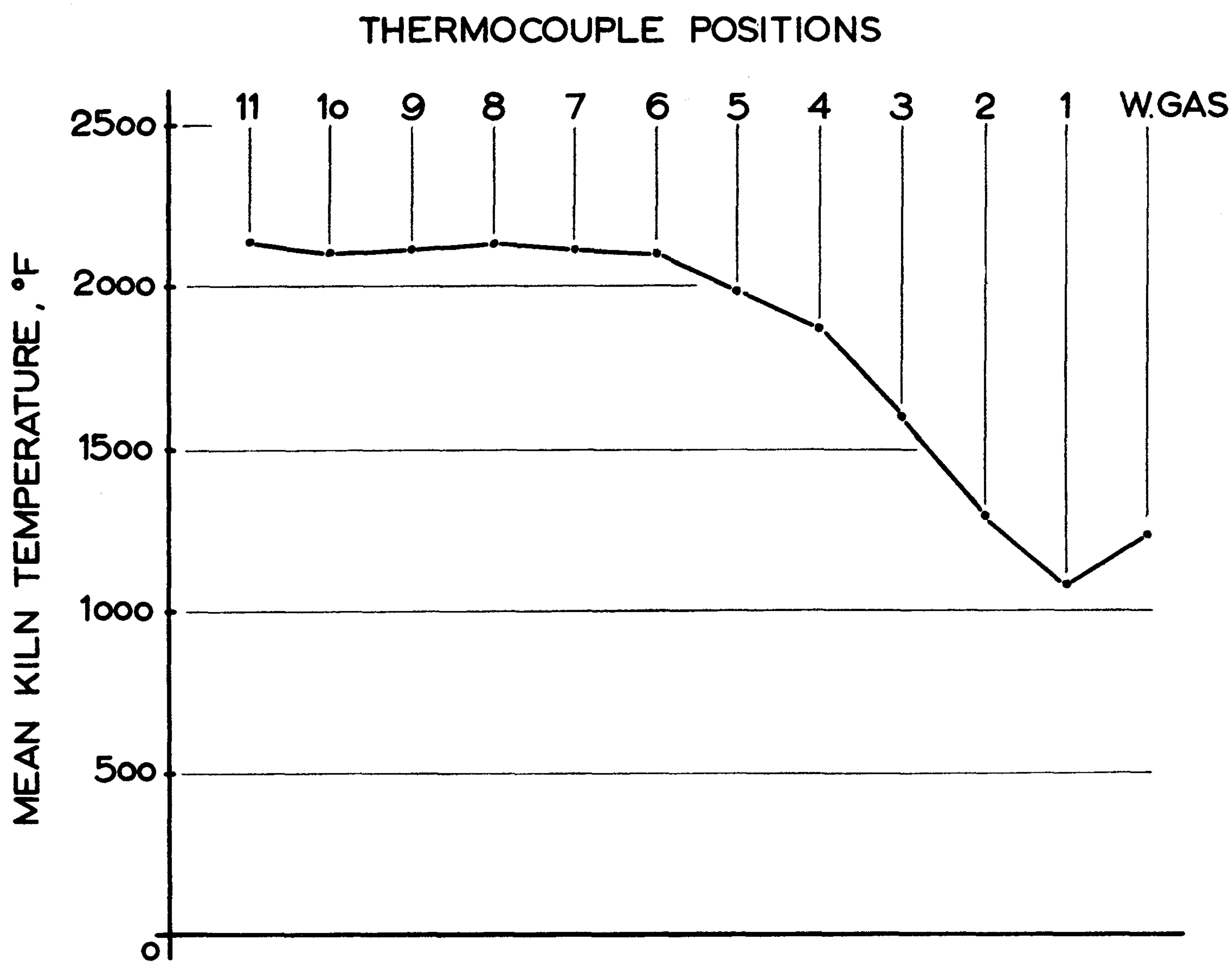
8. The following description of the SL Process equipment is based on the Hamilton plant of the Steel Company of Canada. The LURGI Companies in Frankfurt/Main, Germany, were responsible for the design and supply of the process equipment. To minimize personnel, the plant was fully instrumented and practically all of the operations automated and controlled remotely from a single control center. In addition to being highly automated, the plant was designed to provide the maximum of process data.

9. The plant has been described by Mr. J.G. Sibakin in his paper entitled: "Development of the SL Direct Reduction Process", however, it is worth-while to again describe the equipment (a). The plant consists of four sections: raw material handling system, main kiln, rotary cooler and finished products handling system. A schematic layout of the plant may be seen in Fig. 1.

10. The raw materials consisting of pellets, dolomite and coal, are brought to the plant by rail and truck and are conveyed to their respective storage bins. Pellets and dolomite are screened to remove the oversized and undersized particles prior to their entering the bins. From the storage bins, the materials are fed continuously, by means of weighing feeders, in the desired portions onto a common collecting conveyor. The materials then pass through a rotary gate-feeding mechanism, which prevents escape of the kiln gases, down a feed spout into the kiln.

11. The kiln, excluding the two stationary heads, is 115 feet long, has an internal diameter of about $7\frac{1}{2}$ feet and can be rotated at a constant speed over a wide range of speeds. It is lined with a double course of refractory bricks, making a lining thickness of about $8\frac{1}{2}$ inches.

12. Ten burners are mounted on the shell of the kiln. The burners are evenly spaced with each offset in succession from the next by 72 degrees. The air and gas for the burners enter separate manifolds from opposite ends of the kiln. The transfer of gas and air from the stationery kiln heads to the rotating manifolds is accomplished through circular cavities enclosed by inner and outer



TEMPERATURE PROFILE (TEST 1-140 HB, APRIL 30/62) FIG. 2

labyrinth seals. The bearing surfaces of the seals are lubricated with a suitable grease having a drop point of 350°F. One axial burner is located at the discharge end of the kiln.

13. The materials gradually move through the hot kiln, until they are discharged and drop through a bricklined transfer chute onto a stone box which diverts them into the cooler. At this point, the materials are at a temperature of about 1090°C, but soon cool to about 65°C during passage through the rotary cooler.

14. The rotary cooler is mounted below the main kiln. It is 65½ feet long, has an outside diameter of 5 feet and can be rotated at a constant speed over a wide speed range. Only the first 28 feet of this cooler are refractory lined. Water sprays are directed against the outer shell surface along the unlined length. The atmosphere of the rotary cooler consists essentially of gases from the main kiln and prevent reoxidation of the reduced iron.

15. Both the main kiln and rotary cooler slope at an angle of about 2 degrees from the horizontal.

16. The materials discharge from the rotary cooler via another gate mechanism and are conveyed to the product bins. The materials are separated by means of a screen and two drum magnetic separators into three products: coarse sponge iron (plus 3/16 inches), fine sponge iron (minus 3/16 inches) and non-magnetic mixture of calcined dolomite and coal char.

17. The gases generated in the process flow counter-current to the stationary charging head and into two multiclone dust collectors. The relatively dust-free gases are then discharged through a short stack. The pressure of the gas in the kiln is regulated by means of adjustable louvres and an exhaust fan. Plants for the production of 700 and 1000 tons of sponge per day are presently being designed.

V. Operation

18. In all endothermic chemical reaction it is advantageous to have the reaction temperature as high as possible to obtain the maximum results. The controlling temperature in the SL Process is the lowest softening temperature of the various materials of the charge used. As a general practice the gas volume is kept constant and the air admission at each burner is varied to accommodate the materials in process and the temperature profile. The exit gases are analyzed continuously and generally contain less than 1.0% total combustibles (hydrogen + carbon monoxide).

19. During the past two years of operation there has been no ringing in the kiln which is indicative of the excellent temperature control available. A typical temperature profile of a 140 net ton test is indicated in Fig. 2.

20. Typical data for recent production runs are indicated in Appendix I.

VI. Utilization of SL Sponge

21. Test results from the United States Bureau of Mines Experimental Blast Furnace at Bruceton, Pa., indicate that substantial increases in blast furnace productivity and much lower coke rates can be obtained by the use of prereduced pellets. A maximum decrease in coke rate of 44% and an increase in production rate of 55% were obtained by increasing the average iron content of the burden from 66.19% to 86.49% Fe by removal of 95% of the oxygen in the iron minerals (b).

22. The sponge iron product has been used in several different electric arc furnace steel making operations, making both normal carbon steel and low and high alloy steels.

23. In one steel plant all the electric furnace test heats were cast through the continuous casting process. This process requires a ladle temperature of about 1660° C for most grades of steel, which is about 50° C above normal ingot pouring temperatures. The power consumption for these tests was therefore about 50-100 KWH/ton above most other electric furnace operating results due to the additional thermal requirements of the steel for continuous casting application.

24. From the melting of 325 tons of SL pellets and 40 tons of SL briquettes in a 4700 K.V.A. furnace with up to 80 per cent of the charged material consisting of SL sponge iron, the following conclusions were made:

a. SL sponge iron significantly improves the electric furnace production of medium carbon steels through the acquisition of better control over the meltdown analysis of the steel. A decrease of up to 20 per cent in the finishing time for test heat may be realized using SL pellets.

b. The number of charges required to reach the furnace melting capacity are decreased 50 per cent with the increase in charge density provided by SL pellets. This provides a decrease of up to 11 per cent in total power consumption and an increase of about 10 per cent in the production rate.

c. The regular replacement of 30 to 50 per cent of the scrap by SL iron in the electric furnace is technically feasible and will improve operations over the long run.

d. It is estimated that a productivity increase of up to 40 per cent and power saving of up to 20 per cent over normal practice, may result from an efficient continuous charging operation utilizing SL pellets.

25. Electric furnace data from another plant test run on SL sponge pellets and sponge briquettes are shown in Appendix II and indicate favourable comparisons with scrap.

26. If the SL plant is in close proximity to the electric furnace, then sponge pellets may be considered. If a long storage life is required, then the SL pellets should be briquetted.

27. SL sponge has been used in a small-scale electric induction furnace with excellent results and further work in this direction is suggested.

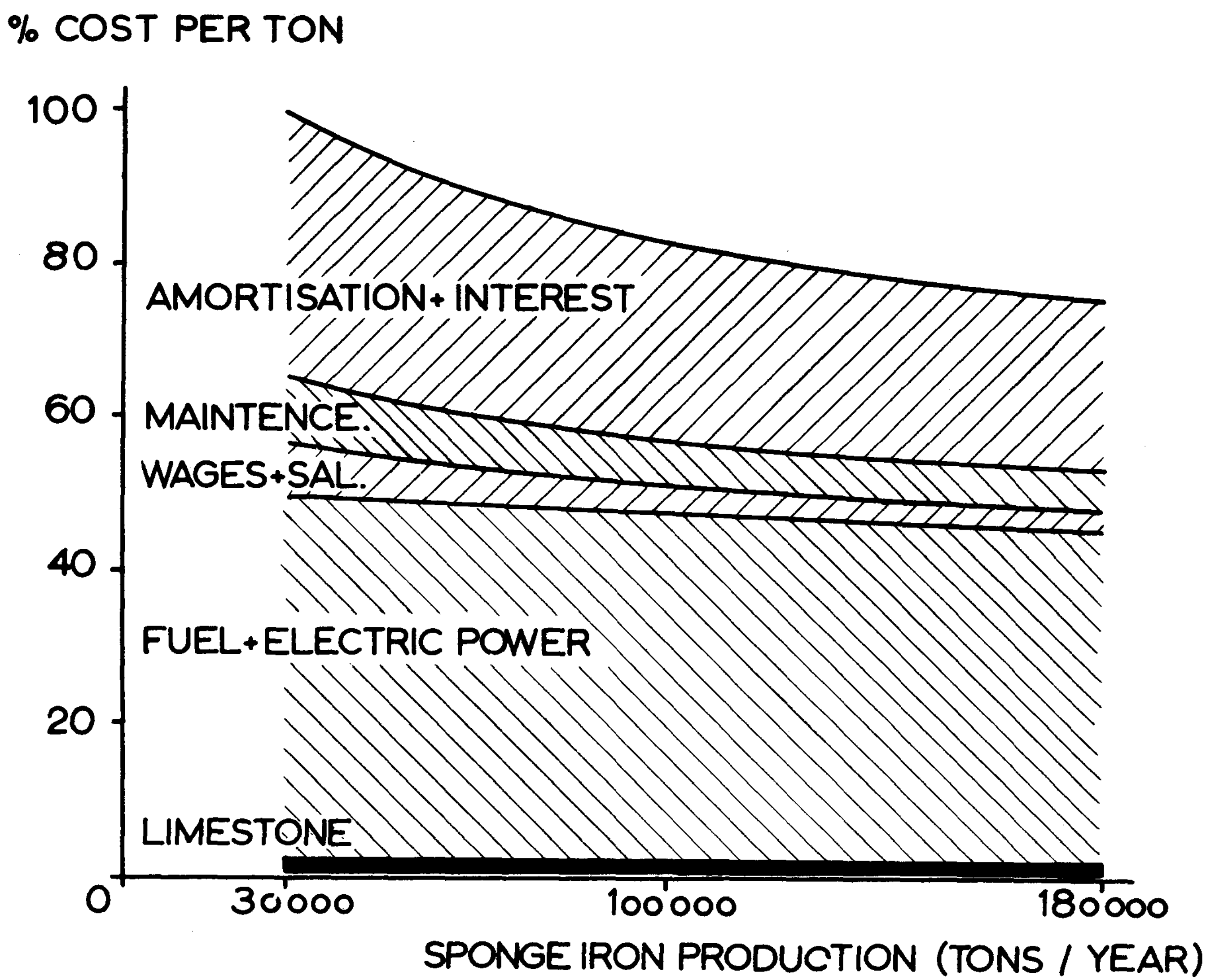
28. Large-scale tests have been conducted in Hamilton on the use of SL sponge iron pellets as a scrap substitute in the LD steel making operation. It is contemplated under certain conditions to replace scrap with its wide range of composition and price with a material of known composition at a relatively fixed price. It is also considered that SL sponge pellets or briquettes can be handled easier than scrap through the existing flux handling system and charged by gravity to the LD vessel.

29. In the tests, up to 15% pellets as scrap substitute have been charged after ignition without difficulty.

30. Total pellet additions of up to 20% gave smooth operation during the blowing cycle.

31. The pellets gave better cooling control and are slightly more efficient than regular scrap.

32. Based on the satisfactory performance of the pellets future tests will be designed for faster and more continuous SL sponge additions, particularly for additions after ignition. The operating personnel anticipate trials using SL sponge as a complete



OPERATING COSTS FOR SL-SPONGE IRON PRODUCTION

FIG. 3

substitute for scrap.

