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by R. R. Rogers
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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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OTTAWA

EXTRACTION METALLURGY DIVISION

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FROM CANADIAN JAVELIN LTD. AT KRISTIANSAND, NORWAY,
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January 9, 1963

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INTRODUCTION

In a letter addressed to the Honorable Jacques Flynn, Minister of Mines and Technical Surveys, Ottawa, dated January 25, 1962, Premier J. R. Smallwood of Newfoundland stated in effect that the Julian Iron Co. of Labrador had shipped 150 tons of their iron ore concentrate to Elektrokemisk A/S of Kristiansand, Norway, for experimental smelting to produce pig iron. He requested that a high-ranking member of this Department be sent to Norway to observe these experiments which might prove to be of great importance to Canada.

In a telegram dated February 8, 1962, the Minister notified Premier Smallwood that an officer of the Department would be sent to Norway. Shortly thereafter the Director of the Mines Branch informed the writer that he had been chosen to represent the Department at the smelting investigation.

Although the experiments were commenced on February 12, the writer was present only from February 17 to February 23 which was the period during which the most significant results were obtained. The experiments were witnessed by the following specialists in addition to Mr. F. C. Collin, Mr. K. Sandvold and other members of the Elektrokemisk staff:

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

Mr. F. Gover,
Deputy Minister of Mines of Newfoundland

Mr. William Dailey,
Pickands-Mather and Co.

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Mr. D. A. Sutch, President,
Ramseyer and Miller, Consultants, New York.

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

Merely a brief summary of the experimental work is given in the present report. More complete details may be obtained from the excellent reports issued by Elektrokemisk A/S, Oslo, Norway, (dated February, 1962) and Ramseyer and Miller Inc., Consultants, (dated June 1, 1962). The present report also gives the views of the author as to the feasibility of the process for treating Julian iron ore concentrates.

THE EXPERIMENTAL SMELTING

Smelting Process

The most usual method of producing pig iron consists of:

1. the agglomeration of the ore concentrate in a sintering plant, during which the material is heated to incipient fusion and then cooled prior to screening and transportation;
2. the reduction and smelting of the resulting sinter in a blast furnace.

In the Elektrokemisk process used in the present tests, the ore submitted by Canadian Javelin Ltd. was pelletized, then baked and pre-reduced simultaneously in a simple vertical shaft. Finally the hot, prereduced pellets were introduced into the electric arc smelting furnace where the remainder of the reduction and the melting took place. In this new technique the agglomeration plant is simplified by the elimination of the complicated heat-treating equipment. The shaft pretreatment conditions the charge entering the electric furnace, resulting in a considerably reduced power requirement and a higher rate of pig iron production.

The mixture of iron ore concentrates, coal and Portland cement was pelletized on a rotating disc. The raw pellets were hardened to a certain extent due to the action of the cement during a storage period of three to five days. They then were sufficiently hard for transportation and handling within the plant.

Batches of the furnace charge, consisting of pellets, coke and fluxes, were fed into the top of the shaft, which was located above the electric

furnace. While passing down the shaft the material was heated in a stream of hot gases travelling in the opposite direction, to a temperature of 1400 to 1650°F (760 to 900°C). During this treatment (1) the pellets were baked hard, the carbonization of the coal forming a strong carbon bond, and (2) prereduction by the action of the hydrogen and hydrocarbons in the coal took place removing 10 to 30 per cent of the oxygen in the ore. The gas for heating the shaft was produced in a separate combustion chamber. In commercial installations this heating would be done with $\text{CO} + \text{CO}_2$ from the electric furnace.

The red-hot pellets were discharged continuously from the shaft into the electric furnace below. Due to the intimate contact between the ore and coke and to the shape and size of the pellets, the charge was reactive and porous and thus had excellent smelting properties. The CO_2 content of the gas from the furnace was high, in spite of the comparatively small depth of the charge.