33. A partial summary of some of the test data is shown in Appendix III.

VII. Investment Costs

34. Assuming the pellets are available and delivered to the reduction plant along with the necessary coal and dolomite or limestone, then the investment costs for receiving these materials, the process equipment and separating the magnetics from the non-magnetics, including the briquetting of the magnetics to assure their long storage life, will vary between $25,00 and $12.00 per annual ton of capacity depending on the size of plant.

VIII. Operating Costs

35. The operating costs are best illustrated in Fig. 3 as a percentage of the total cost per ton of sponge.

IX. Economic Developments

36. In highly industrialized areas the SL Process can produce sponge iron with known characteristics and chemical analyses, suitable for electric furnace melting to make the highest quality alloy steels.

37. In certain areas of industrial countries, where scrap commands a high price, due to transportation distances, local iron deposits can be worked economically to produce a substitute iron melting stock. In industrial areas where an increase in pig iron production is required, the use of partially reduced pellets will permit higher rates of production without additional blast furnaces or an increase in the number of coke ovens. The use of partially reduced pellets in blast furnaces will be the next step of beneficiation of the blast furnace burden, after the production possibilities of indurated pellets or self-fluxing sinter have been exhausted.

38. In non-industrial countries, the SL Process will permit the production of steel without the capital requirements of coke ovens and blast furnaces. The SL Process will also permit the use of local non-coking coals of various ranks.

39. From a capital cost point of view where new iron or steel production plants are being considered, or where existing iron production must be increased, the SL Process is highly competitive and worthy of closest examination by potential and current steel producers.

References

(a) SIBAKIN, J. G. Development of the SL Direct Reduction Process Preprint, General Meeting, The American Iron and Steel Institute, New York, May 23, 1962, 42 pp.

(b) MELCHER, N. B. Smelting Prereduced Pellets in an Experimental Blast Furnace, Twenty-fourth Annual Mining Symposium, University of Minnesota and Annual Meeting of Minnesota Section, AIME 1963, pp. 47-51

APPENDIX I. SL DIRECT REDUCTION TEST DATA

TRIAL	1-140 HB
DATE	Apr. 30/62
TIME-START	9: 00 pm
END	9: 00 am

CHARGING RATES N. T. / DAY

Hilton Pellets		139.1
Anthracite		69.9
Dolomite		3.6

PERFORMANCE

Kiln Speed r.p.m.		0.40
% Metallization		95.69
% Reduction		97.09
Carbon Charged lb/N.T.H.		723.7
Carbon Discharged lb/N.T.H.		381.1
Carbon Consumed lb/N.T.H.		342.6
Temperature Profile	11	2131
(°F by Thermocouple no.)	10	2103
	9	2120
	8	2133
	7	2110
	6	2103
	5	1989
	4	1884
	3	1599
	2	1297
	1	1074
	Waste Gas	1231
Heat Consumption, 10^6 BTU/NTH		8.488

APPENDIX II. MELTING TESTS

SL PELLETS AND BRIQUETTES

CHARGE MATERIALS (Pounds)	Control 4-23-62	SL - 6 4-24-62	Control C 3925	SL C 3926
Mill Ends - Crops	2 000	2 000	2 000	1 000
R.R. Wheels (3.5%C)	2 100	3 500	2 100	2 800
Railroad #1	5 000	10 000	5 000	--
Auto	27 400	10 600	28 900	3 500
Bundles	9 000	3 400	7 500	--
SL Pellets	--	16 820	--	--
SL Briquettes	--	--	--	38 700
% SL	--	36.4	--	84.1
Total Scrap	45 500	46 320	45 500	46 000
Burnt Lime	500	500	--	--
Carbon	--	--	--	--
Ore	300	300	--	--
Limestone	--	--	1 500	1 000
FEED MATERIALS				
Ore	600	--	--	--
Burnt Lime	650	450	400	400
Limestone	500	400	200	--
All Other (incl. Alloys)	333	370	474	556
POWER				
TOTAL KWH				
To Melt Total Charge	9 200	9 300	9 200	9 200
Power on to Tap	10 900	10 600	11 400	11 500
KWH per Ton				
To Melt Total Charge	450	450	442	459
Power on to Tap	533	513	548	574
TIMES-ACTUAL				
Charge to all melted	$1^h 52^m$	$2^h 13^m$	$1^h 57^m$	$1^h 53^m$
Charge to Tap	$3^h 12^m$	$3^h 04^m$	$3^h 00^m$	$3^h 02^m$
Tap to Tap	$3^h 38^m$	$3^h 26^m$	$3^h 20^m$	$3^h 26^m$

APPENDIX II. MELTING TESTS

SL PELLETS AND BRIQUETTES

	Control 4-23-62	SL-6 4-24-62	Control C 3925	SL C 3926
TIMES-NET (Less Delays)				
Charge to all melted	$1^h 47^m$	$2^h 13^m$	$1^h 54^m$	$1^h 53^m$
Charge to Tap	$3^h 01^m$	$3^h 04^m$	$2^h 57^m$	$3^h 02^m$
NET TIME POWER TO FURNACE				
Power on to all melted	$1^h 36^m$	$2^h 00^m$	$1^h 52^m$	$1^h 51^m$
Power on to Tap	$2^h 57^m$	$2^h 35^m$	$2^h 55^m$	$3^h 00^m$
GOOD INGOTS PRODUCED (TONS)	20.42	20.65	20.82	20.03
CHEMISTRY -STEEL %				
C	0.31	0.31	0.30	0.16
Mn	0.58	0.56	0.58	0.50
P	0.019	0.030	0.015	0.009
S	0.038	0.030	0.038	0.033
Si	0.13	0.12	0.10	0.09
Cu	0.39	0.23	0.32	0.09
METALLIC YIELD				
Total Charge (T)	22.75	23.16	22.75	23.00
Yield (%)	90.0	89.5	91.5	87.1%
Yield % @ 86.8%* SL	-		-	97.9%
@ 93 % SL	90.0	91.5	91.5	92.5%

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* 86.8% metallic Fe

APPENDIX III.

STEELMAKING DATA FROM HEATS USING SL PELLETS

Heat No.	66 204	66 306	66 340
Total charge pounds	239 500	276 800	257 000
Weight SL	24 000	41 000	48 000
SL % of charge	10	15	20
Added with scrap	10	-	5
After ignition	-	15	15
Scrap weight	40 800	30 000	20 800
% scrap	17	10.8	8.1
Total coolant	62 400	68 000	63 000
% coolant	26	24.5	24.5
Hot metal weight	177 100	209 900	193 000
% hot metal	74	75.7	75.2
Fce operation sparking	Nil	Nil	Nil
Slag	Fluid	Fluid	Fluid

APPENDIX II

to Memorandum re

SOFT IRON PIGLETS

DEVELOPMENT OF THE SL DIRECT REDUCTION PROCESS

by

J. G. SIBAKIN

May 23, 1962

December 1963

Prepared for presentation at the General Meeting of American Iron and Steel Institute, at New York, May 23, 1962

DEVELOPMENT OF THE SL DIRECT REDUCTION PROCESS

By

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The Steel Company of Canada, Limited
Hamilton, Ontario, Canada

Synopsis

Direct reduction tests carried out in three experimental rotary kilns are reviewed. The results of the tests led to the development of the SL process.

Low heat consumption achieved in the SL process depends upon the ability to make maximum use of the available kiln volume and to maintain the combustible gas and sensible heat content of the waste gas at a low level. A certain amount of carbon must be discharged with the sponge iron so that it is highly reduced. Recirculation of the discharged carbon is feasible. The sulphur content of the sponge iron is controlled by the use of a flux and by the employment of sized ore. Very high reaction temperatures are employed without fusion of the materials within the kiln.

Economic commercial production of sponge iron as melting stock for steelmaking is indicated.

Introduction

In many parts of the world, intensive metallurgical research has for years been directed towards developing an economic process for converting iron ore, without an intervening melting step, directly into metallic iron. As a result, several hundred processes have been proposed, but from the outset most of them were either unworkable or too costly to be seriously considered by industry. Some of the more promising processes such as the Hoganas, Hy L, RN, Wiberg, etc., have been tested on a pilot plant scale and, of these, the more successful have been put into commercial operation. A partial list of the better known direct reduction processes appears in Table 1 along with published performance data.[1]

The product of direct reduction processes, usually referred to as "sponge iron" due to its porous, sponge-like structure, is used mainly as high quality melting stock for iron and steelmaking. Sponge iron, in order to be more widely employed in the industry, must be economically competitive, on a long term basis, with the material it was designed to replace; i.e. scrap. The economic worth of sponge iron, however, is difficult to assess as it has several advantages which would be worth more to some companies than to others. For example,

1. it is a virgin material with a low "tramp" element content; e.g. Cu, Sn,

TABLE 1
Direct Reduction (Solid Product) Processes and Performance

Process	Type of Reductant	Type of Vessel	% Metallization $\frac{\text{Fe metal}}{\text{Fe total}}$	Heat Requirements Per Net Ton of Product, BTU	Estimated Heat Requirements Per Net Ton of Metallic Iron, BTU
Esso-Little	Gaseous	Fluidized Bed Reactor	Up to 95	15.7×10^6	18.6×10^6
H-Iron	Gaseous	Fluidized Bed Reactor	Up to 95	17.4×10^6	17.9×10^6
Hy L	Gaseous	Reduction Vessel Batch Type	94	22.3×10^6 (18.2×10^6) *	26.1×10^6 (21.3×10^6) *
Wiberg-Soederfors	Gaseous	Shaft Furnace	90	10.6×10^6	13.8×10^6
Freeman	Solid	Rotary Kiln	99	28.8×10^6	29.4×10^6
Hoganas	Solid	Saggers and Funnel Furnace	(not given)	16.6×10^6	-
Kalling-Domnarfvet	Solid	Rotary Kiln	90	16.2×10^6	19.5×10^6
R N	Solid	Rotary Kiln	87	17.5×10^6	20.7×10^6

* related to 500 ton per day installation.

2. it has a relatively stable and known chemical composition,
3. it may have, particularly when briquetted, a high charge density and a shape that lends itself to rapid charging techniques, and
4. its price is stable regardless of demand.

The competitive position of sponge iron will obviously depend upon the needs of a particular company, the cost of raw materials and the quality and cost of scrap in the location where its usage is planned. It will also depend upon the direct reduction process employed which, if it is to be commercially successful, should have:

1. a low investment cost per annual ton of production,
2. a low conversion cost with some flexibility in the choice of fuels that can be used, and
3. trouble-free, low maintenance operation.

It follows that only a continuous process, which has been optimized from the standpoint of product quality and trouble-free performance, and which requires a minimum of operations using simple, standard equipment, has a chance of becoming a widely used process in the steel industry.

In an investigation of alternate means for processing high-purity iron ore concentrate from Labrador, which will be available to The Steel Company of Canada, Limited, in the near future, a program of studying direct reduction techniques was initiated in 1958. For the program, a rotary kiln was selected as the most promising type of equipment, as it is comparatively inexpensive to build, reliable to operate and suited to continuous processing. Although promising, the rotary kiln has, according to the experience of other investigators,[2] a serious drawback when used for the direct reduction of iron ore: rings or accretions may form on the lining and agglomeration of the charge into a large, pasty mass may occur, necessitating a shutdown and long delay for repairs. In addition to overcoming this obstacle to trouble-free performance, a process which would economically produce a product of acceptable quality had to be developed.

The test work which is outlined in this paper was carried out in three pilot kilns and has resulted in the development of the "SL" process.

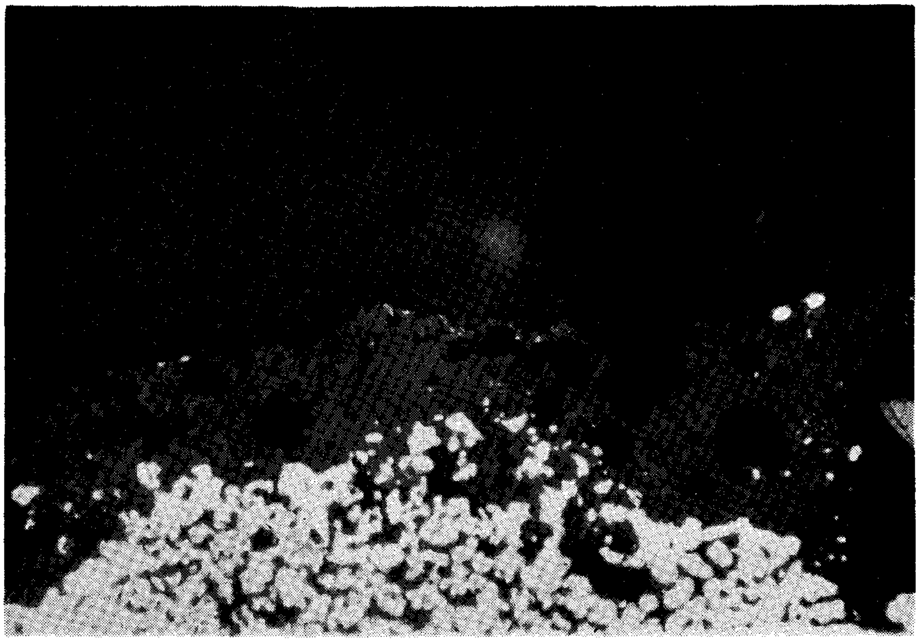

Fig. 1 — Partial cross-section of gangue coated reduced pellet.

Early Process Development

First Kiln Test

In October 1958, the first test of the series which subsequently led to the development of the SL process was performed in a 30-foot long, 4-foot inside diameter, rotary kiln equipped with an oil fired axial burner. The test lasted for 100 hours and consisted of three periods:

1. a period when only coke breeze (92.5 per cent minus 10 mesh), limestone fines (90 per cent minus 10 mesh) and screened Hilton pellets (plus 1/8 inch) were used in the charge. (See Table 5 for chemical composition of Hilton pellets),
2. a period when the non-magnetic fines from the kiln discharge were recharged at approximately the same rate as they were produced, and
3. a period identical to the second except that crushed pellets (minus 1/8 inch) and pellet screenings from the first two periods were charged to the kiln.

It was hoped that the test would demonstrate that pelletizing prior to reduction was unnecessary and that at least a portion of the discharged non-magnetics, rich in fuel, could be recovered by recycling them through the kiln.

The test was carried out without serious mechanical difficulty. The only interruption to smooth operation that occurred was the formation of a large, round agglomerate in the third period due, it was believed, to excessive amounts of fine particles and to too high a reaction temperature.