Whereas an ordinary electric furnace for iron ore smelting is three-phase (i.e. it has three centrally-located electrodes and the hearth is not included in the circuit), the furnace used in the present experimental work was single-phase with connections to one central electrode and the hearth. Apparently the Elektrokemisk engineers assume that the conditions surrounding the single electrode in their experimental furnace are reasonably similar to those surrounding each of the three electrodes in a three-phase furnace. The furnace used has a transformer rated at 2000 kVA with secondary voltage steps from 35 to 80 volts.

Raw Materials

The chemical analyses of the ore, fluxing materials and reducing agents are given in Tables 1 and 2. A comparison of the reactivities of typical reducing agents is given in Table 3.

About 145 tons of a high grade concentrate of specular hematite and about 147 tons of Nova Scotia coal, were received for the test. The coal was a strongly baking, coking type which was favorable for the production of strong pellets, but the sulphur content was very high. The two cokes were of English and Irish origin and the fluxes were drawn from the stock at the plant.

Pelletizing

The mixture of ore concentrate, coal and Portland cement was ground to an average of 73 per cent minus 200 mesh with a specific surface of 17000 sq.in./cu in. Pelletizing was done on a 5 ft dia rotating disc machine. The pellet size was 5/8 to 1 in. dia and the production rate was 2400 lb/hr. The production of these pellets presented no difficulties.

Information regarding the two types of pellets used in the investigation, is given in Table 4.

Smelting Experiments

The smelting experimental work was divided into eight periods. During the first two periods the pellets were not preheated but were charged cold into the electric furnace. During the last six periods the pellets were preheated and partially reduced in the shaft furnace before final smelting in the electric furnace. A summary of the more important experimental results is given in Tables 5a, 5b and 5c. Additional results are presented in the report issued by Elektrokemisk A/S.

DISCUSSION AND CONCLUSIONS

The experiments summarized in Tables 5a, 5b and 5c showed conclusively that the Julian Iron Co. concentrates can be smelted without any difficulties other than those associated with normal operations, when using the Elektrokemisk method of pelletizing, preheating, prereduction and smelting. It became evident that the Nova Scotia coal used in the experiments, though excellent in some respects, had too high a sulphur content (2.85 per cent) for the purpose. Apparently a lower sulphur coal, either from Nova Scotia or elsewhere, would be required to furnish at least part of the carbon requirements.

The writer would have preferred to have these smelting experiments performed in a pilot-scale three-phase furnace since the final commercial-scale furnaces would be of the three-phase type. However he is convinced that the Elektrokemisk staff are well equipped to design satisfactory commercial-scale equipment for processing the Julian concentrates in view of their many years of experience in this field. By the time the Julian Iron Co. is ready to proceed with this project additional experience will have been gained from the plant at Mo-i-Rana and from a new installation in Portugal which will be using the Elektrokemisk method of preheating and prereducing the material entering the electric pig iron furnace.

ACKNOWLEDGEMENT

The writer wishes to take this opportunity to express his appreciation to the staff of Elektrokemisk A/S, particularly Messrs. F. C. Collin and K. Sandvold, for their kindness and excellent cooperation during his visit in Norway. Through their efforts it was possible not only to be present at the Kristiansand plant during the pilot-plant experiments but also to visit the large electric iron ore smelting plant at Mo-i-Rana.

TABLE 1
Chemical Analysis of Ore and Fluxing Materials

Material	Analysis, Dry Basis (%) [*]						
	SiO ₂	Fe ₂ O ₃	Fe(total)	Al ₂ O ₃	CaO	MgO	Ignition Loss
Ore conc	3.1	--	66.3	0.73	0.17	0.57	--
Limestone	5.01	1.15	--	1.7	48.5	1.12	40.7
Dolomite	4.46	--	0.24	--	30.6	16.7	44.5
Quartz	98.44	--	--	0.62	--	--	--
Bauxite	1.7	23.9	--	60.2	--	--	--
Portland cement	22	--	--	7	66	--	--