The same conditions that favored the formation of agglomerates and wall accretions also caused some of the pellets to be coated with gangue. A cross-section of a gangue coated pellet may be seen in Fig. 1. In the photograph, the outer surface of a sponge iron pellet (white area in lower half of the photograph) appears to be coated with a continuous film of slag or gangue. Within the gangue film, discrete particles of coke and reduced iron may been seen. (The uniformly gray area in the upper half of the photograph is plastic which was used to mount the specimen.) A sulphur print of a gangue-coated reduced pellet (see Fig. 2) shows that the sulphur is concentrated mainly in the gangue coating.

Some of the results obtained from the test are listed in Tables 2 and 3. These results indicated that in employing a rotary kiln for direct reduction:

1. it does not seem possible to nodulize fine ore particles and, at the same time, reduce them without entrapping into the nodules very substantial amounts of coke ash and sulphur-rich calcined limestone.
2. it is essential to have close temperature control and raw materials free from fines, otherwise large agglomerates, wall accretions and/or coating of the ore particles with sulphur-rich gangue minerals are likely to occur.

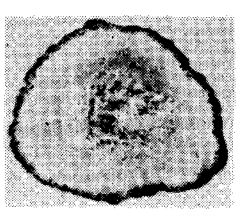

Fig. 2 — Sulphur print of gangue coated reduced pellet, showing heavy concentration of sulphur at pellet surface.

TABLE 2

Pellet Degradation During Reduction

	PERIOD I	PERIOD II	PERIOD III
Mean Pellet Size Before Reduction, inches	0.65	0.54	0.029
Mean Pellet Size After Reduction, inches	0.37	0.31	0.023
Change in Mean Size During Reduction, inches	Minus 0.28	Minus 0.23	0.001

3. it appears that the gangue coating not only increases the sulphur content of the product, but also lowers its metallic iron content by dilution with gangue and by impeding reduction since it acts as a barrier to the diffusion of reducing gases into, and spent gases out of, the pellet.

Lurgi Kiln Tests

A series of kiln tests was planned to determine whether reduction of iron ore in the absence of fine ore and flux particles would improve the quality of the sponge iron produced and decrease the incidence of wall accretions and charge agglomeration. For these tests, pellets of various sizes from 6 mm (¼ inch) to over 25 mm (1 inch) were specially produced, and limestone and dolomite were screened to remove the minus 1 mm (16 mesh) and plus 3 mm (7 mesh) fractions. Anthracite, having a high ash fusion temperature, was obtained and was ground to three size ranges for the test: minus 1 mm (16 mesh), minus 5 mm (4 mesh) and minus 10 mm (13/32 inch).

The second test was performed in a Lurgi-kiln which had a length of 9 metres (29.6 feet) and an inside diameter of 0.5 metres (19.7 inches), and was heated by six, shell-mounted, evenly spaced burners and one axial burner located at the discharge end. In order to obtain close control of bed temperature, as measured by thermocouples along the length of the kiln, provision was made for the introduction, through the burners, of varying quantities of city gas and/or air. With this flexible

TABLE 3

Effect of Gangue Coating on Sponge Iron Composition

	PERIOD I			PERIOD II			PERIOD III		
	% S	% Gangue	% Fe	% S	% Gangue	% Fe	% S	% Gangue	% Fe
Composition before Reduction	0.052	3.29	66.80	0.056	3.80	66.37	0.057	3.27	66.88
Calculated Composition After Reduction - no pick-up	0.071	4.49	91.02	0.079	5.29	92.52	0.074	4.27	87.40
Actual Composition After Reduction	0.46	9.80	85.59	0.57	15.05	82.50	0.86	15.54	76.39
Increase due to Gangue Coating	0.389	5.31	-5.43	0.491	9.76	-10.02	0.786	11.27	-11.01

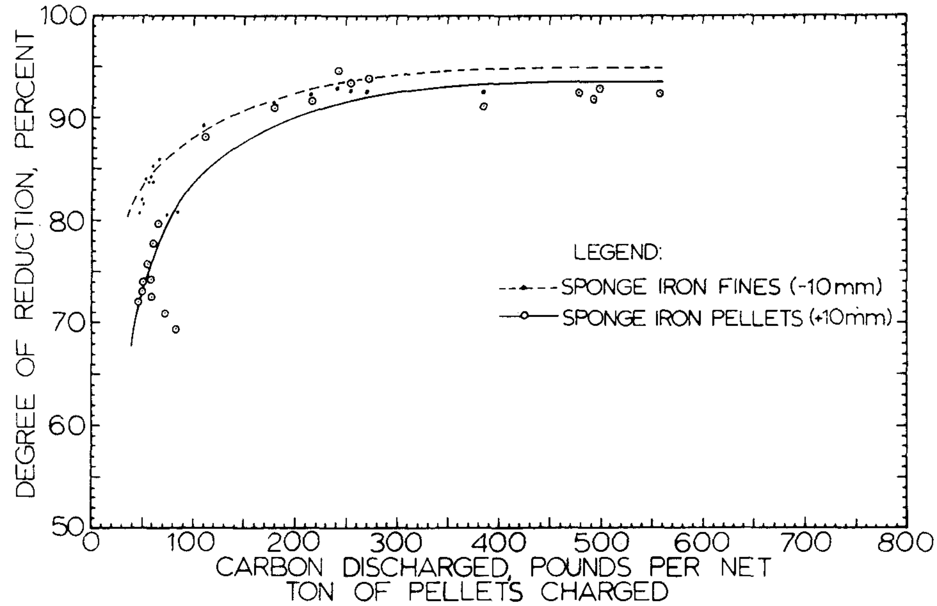

Fig. 3 — Relationship between degree of reduction and carbon discharged from kiln. Established during Lurgi-kiln test, 1959.

burner system, either the city gas and/or the coal in the bed could be used as the source of heat required for the process.

The tests were carried out in 1959 during the months of October and November. In the tests, the size of pellets, amount and type of flux, and amount and size of anthracite were changed at specific intervals while the pellet charging rate, kiln rotation speed and reaction temperature, within the range of 1960 and 2020F, were held constant.

During a preliminary test, in which a reaction temperature of 2050F was used, some formation of pellet clusters occurred and so a maximum reaction temperature of 2020F was used throughout the remainder of the tests. The minus 1 mm anthracite was also tried in a preliminary test and found to be unsatisfactory due to the high loss of coal dust carried out by the waste gases.

The results of the Lurgi-kiln tests indicated several important primary relationships:

1. The degree of reduction obtained in the product is a function of the amount of carbon discharged and of the size of the pellets used.
2. The sulphur content of the product is a function of

the amount of flux charged and of the size of pellets used.

3. The degree of pellet degradation is mainly a function of pellet size.

In Fig. 3, it may be seen that the greater the amount of carbon discharged along with the sponge iron, the greater the reduction of the pellets. It appears that at least 300 lb of carbon per net ton of pellets charged must be discharged to obtain a well-reduced product.

The degree of reduction (Wt of O_2 removed/Wt of O_2 initially present) obtained for any given amount of discharged carbon increased as the pellet size used decreased, reaching a maximum at a mean pellet size of about 0.4 inches, to lower reductions being obtained for pellet sizes smaller than this.

The sulphur content of the sponge iron pellets as shown in Fig. 4 increased hyperbolically as the amount of dolomite used decreased. Dolomite and limestone appeared equally effective in maintaining the sulphur content of the sponge iron low. The points represented by circles in Fig. 4 come from pilot plant tests which will be discussed later in this paper. The sulphur content of the sponge iron pellets was also related to

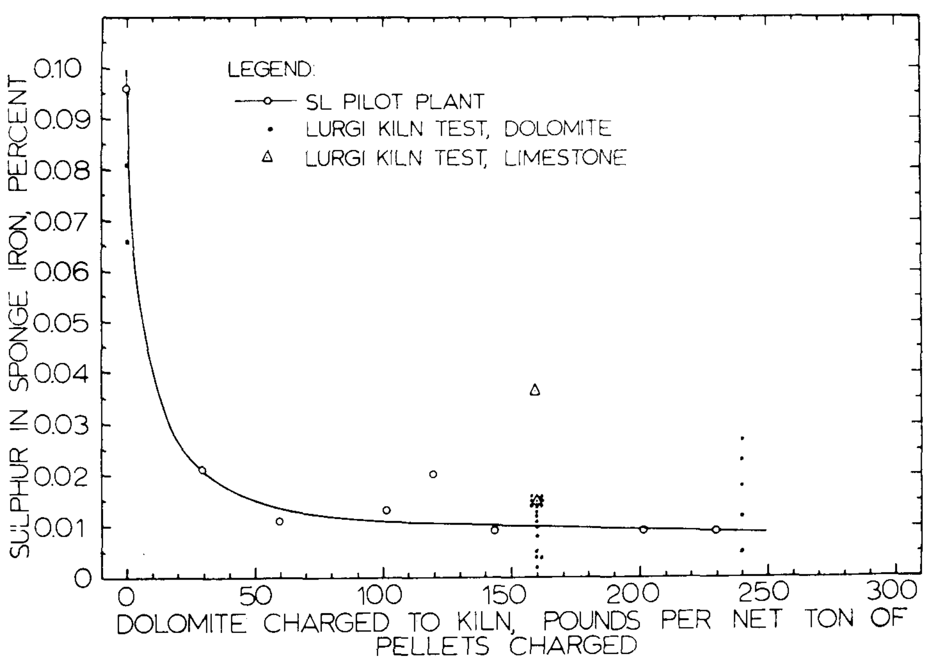

Fig. 4 — Relationship between sulphur content of sponge iron pellets and weight of dolomite charged to kiln.

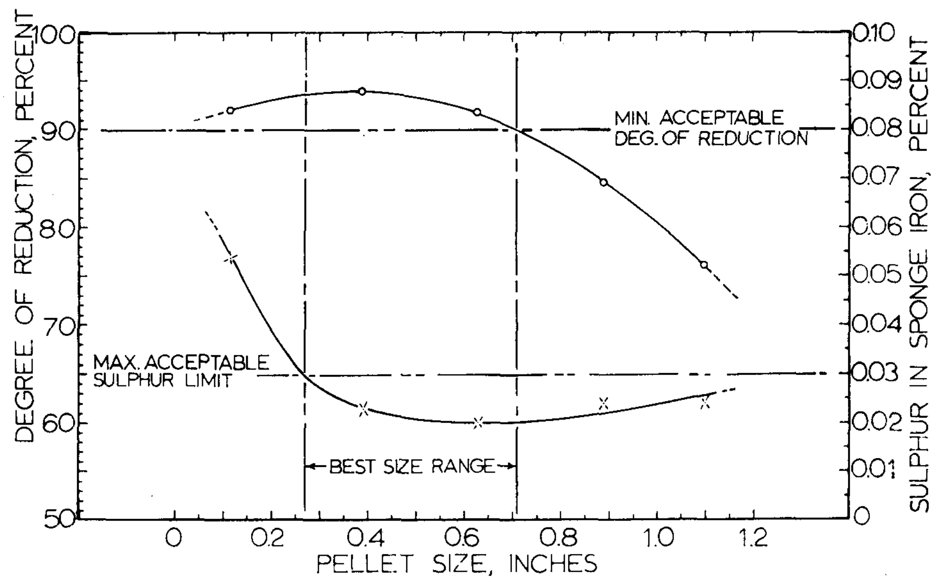

Fig. 5 — Relationship between degree of reduction and ore pellet size — upper curve.
Relationship between sulphur content of sponge iron and ore pellet size — lower curve.

their size as may be seen in Fig. 5, a higher sulphur content being obtained in the smaller sizes.

Similarly, the amount of gangue picked up during reduction either in the form of a coating or of adhering particles, increased as the pellet size decreased.

In the tests, the large pellets had a greater tendency to degrade into finer particles than did the small pellets. This is indicated in Table 4. The degree of degradation used in this table has been defined as the per cent increase, during reduction, of pellet particles smaller than were present prior to reduction.

TABLE 4

Degradation of Pellets During Reduction

TEST NO.	1	2	3	4
MEAN PELLET SIZE USED, mm.	9.5	12.5	22.5	31.0
DEGREE OF DEGRADATION, %	6.0	7.0	45.0	84.9

From the series of tests carried out, the importance of pellet particle size was most evident. On the one hand, small pellet sizes were more resistant to degradation and, down to a certain size, were more highly reduced than large pellets but, on the other hand, large pellet sizes had a lower sulphur and gangue content after reduction. Clearly, an optimum size or range of sizes existed where a product both highly reduced and low in sulphur and gangue was produced. This may be seen in Fig. 5 in which the optimum size range for the tests is shown to be between about ¼ and 11/16 inches.

As a result of the reduction in the amount of fines present in the raw materials, the sulphur and gangue content of the product were much lower than were obtained in the first test. The decreased quantity of fines and the better means of kiln temperature control made it possible to operate for the entire duration of the tests at reaction temperatures only 30F below the agglomeration point without the appearance of wall accretions or the occurrence of charge agglomeration.

Advanced Process Development

Pilot Plant

The construction of a pilot plant which would prove out, on a large scale, the technical and economic feasibility of the SL process was started in the Autumn of 1960, and was completed towards the Summer of the following year. (See Fig. 6). The plant was designed to provide the maximum of data on the process and to demonstrate that it could be operated by a minimum of personnel. It was, therefore, fully instrumented and many of the operations, i.e. material loading, screening, proportioning, were made automatic and controlled remotely from a single control centre.

The plant consists of four sections: raw material handling system, main kiln, cooler-kiln and finished products handling system. A schematic layout of the plant may be seen in Fig. 7.

The raw material, i.e. pellets, dolomite and coal, are brought to the plant by rail and truck and are conveyed to their respective storage bins. The pellets and dolomite are screened to remove the oversized and undersized particles prior to their entering the bins. From the storage bins, the materials are fed continuously, by means of Schenck feeders, in the desired pro-

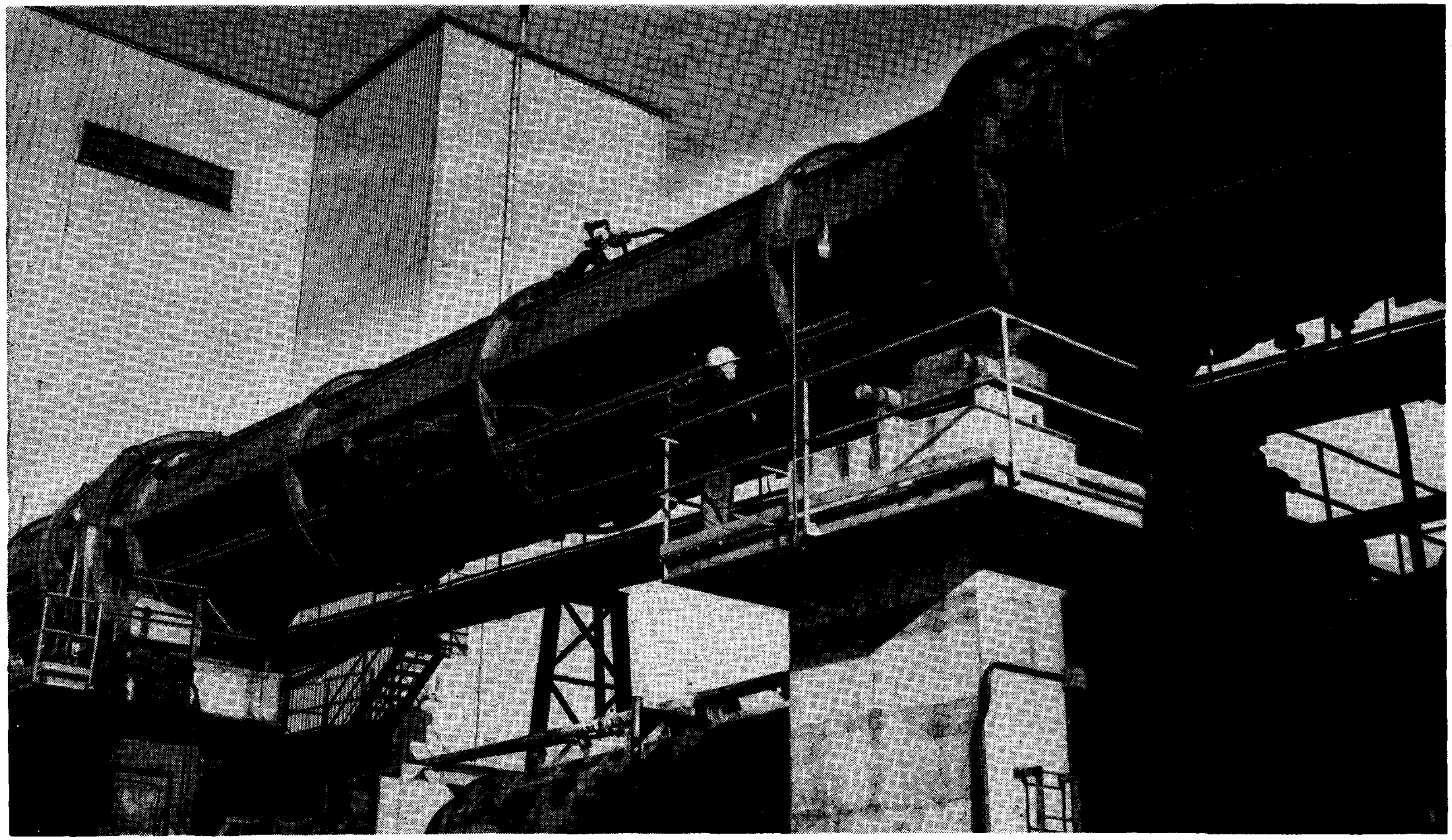

Fig. 6 — Photograph of SL direct reduction pilot plant at The Steel Company of Canada, Limited.

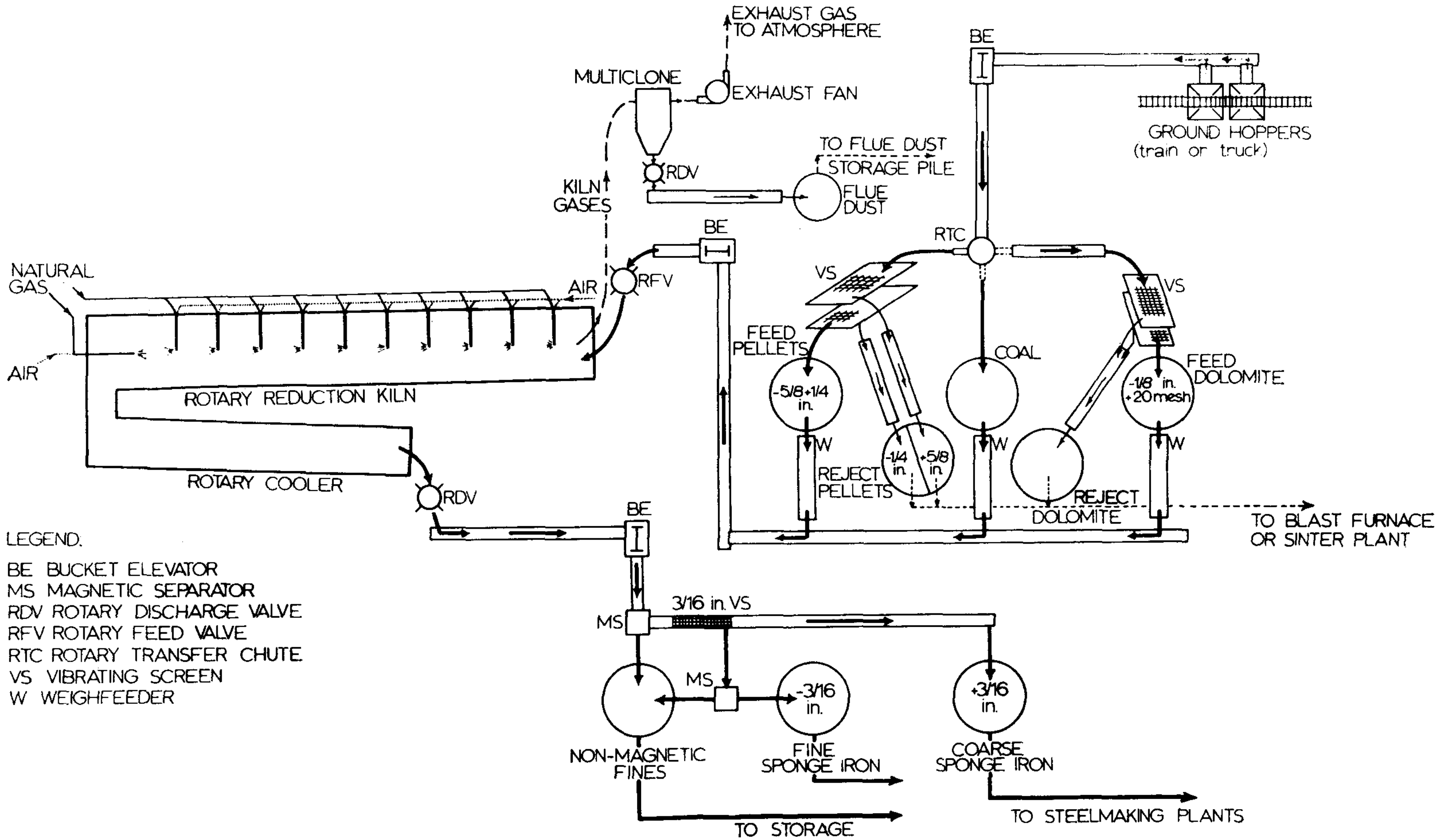

Fig. 7 — Schematic arrangement of pilot plant at The Steel Company of Canada, Limited.

portions onto a common collecting conveyor. The materials then pass through a rotary gate-feeding mechanism, which prevents escape of the kiln gases, down a feed spout into the kiln.

The kiln, excluding the two stationary heads, is 115 feet long, has an internal diameter of about 7½ feet and can be rotated at a constant speed over a wide range of speeds. It is lined with a double course of refractory bricks, making a lining thickness of about 8½ inches. Internally, it is partitioned into three sections by two retaining rings which serve to increase bed depth.

Ten burners are mounted on the shell of the kiln and are evenly spaced with each offset in succession from the next by 72 degrees. The air and gas for the burners enter separate manifolds from opposite ends of the kiln. The transfer of gas and air from the stationary kiln heads to the rotating manifolds is accomplished through circular cavities enclosed by inner and outer labyrinth seals. The bearing surfaces of the seals are lubricated with No. 650 spindle grease having a drop point of 350F. One axial burner is located at the discharge end of the kiln.

The materials gradually move through the hot kiln, until they are discharged and drop through a bricklined transfer chute onto a stone box which diverts them into the cooler-kiln. At this point, the materials are at a temperature of about 2000F but soon cool to about 150F during passage through the cooler-kiln.

The cooler-kiln is mounted below the main kiln. It is 65½ feet long, has an outside diameter of 5 feet and can be rotated at a constant speed. Only the first 28 feet of this kiln are refractory lined. Water sprays are directed against the outer shell surface along the unlined length. The atmosphere of the cooler-kiln consists essentially of gases from the main kiln. These gases migrate into it slowly due to a slightly positive gas pressure being maintained in this area.

Both the main kiln and cooler-kiln slope at an angle of about 2 degrees from the horizontal.

The materials discharge from the cooler-kiln via another rotary gate mechanism and are conveyed to the product bins. The materials are separated by means of a screen and two drum magnetic separators into three products: coarse sponge iron (plus 3/16 inches), fine sponge iron (minus 3/16 inches) and non-magnetic mixture of calcined dolomite and charred anthracite.

The gases generated in the process flow counter-current to the solids and pass out of the kiln through a stack connected to the stationary charging head and into two multiclone dust collectors. The relatively dust-free gases are then blown out through a short stack. The pressure of the gas in the kiln is regulated by means of adjustable louvres and an exhaust fan.

Operation of Pilot Plant

From an operating viewpoint, the shell burners are the most important means for controlling the process. All of the shell burners are designed to fire axially, counter-current to the flow of kiln gases. This design of burner causes the flame to fan out and curve back, thus radiating its heat more uniformly to the kiln walls and bed surfaces. No section of the walls, therefore, becomes overheated. An overheated wall may act as a starting point for the formation of a "ring."

The shell burners were originally constructed with a pre-mix chamber and a refractory lined pipe. This construction was changed because the pre-mixed gas tended to ignite explosively within the burner tube and, in some burners, the refractory lining rotated and closed off the burner port, making them inoperable. The current type of burner design may be seen in Fig. 8.

In operating the kiln, the shell burners and the end burner were adjusted to give a kiln temperature profile such that the charge materials were brought up to the desired reaction temperature in the shortest distance from the charge end of the kiln. In this way, the materials were held at reaction temperature for the longest possible time. A typical temperature profile may be seen in Fig. 9.

It was found that the temperature profile, as shown in Fig. 9, could be most easily maintained when the natural gas was distributed in equal volumes to shell burners Nos. 3 to 10 and the air introduced in all burners as required to maintain temperature and to consume all of the combustibles in the kiln gases prior to their exit from the kiln chamber. In proceeding from shell burner No. 10 to No. 3, the air-to-gas ratio was increasingly more oxidizing. Usually, it is not necessary to supply gas to burners Nos. 2 and 1 except during start-up

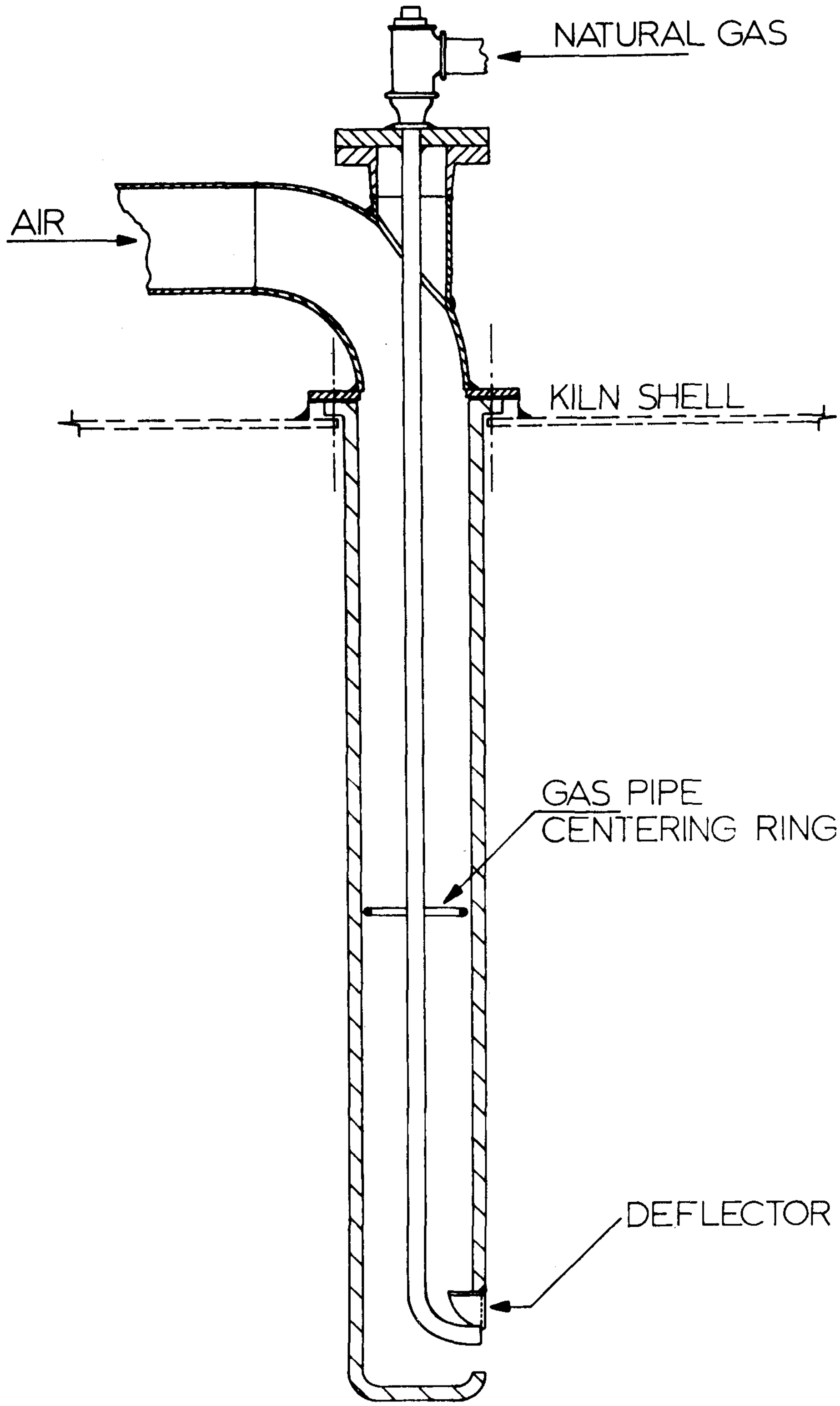

Fig. 8 — Modified shell burner currently in use at pilot plant.