* The concentrate also contained 0.2% ferrous iron, 0.02% sulphur and 0.024% phosphorus

TABLE 2a
Chemical Analysis of Reducing Agents

Material	Material Analysis, Dry Basis (%)				
	Volatiles	Ash	Fixed Carbon	S	Reacti- vity*
Nova Scotia coal	31.1	8.7	60.1	2.85	0.96
Coke I: 3/8" -1"	3.5	13.0	83.5	1.33	1.52
Coke II: 3/16" -1"	3.7	11.9	84.3	1.14	1.10

* Compare these values with those in Table 3

TABLE 2b
Chemical Analysis of Reducing Agents-

Material	Ash Analysis (%)				
	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO
Nova Scotia coal	34.1	32.5	18.0	3.9	1.0
Coke I: 3/8" - 1"	45	15	25	3	-
Coke II: 3/16" - 1"		(approximate)			

TABLE 3
Comparison of Reactivities of Typical Reducing Agents

Typical Material	Reducing Power	Reactivity Range
Metallurgical coke	poor	0.1 - 0.3
Anthracite gas coke	medium	0.3 - 0.7
Low temperature coke	good	0.7 - 1.0
Special cokes	good	1.0 - 2.0
Chars	good	> 2.0

TABLE 4
Types of Pellets Used During the Investigation

	Fixed Carbon (lb/ton)	Cement (%)	Quantity Produced (tons)	Used in Smelting Periods
Type I pellet	340	5	110	1 to 6
Type II pellet	244	3	32	7 and 8

TABLE 5a

Results of Experimental Smelting

Period No.	Duration (hr)	Raw Materials (dry basis) (lb)						
		Pellets	Coke I	Coke II	Dolomite	Limestone	Quartz	Bauxite
1	21.9	16071	1219	--	883	439	737	82
2	42.0	30735	2298	--	1689	675	1247	338
3	23.4	26717	1623	--	1545	662	890	221
4	29.0	32863	2397	--	1901	1066	1086	272
5	35.8	31528	567	1519	1823	2272	1316	781
6	12.1	12826	--	980	1801	1272	954	530
7	31.8	30856	1245	2161	2826	2260	1272	848
8	20.4	17839	1157	784	1634	1307	837	490

TABLE 5b
Results of Experimental Smelting (contd)

Period No.	Shaft Furnace		Electric Furnace Products		Electrical Data		
	Preheating Temp (°F)	Reduction (%)	Metal (lb)	Slag (lb/net ton of metal)	Volts	kW	kWh
1			8664)) 16046)	600	(75 (66	357 347	7810 14570
2	1535))	26.9	(13514) () (18274)	610	(48 (46	344 350	8050 10140
3	1535)		(17733 (760	48	307	10980
4	1490)	19.1	(6550	1200	52	357	4320
5	1435))		(18232) () (10196)	700	(48 (44	389 358	12360 7300
6							
7							
8							

TABLE 5c
Results of Experimental Smelting (concluded)

Period No.	Analyses (%)							Consumption Data (per net ton of pig iron)		
	Metal			FeO	Slag		kWh (corrected to 1% Si)	Electrode (lb)	Fixed Carbon (lb)	
	Si	C	S		CaO+MgO	S slag				
				SiO ₂		S metal				
1	2.62	2.09	0.38	1.15	1.19	3.6	1660	17.6	584	
2	1.93	1.91	0.49	3.08	1.12	2.0	1735	12.4	599	
3	1.45	1.98	0.49	2.84	1.15	1.9	1155	9.4	572	
4	1.42	2.05	0.41	2.30	1.18	2.7	1070	8.4	557	
5	1.32	2.10	0.48	3.28	1.27	1.8	1210	9.4	532	
6	1.50	2.59	0.23	0.96	1.51	5.6	1275	--	--	
7	1.47	3.22	0.21	1.03	1.43	4.8	1315	6.2	559	
8	2.05	3.46	0.12	0.67	1.55	12.2	1340	6.4	572	