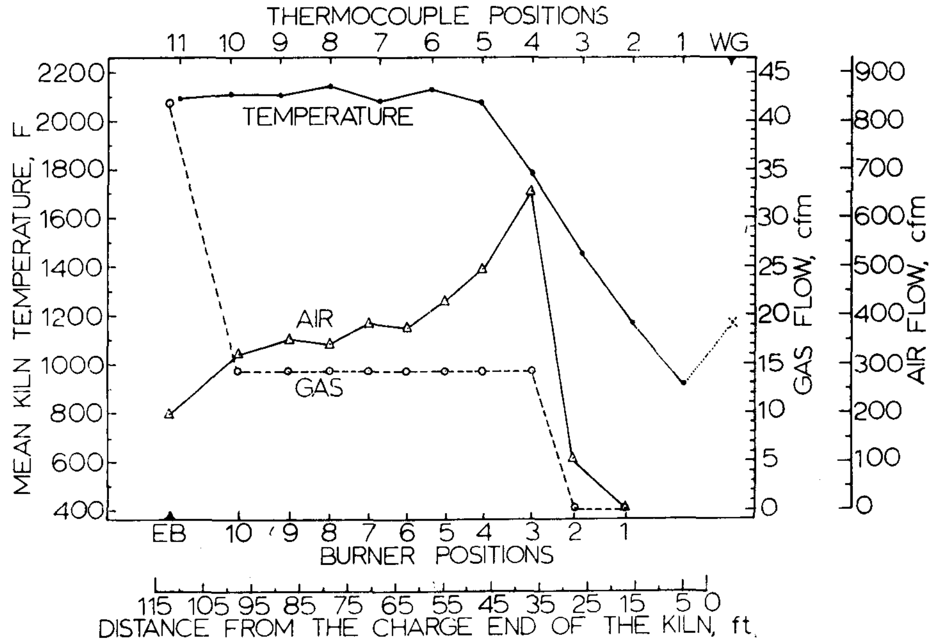

Fig. 9 — Typical temperature profile employed in operation of pilot plant. Gas and air distribution to various burners also shown.

periods. The air-to-gas ratio of the end burner was maintained neutral; i.e. 10:1, or slightly reducing at all times, as an oxidizing flame in this area would increase the possibility of surface reoxidation of the pellets.

The volumes of air admitted via burners Nos. 3, 2 and 1 were determined more by the combustible (CO, H_2 and CH_4), and oxygen content of the waste gas than by its temperature. If too little air was used, the amount of combustibles in the waste gas tended to increase while the temperature of the kiln and the waste gas decreased. In order to maintain a steady kiln temperature profile under these conditions, more gas and air would have to be introduced into the middle and discharge sections. If too much air was used, a similar situation would occur, although it was the oxygen content, rather than the combustible content of the waste gas, that increased abnormally.

Pilot Plant Tests

General Description of Tests

The object of the first pilot plant test was to find the optimum operating conditions for the economic conversion of iron ore pellets into high quality sponge iron melting stock.

TABLE 5
Typical Chemical Analysis of Raw Materials

COMPONENT	COMPOSITION, percent by weight in -			
	Hilton Pellets	Dolomite	Anthracite	
			"Barley"	"Buckwheat No.4"
H_2O	0.80	0.06	12.40	11.30
Fe (total)	66.71			
Fe (bivalent)	0.64			
C	0.035			
S	0.010	0.082	0.74	0.57
Gangue or Ash	3.87	1.66	10.69	14.59
Volatile Matter			6.15	5.21
Fixed Carbon			70.76	68.90
CaO		30.78		
MgO		20.39		
Loss on Ignition		47.11		

For these tests, the operation conditions were periodically changed while the type and particle size of the raw materials were maintained constant, with the exception that two sizes of coal were employed. These tests were, therefore, the converse of the Lurgi-kiln tests. (See tables in Appendix for complete outline of tests).

Typical chemical and size analyses of the raw materials used in the tests are listed in Tables 5 and 6.

From the Lurgi-kiln tests it was known that either limestone or dolomite could be used in the process. Dolomite was selected since it has a lower temperature of calcination and is less susceptible to spalling than limestone.

The dolomite was screened to remove the plus ⅛ inch and minus 20 mesh particles. There is no limit to the maximum particle size except that large particles can be expected to have a lower sulphur adsorbing power due to their low surface to volume ratio. This will be demonstrated later in this paper. A dolomite particle size smaller than 20 mesh could have also been used in the process provided the very fine particles were removed. This was not done as it is a time consuming and difficult operation using a fine mesh screen.

The pellets were screened to remove the plus ⅝ inch and minus ¼ inch fractions as indicated from the Lurgi-kiln tests. The oversized and undersized materials, which represented about 10 per cent of the total weight of pellets received, were sent back to the ore yard for use in either the Open Hearth Furnaces (oversize) or in the sinter plant (undersize).

For this first series of tests anthracite was chosen and purchased prescreened from the supplier in the so-called "Barley" and "Buckwheat No. 4" size ranges. The main consideration in selecting the coals used was the ash fusion temperature which should exceed a maximum kiln reaction temperature of 2300F. The Barley and Buckwheat coals had ash fusion temperatures of 2900F and 2700F respectively. Other less expensive coals will be used in future tests.

Natural gas having the composition indicated in Table 7 was used in the kiln burners.

TABLE 6

Typical Screen Analyses and Bulk Densities of Raw Materials

PARTICLE SIZE	RAW MATERIAL			
	Hilton Pellets	Dolomite	Anthracite	
			"Barley"	"Buckwheat No.4"
+5/8 inch	0.0			
-5/8 +1/2 inch	8.4			
-1/2 +3/8 inch	70.8			
-3/8 +1/4 inch	19.4			
-1/4 inch	1.4			
+6 mesh		0.2	28.5	8.9
-6 +10 mesh		60.9	58.0	20.2
-10 +20 mesh		35.8	10.9	51.8
-20 +35 mesh		1.9	1.4	14.1
-35 +65 mesh		0.1	0.4	2.4
-65 mesh		1.2	0.8	2.6
Bulk Density lb. per cu. ft.	136.4	76.1	48.0	53.2

TABLE 7

Typical Natural Gas Analysis

COMPONENT	O_2	N_2	H_2	CH_4	C_2H_6	C_3H_8	iso-C_4H_{10}	n-C_4H_{10}	C_5H_{12}	C_6H_{14}
COMPOSITION PERCENT BY VOLUME	0.1	3.6	0.1	88.1	5.6	1.8	0.4	0.4	0.0	0.0

Kiln Performance During Tests

No ring formation or agglomeration of the charge occurred at any time during the tests despite the use of reaction temperatures in the range of 2050 to 2200F (see tables in the Appendix).

Throughout the tests, the temperature profile previously shown in Fig. 9 was maintained regardless of whether a high or low gas rate was being employed. This was possible since, to some degree, the heat required could be supplied by burning more or less coal in the bed as the gas supply was varied. In Table 8, the amount of air available to consume coal in the kiln is indicated for several gas rates.

For a given kiln temperature profile, it was found that a minimum gas rate existed below which a drop in the kiln temperature occurred. The permissible minimum gas rates for different coal to ore ratios and coal sizes is shown in Table 9. It appears from this table that lower gas rates could be employed when either Buckwheat sized coal or high coal-to-ore ratio were used. This may have been due to the higher reactivity, i.e. greater particle surface area, of the finer sized coal and the greater availability of coal respectively. As may be observed in Table 10, the utilization of available kiln volume was quite high for the tests. It would seem that having shell burners along the kiln permitted greater productivity than could normally be expected from a standard kiln.

Degradation of Pellets During Tests

As the Lurgi-kiln tests had shown that pellet size was a major factor in determining the degree of degradation that would be suffered by the pellets during reduction, this factor was eliminated in the pilot plant tests by the use of sized pellets. A variation in the amount of fine sponge iron produced,

TABLE 8
Typical Utilization of Air

NATURAL GAS CONSUMPTION per ton of pellets charged	AIR DISTRIBUTION, Cu. ft. at N.T.P.			
	Total Input	Used for Complete Combustion of Natural Gas	Discharged in Waste Gas	Available to Burn Coal
2,509	55,563	25,086	957	29,520
2,128	53,530	21,262	4,831	27,437
2,371	51,529	23,733	2,159	25,637
2,190	48,505	21,910	2,828	23,767
2,003	50,431	20,014	2,038	28,379

TABLE 9
Minimum Natural Gas Consumption

TYPE OF ANTHRACITE	CHARGING RATE net tons pellets per day	COAL/ORE RATIO	MINIMUM NATURAL GAS cu. ft. at N.T.P. per net ton of pellets charged
Barley	100	0.4	2281
		0.5	2176
Buckwheat No.4	100	0.4	2003
		0.5	1870

TABLE 10
Kiln Volume Utilization

CHARGING RATE net ton ore pellets per day	KILN VOLUME UTILIZATION net tons sponge iron per day per 100 cu. ft. available volume
80	1.16
100	1.45
120	1.78
130	1.87
140	2.06

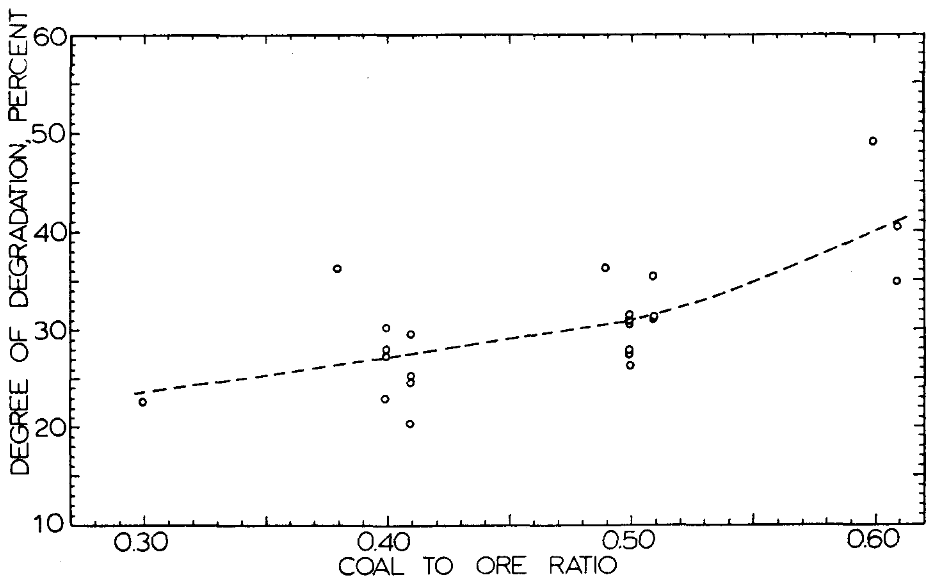

Fig. 10 — Relationship found to exist between degree of degradation and coal/ore ratio of charge.

TABLE 11
Typical Screen Analyses of Kiln Products

PARTICLE SIZE	PRODUCT	
	Sponge Iron	Non-Magnetics
+5/8 inch	0.0	
-5/8 +1/2 inch	3.3	
-1/2 +3/8 inch	38.7	
-3/8 +1/4 inch	25.1	
-1/4 +3/16 inch	8.8	
-3/16 inch +6 mesh	6.1	3.2
-6 +10 mesh	11.1	49.2
-10 +20 mesh	4.7	31.1
-20 +35 mesh	1.3	9.2
-35 +65 mesh	0.5	3.8
-65 mesh	0.3	3.5

however, did occur and as may be seen in Fig. 10, appeared to be related to the amount of coal used: the higher the coal-to-ore ratio, the greater the amount of degradation. No satisfactory explanation for this relationship was evident. The effect of increased production rate and kiln rotation speed

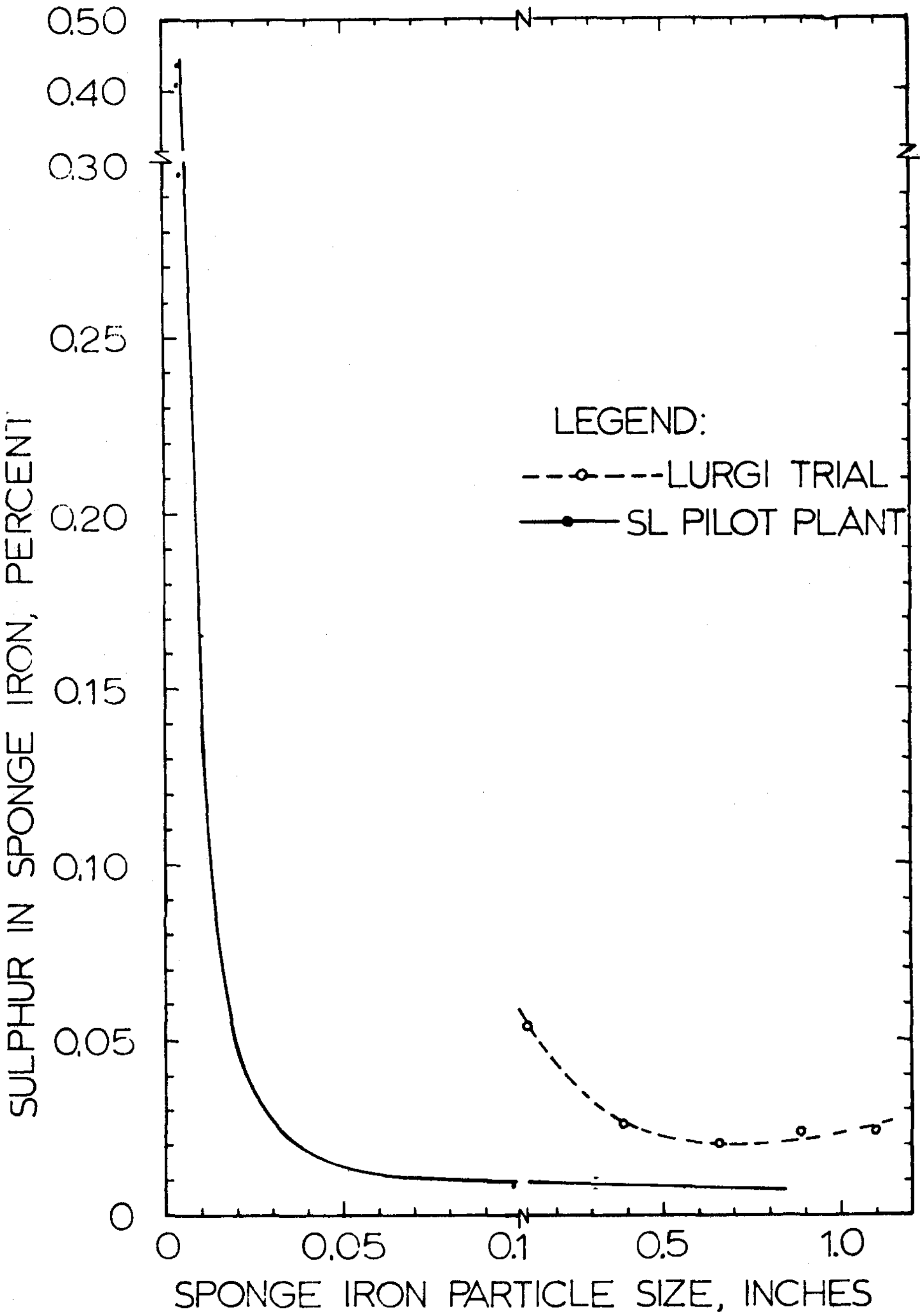

Fig. 11 — Relationships between sulphur content of sponge iron and sponge iron particle size.

upon the degree of degradation did not appear significant for the range investigated. Typical size gradings of the metallic and non-metallic products are shown in Table 11.

Sulphur and Gangue Content of Sponge Iron

Three factors were found to be significant in controlling the sulphur content of the sponge iron produced:

1. the size of the sponge iron particles,
2. the size of the dolomite particles, and
3. the amount of dolomite used.

As shown in Fig. 11, the sulphur content of the sponge iron increased hyperbolically as its particle size decreased. This relationship was believed to be due to two factors:

1. The separation of non-magnetic high sulphur bearing materials from magnetic low sulphur ones is more difficult to accomplish as the size of the particles becomes smaller and as the two types of particles, i.e. magnetic and non-magnetic, become more nearly the same in size.
2. For a given depth of surface enrichment of sulphur compounds, or coating of gangue minerals, small pellets will have a higher overall percentage of sulphur than large ones due to the greater surface-to-volume ratio of the small pellets.

The broken line in Fig. 11 is the relationship previously established in the Lurgi-kiln tests. It appeared that the sulphur content of any given size of sponge iron produced in the pilot plant tests was substantially lower than that produced in the Lurgi-kiln tests.

The influence of dolomite particle size was assessed by hand-picking dolomite from the non-magnetic discharge, separating it into three size fractions and analyzing each for sulphur. The results of this procedure are listed in Table 12 and indicate that the amount of sulphur adsorbed per unit weight of dolomite increased as its particle size decreased.

The amount of dolomite charged was held, in most tests, at a constant level of 120 lb per net ton of pellets charged. To determine the influence of dolomite, the amount used in one test was varied from 0 to 230 lb per net ton of pellets

TABLE 12

Sulphur Adsorption Power of Dolomite Particles

MEAN DOLOMITE PARTICLE SIZE, inches	0.098	0.049	0.025
SULPHUR CONTENT, %	2.50	3.20	5.12

charged. The results of this test are plotted in Fig. 4. A minimum of 30 lb dolomite per net ton of pellets charged appears to be necessary in order to maintain the sulphur content of sponge iron below 0.025 per cent.

The amount of sulphur either picked up or lost in the kiln during reduction was negligible since theoretically, if no sulphur was picked up or lost, the sulphur content of the sponge iron would be 0.014 per cent when the pellets prior to reduction contain 0.010 per cent sulphur. This was confirmed by sulphur prints which showed no signs of sulphur enrichment on the surface of the reduced pellets.

Degree of Reduction Obtained in Tests

The importance of having an excess of carbon discharged was again evident from the results as plotted in Fig. 12. As was the case in the Lurgi-kiln tests, the fine sponge iron was the most completely reduced. The amount of carbon discharged is related to the amount charged as illustrated in Fig. 13.

The increase in reduction with an increase in the amount of carbon in excess of that required for reduction and for generation of heat may be explained as follows:

1. the presence of solid carbon throughout the bed causes the reduction of CO_2 and H_2O, produced at reaction temperature within the bed, to CO and H_2, allowing the reduction of the iron oxides to proceed unhindered;
2. the solid carbon exposed on the surface of the bed reacts with the excess oxygen from the burners, creating heat and protecting the reduced pellets from reoxidation;
3. the presence of solid carbon in the discharge end of the kiln and in the cooler-kiln further protects the re-

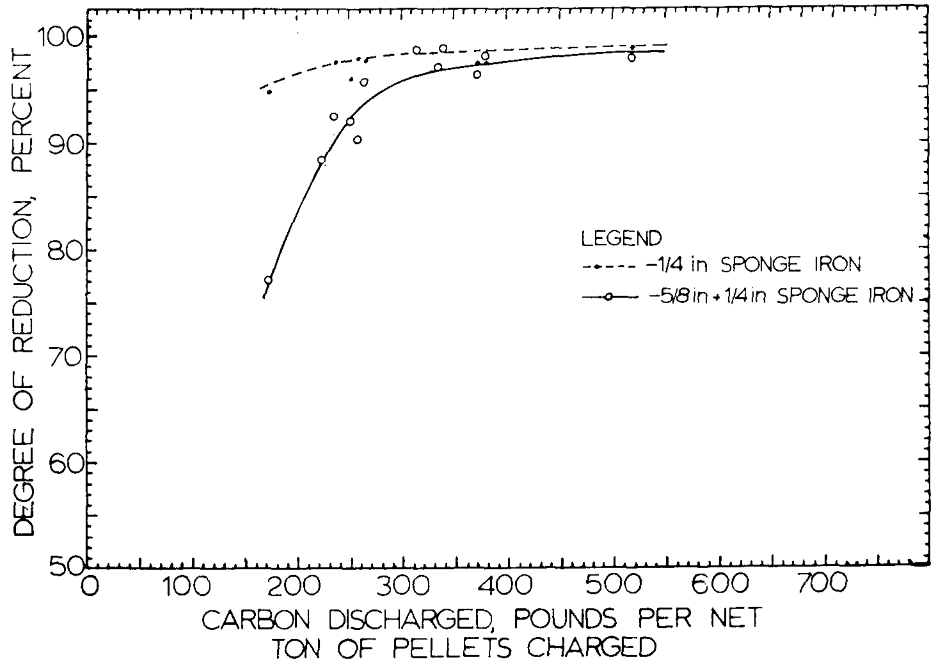

Fig. 12 — Relationship between degree of reduction and carbon discharged from kiln. Established in pilot plant tests.

duced pellets from the possibility of reoxidation during cooling.

The finer sponge iron was usualy more completely reduced in the tests. There are several possible reasons for this:

1. since the reduction of iron oxide by H_2 and CO pro-

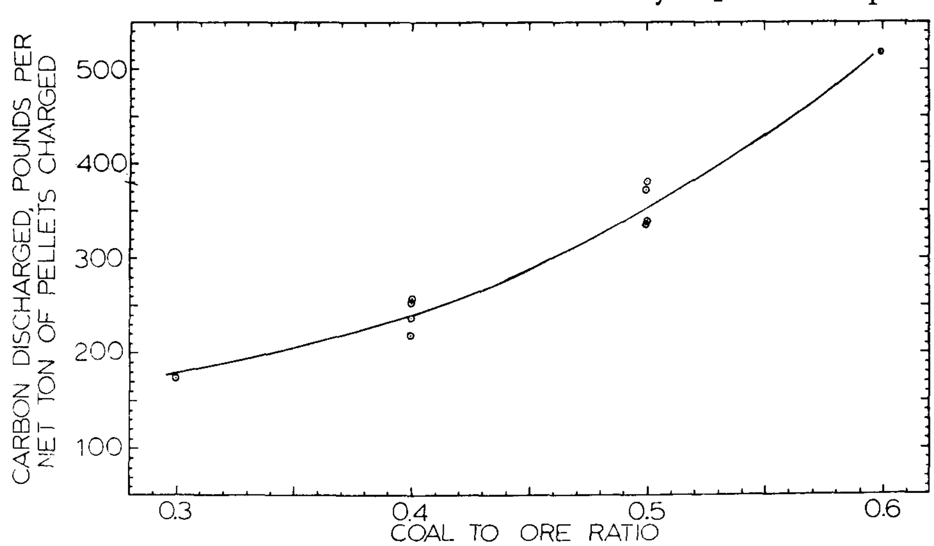

Fig. 13 — Relationship between carbon discharged from kiln and coal/ore ratio of charge.

ceeds through the pellet topochemically (see Fig. 14) small pellets within a given period will be more completely reduced than large pellets;

2. large pellets, which have a tendency to migrate to the surface of the bed, are therefore exposed to less strongly reducing conditions as well as passing through the kiln more rapidly than small pellets;
3. large pellets tend to be less reducible than small pellets due to certain factors in the pellet roasting process which result in the smaller pellets having a higher reducibility.

Within the range of kiln rotation speeds (0.25 to 0.4 rpm) and pellet charging rates (80 to 140 net tons per day) investigated, no significant change in the degree of reduction occurred provided a high enough coal-to-ore ratio was used. This suggests that the residence time in the kiln was sufficient and that still higher production rates may be attained.

Heat Consumed in the Tests

The amount of heat consumed in the process may be based upon any one of several unit weights such as the weight of

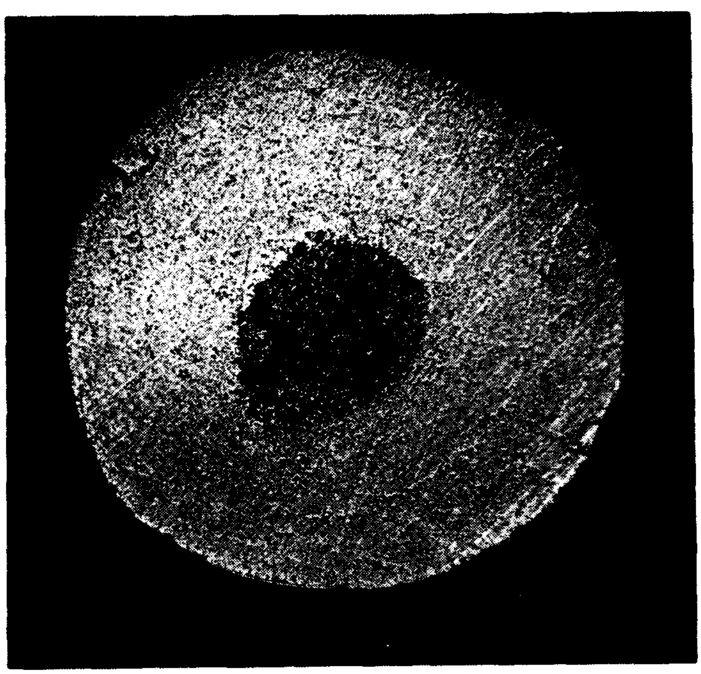

Fig. 14 — Cross-section of partially reduced pellet, showing topochemical progress of reduction.

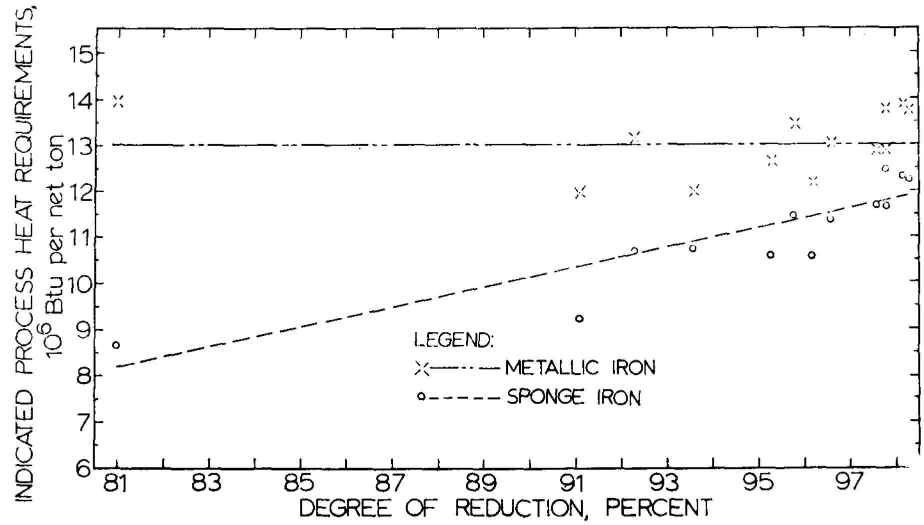

Fig. 15 — Relationships between indicated heat consumption and degree of reduction.

sponge iron produced or the weight of metallic iron contained in the sponge iron. The indicated amount of heat consumed by the process in one series of tests when 100 net tons per day of pellets were charged, is plotted in two ways (based upon the aforementioned unit weights) in Fig. 15. As may be seen, the heat consumed per unit weight of metallic iron produced was strongly dependent upon the degree of reduction while the

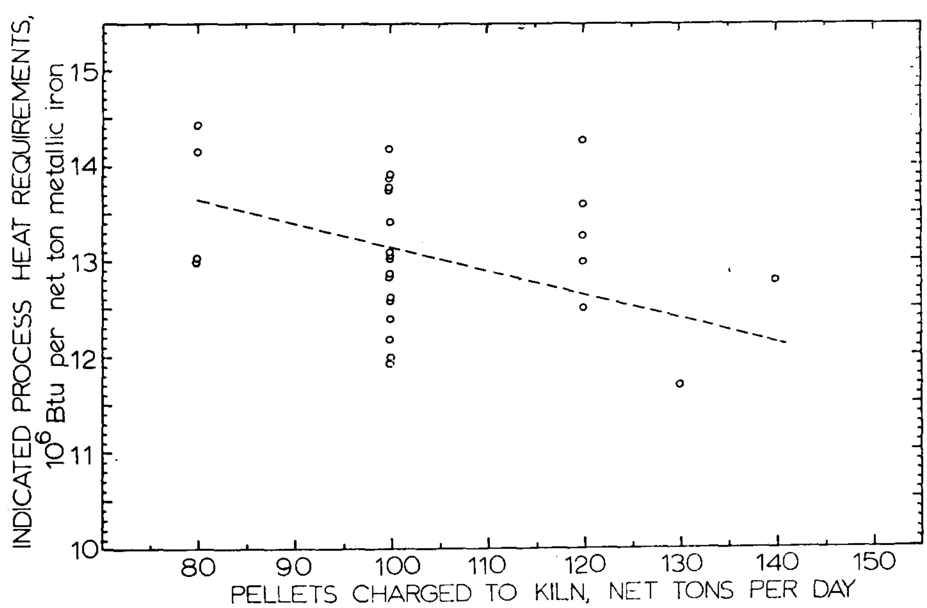

Fig. 16 — Relationship between indicated heat consumption and pellet charging rate.

heat consumed per unit weight of metallic iron produced was for all practical purposes independent of it. For this reason, the latter was favoured as being the more useful from the viewpoint of economic and technical considerations.

A major factor affecting the heat consumption of the process was found to be the production rate. In Fig. 16, it appears that the heat consumption continued to decrease with increasing pellet-charging rates over the range investigated.

A heat balance for one of the best operation conditions found in the reported series of tests may be seen in Table 13. The indicated heat consumption of the process was determined

TABLE 13

Heat Balance per Ton of Sponge Iron and per Ton of Metallic Iron

HEAT CONSUMPTION	B.t.u. per Net Ton Sponge Iron	Percent	B.t.u. per Net Ton Metallic Iron
Heat Content of Anthracite Charged	12.43×10^6		14.40×10^6
Less Heat Content of Char Discharged	4.30×10^6		5.54×10^6
Heat Supplied by Coal	7.68×10^6	72.7	8.86×10^6
Heat Supplied by Natural Gas	2.88×10^6	27.3	3.33×10^6
Indicated Heat Consumption	10.56×10^6	100.0	12.19×10^6
DISTRIBUTION OF HEAT CONSUMED			
Reduction of Oxides	5.55×10^6	52.6	6.41×10^6
Sensible Heat of Waste Gas	2.00×10^6	18.9	2.31×10^6
Unaccounted (radiation losses, etc.)	1.60×10^6	15.1	1.85×10^6
Sensible Heat of Solids	1.00×10^6	9.5	1.15×10^6
Combustible Content of Waste Gas	0.22×10^6	2.1	0.25×10^6
Evaporation of Moisture	0.14×10^6	1.3	0.16×10^6
Calcination of Dolomite	0.05×10^6	0.5	0.06×10^6
Total	10.56×10^6	100.0	12.19×10^6

TABLE 14

Material Balance for the SL Process Pilot Plant

MATERIAL	AMOUNT per net ton iron ore pellets	AMOUNT per net ton metallic iron
Input:		
Iron Ore Pellets (66.5% Fe)	2,000 lb.	3,156 lb.
Anthracite (10.4% H_2O : 80.9% F.C.,dry)	790 lb. (537 lb. C)	1,247 lb. (904 lb. C)
Dolomite	58 lb.	92 lb.
Natural Gas	2,190 cu. ft. (N.T.P.)	3,455 cu. ft. (N.T.P.)
Air	48,505 cu. ft. (N.T.P.)	76,530 cu. ft. (N.T.P.)
Output:		
Sponge Iron (91.1% Fe : 95.2% metallization)	1,463 lb. (1268 Fe met.)	2,308 lb. (2000 lb.Fe met.)
Non-Magnetics (73.4% F.C.)	361 lb. (265 lb. C)	569 lb. (418 lb. C)
Waste Gas	63,837 cu. ft. (N.T.P.)	100,720 cu. ft. (N.T.P.)
Flue Dust	1.6 lb.	2.5 lb.

by subtracting the heating value of the discharged charred anthracite from the heat input value. Table 13 shows that 72.7 per cent of the heat consumed in the process is supplied by the coal and the remainder by the gas.

The heat consumption of the SL process compares favourably with that of other processes (see Table 1). This is due to the very high productivity of the kiln and the very low chemical heat energy in the waste gas. Normally the combustible content of the waste gas was maintaineed at less than 0.5 per cent. In the pilot unit the sensible heat of the waste gas was lost but in a commercial unit up to about one-half of the heat in the waste gas could be recuperated in preheating the air for the shell burners. This would further decrease the indicated heat consumption by approximately 800,000 Btu/net ton metallic iron.

Material Balance for the Tests

A material balance for the test from which the heat balance shown in Table 13 was derived, is listed in Table 14.

Product Application

Typical chemical and physical characteristics of well reduced sponge iron are as follows:

	Per Cent
Fe (total)	93.35
Fe (bivalent)	2.50
Fe (metallic)	89.85
S	0.012
C	0.071
SiO_2	2.72
Al_2O_3	0.35
CaO	0.43
MgO	1.47
Residual Elements (by diff.)	0.45
Cu	0.01
Mn	0.05
P	0.007
Ti	0.02
V	0.04
Others	0.003

Apparent density — 3.6 g/cc
Porosity — 53% voids
Bulk density of coarse sponge iron — 114 lb/cu ft
Bulk density of fine sponge iron — 124 lb/cu ft
Degree of metallization — 96%

The gangue and tramp element content given is peculiar to sponge iron obtained from the current production of Hilton pellets.

Steelmaking Tests

At the time of writing this paper, coarse sponge iron had been used in limited quantities in three types of steelmaking vessels: a 50-ton electric arc furnace, a 105-ton L-D converter and a 400-ton open hearth furnace.

In the electric arc furnace, plain carbon and alloy steels have been produced from charges consisting of up to 80 per cent coarse SL sponge iron. The results from the few heats made indicate that sponge iron tends to increase the total power, lime and carbon consumption for a heat, to cause no discernable change in yield of metal obtained and to improve the purity of the steel produced. No abnormal erosion of the sides or bottom of the furnace was experienced in the production of these heats. Some difficulty was, however, experienced in establishing initial electrical contact with the charges, although this was minimized by changes in furnace operating technique.

Several heats have been produced in an L-D converter using coarse sponge iron as replacement for up to 66 per cent of the scrap charge, or 20 per cent of the total converter charge. The coarse sponge iron added with the scrap and lime in the initial charge was uniformly dispersed throughout it with no buildup or sticking to the walls being observed. When more than 5 per cent of sponge iron was added with the scrap, a slight reaction occurred when the hot metal was added. The residual oxygen in the sponge iron apparently reacted with the hot metal producing more than the usual pyrotechnics; however, it was not considered at all serious. Addition of sponge iron through the lime ports after ignition did not seem to affect the furnace operation. In all test heats, ignition was easily obtained and blowing conditions were good. The overall steelmaking performance using up to 20 per cent sponge iron was most satisfactory and the operating personnel were confident that complete substitution for scrap was possible.

Only a few heats in which coarse sponge iron replaced up to 5 per cent of the scrap charged were carried out in an open hearth furnace. The sponge iron was easily handled by the charging equipment and it was observed from the weights of the charging buggies that it had a greater charging density than both light scrap and bundles. Within the limited range of scrap substitution that has been carried out, sponge iron does not appear to significantly change the overall production performance of the furnace.

Briquetting Tests

From observation of the steelmaking tests it became apparent that briquetting of the sponge iron may be essential, at least for use in an open hearth furnace, as the loose sponge iron tended to float on the slag blanket. Because of a possible dust problem, the fine SL sponge iron will doubtlessly have to be briquetted for all types of steelmaking processes. It should be mentioned, however, that SL sponge iron is not pyrophoric.

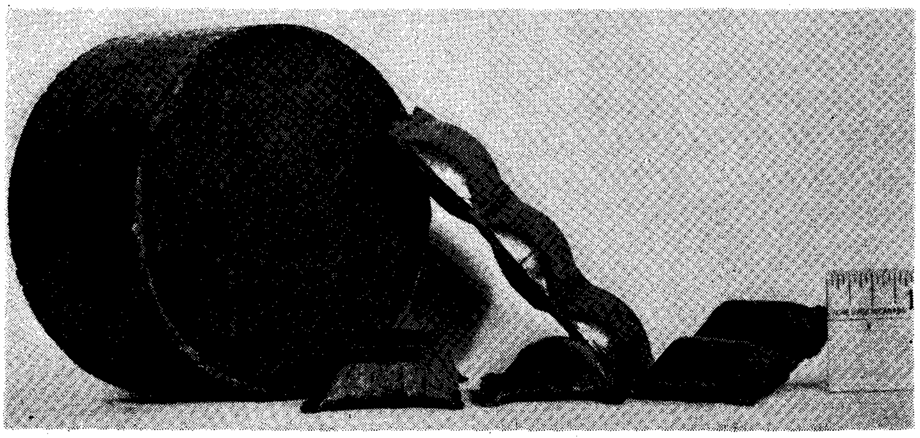

Fig. 17 — Various types of briquette produced from SL sponge iron.

All three types of briquetting press: roll, cylinder and ring-roll, have been tested and the results favour the roll type as it is the least expensive to purchase, has a high output and low die wear. Several different shapes were produced (see Fig. 17). A stick-shaped briquette with one face flat, the other rounded, was considered to be the best from the standpoint of minimum operating cost and maximum output. Various briquetting pressures were also tried and the relationship between pressure and apparent density of the briquette developed is indicated in Fig. 18 which shows that apparent density increases with

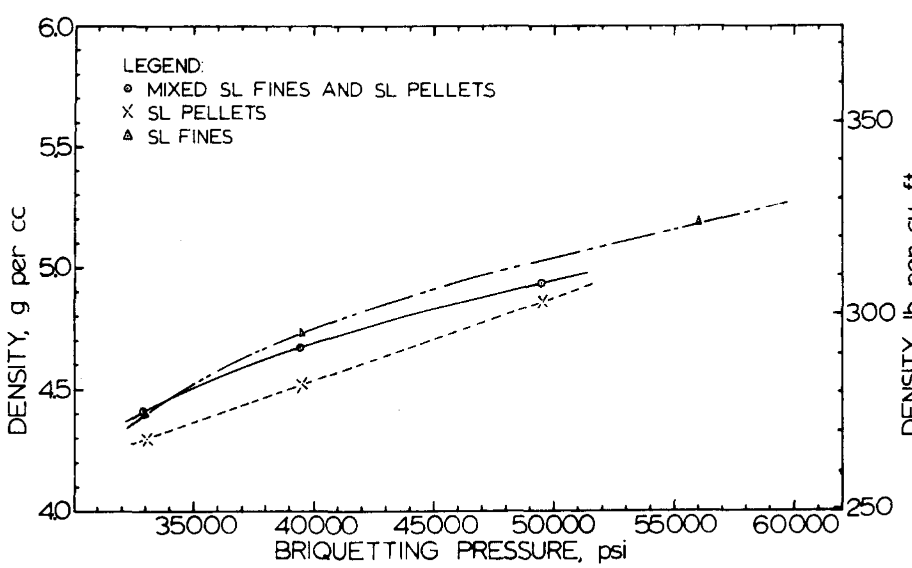

Fig. 18 — Relationships between apparent density of briquettes and briquetting pressure.

pressure and that fine SL sponge iron produces the most dense briquette.

Atmospheric exposure tests have been performed on both loose and briquetted sponge iron. It was found that the loose sponge iron oxidized rapidly changing its iron content from 90.2 to 86.1 per cent in a period of two weeks. The briquetted sponge iron, however, oxidized very slowly, the rusting being confined mainly to the briquette surface. Its iron content changed from 93.7 to 92.8 per cent in a period of 16 weeks.

Charred Anthracite Recovery

Recovery of the charred anthracite from the non-magnetic discharge has not yet been attempted on a large scale. A laboratory investigation, however, has demonstrated that the calcined dolomite particles are readily disintegrated by hydration. A recovery of about 80 per cent of the carbon has been achieved by a single hydration and screening operation.

The analyses of discharged non-magnetics produced when various coal-to-ore ratios were employed are listed in Table 15.

Discussion

The size of coal used in the kiln did not appear to be of serious consequence as no significant change in the process heat consumption was observed. As finer coal sizes are usually

TABLE 15

Typical Chemical Analysis of Non-Magnetic Discharge

COMPONENT (percent by weight)	COAL/ORE RATIO			
	0.3	0.4	0.5	0.6
Fe (total)	4.30	1.96	1.40	1.30
Fe (bivalent)	2.45	0.98	0.65	0.45
Fe (metallic)	0.55	0.44	0.52	0.35
Fixed Carbon	53.35	62.35	69.18	73.41
"Volatile Matter"	1.09	1.01	0.98	0.80
S	1.00	1.20	1.16	1.02
Gangue (incl. S)	40.00	34.17	27.88	24.15

lower in cost, they should be preferred. It is the opinion of the operators, however, that when the coarse sized coal was used, control of the temperature profile was performed with greater ease. Further economies in fuel may be achieved by utilizing lower rank coals, e.g. non-caking bituminous coals.

The close temperature control provided by the Lurgi-type kiln, with its shell burners, seems essential for a successful high production kiln operation. The ability to introduce controlled amounts of gas or oil along the kiln length means that positive temperature control can be achieved regardless of the reactivity of the solid fuel employed. The design of the shell burners also seems to be very important if trouble-free high productivity is to be obtained. The fact that the burners fired centrally down the kiln without flame impingement on the charge or walls and that a minimum of fine, low softening point constituents were contained in the charge, enabled reaction temperatures which bordered upon the actual melting temperatures of some of the mineral phases present in the partially reduced pellets to be sustained.

From the results, it appeared that the pellet size range of minus ⅝ plus ¼ inch, used in the tests was not the optimum for the process. Control of the sulphur content of sponge iron in the large pilot kiln was readily performed; the sulphur content of, even the fine sponge iron was low. Smaller pellets which are easier to reduce, therefore, could have been used allowing even higher kiln production rates. The use of smaller pellets would probably make it necessary to briquette all of the metallic product.

The weight, shape and density of the briquette may prove to be very important in achieving the best results in steelmaking. High density, close-packing briquettes have a higher charge-weight than most types of scrap and thus may decrease furnace charging time. Uniformity in size and shape could lead to a unique gravity charging method such as was used in the L-D converter steelmaking tests.

In the electric arc furnace steelmaking tests, the high non-metallic content, i.e. gangue and ferrous oxide, of the sponge iron gave rise to slag volumes somewhat greater than normally encountered and as a result more electrical energy was required for the heats. It has been stated that a gangue content of no more than 5 per cent in the sponge iron would be acceptable

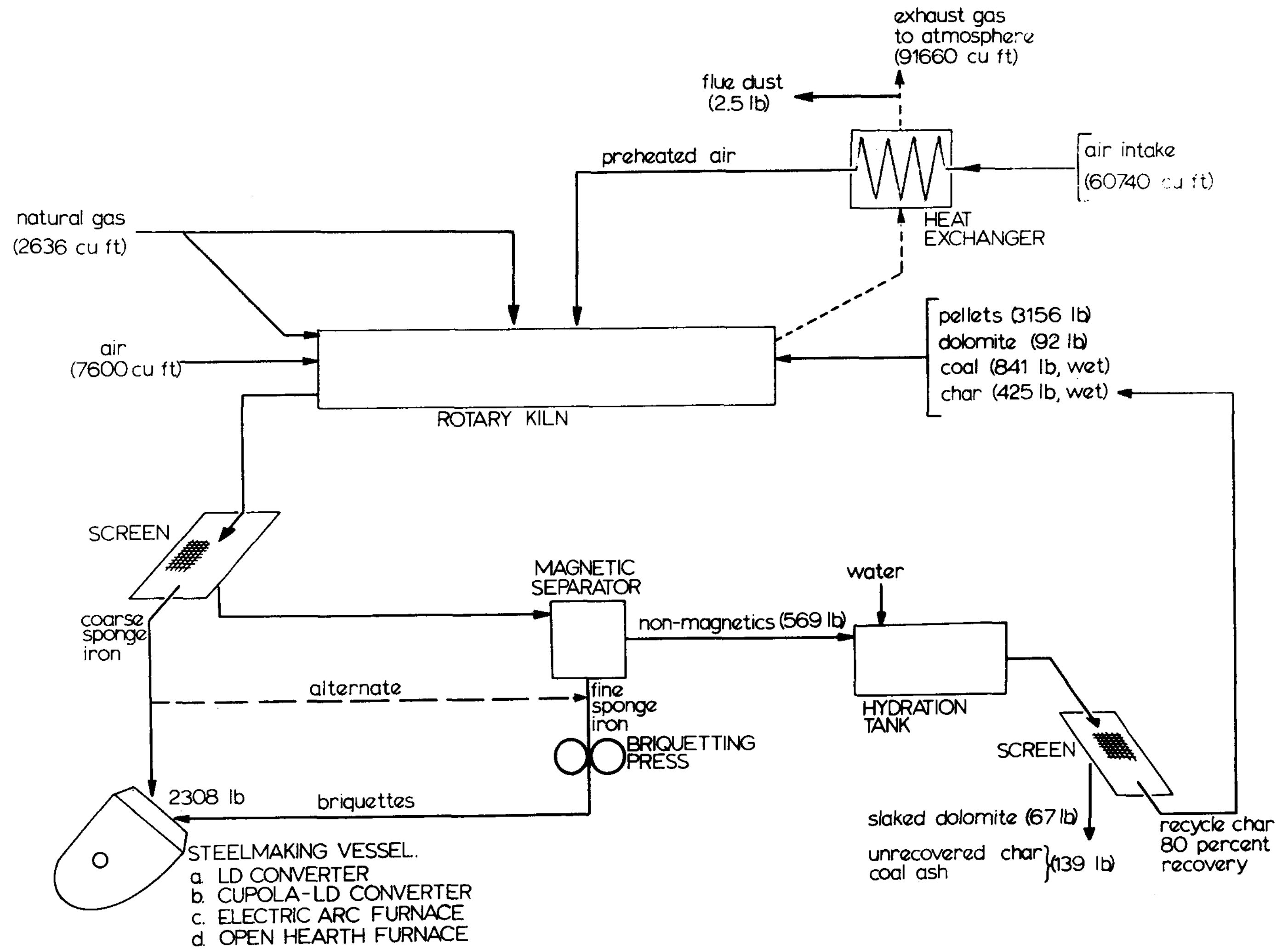

Fig. 19 — Schematic diagram of SL direct reduction process as envisaged in future operations.

for steelmaking.[3] For many ores, a concentrate having a gangue content of less than 5 per cent and even less than 1 per cent in the case of some magnetite ore bodies may be produced for little additional expense. This expense will be offset by lower freight charges, and conversion and steelmaking costs. Upgrading of the sponge iron by magnetic separation after reduction is also possible but is a difficult and expensive separation and renders the fine metallic iron less amenable to briquetting.

In the pilot plant the development of the optimum conditions for the SL process has progressed to an advanced stage. Further tests will continue to be concerned with lowering the heat consumption and raising the output of the unit in striving for the best overall process economy.

The process as now envisaged, using the actual results obtained in the tests, is presented schematically in Fig. 19.

Conclusions

1. A high kiln productivity was achieved, i.e. 2.06 net tons per 100 cu ft of available kiln volume, and higher productivity appears possible.
2. Charge agglomeration and ring formation were avoided by using screened materials and specially designed burners.
3. A minimum of 300 lb of carbon per net ton of ore charged must be discharged to obtain a product adequately reduced.
4. In the SL process, any degree of metallization up to almost complete metallization of the product can be produced.
5. No sulphur was picked up or lost in the process when screened ore (pellets) and 30 lb of flux (dolomite) per net ton of pellets charged were used in the charge.
6. The heat consumption for the SL process may be 12.5×10^6 Btu per net ton of metallic iron when the charred anthracite is recycled and the sensible heat of the waste gas is recuperated.
7. The sponge iron as produced had a bulk density of 115 to 125 lb per cu ft and could be readily briquetted to increase it to over 300 lb per cu ft.
8. The sponge iron produced in the pilot kiln was utilized with encouraging results in an L-D converter, an electric arc and an open hearth furnace.

Acknowledgment

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APPENDIX

SL Direct Reduction Pilot Plant Test Data

Test No.	1	2	3	4	5	6	7	8	9
Raw Material:									
Hilton Pellets, net tons per day	101	101	79	79	80	80	100	101	100
Anthracite, net tons per day	50	40	32	41	41	32	41	50	40
Dolomite, net tons per day	6	6	5	5	5	5	6	6	6
Natural Gas, cu. ft. per net ton pellets (N.T.P.)	2509	2479	2579	2503	2128	2304	2281	2176	2371
Air, cu. ft. per net ton pellets (N.T.P.)	55563	55042	56700	56443	53530	52181	52526	53007	51529
Products:									
Sponge Iron, net tons per day	72	74	59	57	59	60	74	73	73
Non-magnetic discharge, net tons per day	28	20	14	19	21	16	19	24	17
Waste Gas, cu. ft. per net ton pellets (N.T.P.)	74176	71752	73089	75628	70424	67965	68369	68395	67676
Kiln Operation:									
Kiln Speed, r.p.m.	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.30
Temperature, °F at thermocouple no. 11	2121	2113	2072	2140	2087	2108	2104	2092	2086
10	2096	2103	2075	2104	2071	2094	2129	2084	2091
9	2084	2103	2085	2134	2098	2117	2110	2101	2134
8	2093	2116	2085	2127	2067	2072	2143	2146	2171
7	2043	2063	2091	2083	2034	2025	2085	2076	2149
6	2141	2132	2123	2178	2087	2085	2138	2126	2186
5	1998	2000	2027	2095	1910	1927	1987	1965	2060
4	1799	1824	1870	1899	1707	1730	1776	1790	1885
3	1478	1490	1526	1556	1387	1389	1455	1456	1571
2	1171	1183	1159	1204	1065	1086	1169	1163	1254
1	922	926	904	927	854	865	918	918	986
Waste Gas	1133	1102	1019	1074	1001	1009	1110	1122	1142
Kiln Performance:									
Degree of Metallization, percent	97.0	89.3	87.3	98.6	95.8	90.7	91.2	97.0	92.7
Degree of Pellet Degradation, percent	30.5	27.2	25.3	31.2	35.4	29.4	24.6	31.3	22.9
Constituents of Waste Gas, percent H_2	0.02	0.06	0.03	0.05	0.02	0.01	0.01	0.00	0.18
CO	0.21	0.26	0.23	0.32	0.11	0.16	0.14	0.29	0.23
CH_4	0.02	0.02	0.00	0.11	0.00	0.00	0.01	0.00	0.03
O_2	0.27	1.34	1.59	0.21	1.44	1.38	1.09	0.61	0.67
H_2O	15.1	15.4	15.6	16.7	16.7	15.8	15.0	16.0	15.1

APPENDIX (Continued)

Test No.	10	11	12	13	14	15	16	17	18
Raw Materials:									
Hilton Pellets, net tons per day	100	101	99	102	102	101	103	100	100
Anthracite, net tons per day	40	30	60	40	51	50	40	51	52
Dolomite, net tons per day	6	6	6	3	3	3	3	3	3
Natural Gas, cu. ft. per net ton pellets (N.T.P.)	2385	2357	2369	2190	1870	2337	2003	2067	2415
Air, cu. ft. per net ton pellets (N.T.P.)	52000	46372	54500	48505	51521	51881	50431	52149	53822
Products:									
Sponge Iron, net tons per day	74	78	72	74	76	75	77	75	73
Non-magnetic discharge, net tons per day	25	16	35	18	23	20	15	26	25
Waste Gas, cu. ft. per net ton pellets (N.T.P.)	67068	59041	71307	63837	65523	67576	63886	65905	70092
Kiln Operation:									
Kiln Speed, r.p.m.	0.35	0.25	0.25	0.25	0.25	0.25	0.25	0.30	0.35
Temperature, °F at thermocouple no. 11	2111	2120	2087	2106	2084	2138	2099	2061	2098
10	2085	2096	2083	2096	2070	2108	2104	2093	2127
9	2088	2085	2137	2083	2107	2102	2112	2104	2122
8	2145	2096	2113	2128	2126	2132	2149	2123	2148
7	2128	2035	2046	2083	2078	2091	2117	2070	2102
6	2179	2105	2148	2175	2178	2194	2142	2138	2178
5	2018	2027	2089	2095	2080	2155	2167	1998	2064
4	1855	1854	1876	1908	1953	2001	1957	1863	1943
3	1535	1546	1540	1583	1619	1733	1662	1511	1609
2	1227	1216	1199	1245	1251	1338	1285	1198	1288
1	976	971	950	985	950	1024	1015	926	1028
Waste Gas	1119	1133	1120	1120	1114	1201	1149	1070	1151
Kiln Performance:									
Degree of Metallization, percent	87.2	73.4	97.7	95.2	98.4	98.1	93.9	95.5	97.4
Degree of Pellet Degradation, percent	30.2	22.6	34.7	28.0	30.7	31.2	36.3	36.3	31.0
Constituents of Waste Gas, percent H_2	0.12	0.12	0.16	0.10	0.09	0.18	0.03	0.05	0.07
CO	0.21	0.21	0.55	0.42	0.35	0.45	0.39	0.23	0.40
CH_4	0.04	0.06	0.11	0.12	0.05	0.09	0.07	0.06	0.08
O_2	0.81	0.85	0.61	0.93	0.78	0.17	0.67	1.50	0.72
H_2O	15.8	15.4	18.5	15.5	14.7	15.8	14.6	17.8	17.2

APPENDIX (Continued)

Test No.	19	20	21	22	23	24	25	26	27	28	29
Raw Materials:											
Hilton Pellets, net tons per day	120	122	119	121	119	100	100	100	100	130	139
Anthracite, net tons per day	60	61	49	61	72	61	50	40	40	64	70
Dolomite, net tons per day	3.4	3.6	3.6	3.6	3.6	3	1.5	1.5	0.0	3.5	3.6
Natural Gas, cu. ft. per net ton pellets (N.T.P.)	2075	2366	2261	2191	2399	2166	2130	2118	2270	2021	2300
Air, cu. ft. per net ton pellets (N.T.P.)	50396	46568	45691	47567	50768	51837	51067	51193	46862	44786	47710
Products:											
Sponge Iron, net tons per day	91	91	97	89	88	73	73	74	78	93	103
Non-magnetic discharge, net tons per day	35	34	25	31	44	36	25	18	19	34	35
Waste Gas, cu. ft. per net ton pellets (N.T.P.)	64487	62219	59606	62937	67338	66996	64398	64345	58576	58598	63139
Kiln Operation:											
Kiln Speed, r.p.m.	0.30	0.35	0.30	0.40	0.40	0.40	0.25	0.25	0.25	0.35	0.40
Temperature, °F at thermocouple no. 11	2056	2110	2073	2107	2109	2101	2039	2067	2005	2125	2131
10	2085	2126	2088	2110	2095	2081	2075	2071	1998	2079	2103
9	2099	2108	2069	2098	2089	2093	2078	2097	2020	2125	2120
8	2134	2121	2099	2128	2130	2084	2100	2119	2021	2126	2133
7	2081	2092	2068	2079	2095	2085	2066	2081	1967	2076	2110
6	2162	2152	2134	2137	2122	2122	2109	2124	2029	2126	2103
5	1957	2038	2019	1978	1977	1976	2001	2034	1918	1991	1989
4	1817	1913	1904	1880	1844	1961	1892	1951	1822	1886	1884
3	1469	1597	1561	1547	1557	1549	1530	1563	1392	1568	1599
2	1174	1285	1264	1243	1263	1261	1176	1231	1083	1260	1297
1	934	1013	1005	1005	1007	976	940	944	842	1001	1074
Waste Gas	1139	1177	1178	1193	1197	1123	1070	1059	955	1184	1231
Kiln Performance:											
Degree of Metallization, percent	91.4	92.4	79.9	94.4	94.7	94.3	92.7	91.3	71.8	94.3	95.7
Degree of Pellet Degradation, percent	27.3	26.4	20.4	27.9	49.1	40.4	26.2	26.1	24.5	32.5	29.6
Constituents of Waste Gas, percent H_2	0.05	0.23	0.03	0.11	0.09	0.07	0.11	0.12	0.23	0.10	0.18
CO	0.24	0.42	0.25	0.29	0.28	0.23	0.43	0.37	0.58	0.29	0.39
CH_4	0.04	0.10	0.08	0.08	0.05	0.05	0.11	0.11	0.14	0.07	0.11
O_2	1.57	0.10	0.49	0.31	0.25	0.61	1.41	2.29	2.35	0.21	0.09
H_2O	16.1	17.2	17.6	18.4	18.0	19.3	17.61	15.41	17.33	19.08	18.66

BIOGRAPHICAL SKETCH

J. G. SIBAKIN was graduated from Technical University in Russia in 1935 as a metallurgical engineer. He spent one year working in a ferroalloys plant and then returned to Technical University. After three years' postgraduate work, he obtained a degree corresponding to a Doctor of Philosophy. During and after his postgraduate studies, he worked in applied research and development and instructed at Technical University. Mr. Sibakin later worked in the research and development division of a steel plant in Germany. In 1949, he joined The Steel Company of Canada, Limited, and is now manager of the research and development department of that company.