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TESTING OF RAW MATERIALS FOR CANADIAN JAVELIN LIMITED.

Elektrokemisk A/S,
Research Laboratory
Kristiansand S., NORWAY.

TESTING OF RAW MATERIALS FOR CANADIAN JAVELIN LIMITED

Samples:
40 kg Nova Scotia coal, our ref. no. 7348
22 " Julian concentrate, " " " 7349 A
20 " Wabush " , " " " 7349 B
Date of arrival : November 6th. 1961.

I. INTRODUCTION

The above samples have been received from Canadian Javelin limited for evaluation as raw materials for electric pig iron smelting.

A new and promising method developed by Elektrokemisk involves agglomeration of the concentrate by pelletizing a mixture of ore, coal and a binder. The green pellets are hardened by storage or drying. The hardened pellets with some coke and fluxes added, are preheated in shafts followed by electric smelting. By preheating and partly prereducing the charge, a considerable decrease in electric power consumption is obtained.

Consumption figures on raw materials, fluxes and electric power and other operational data can only be established by a smelting test in our pilot plant. The purpose of the present laboratory investigation has been to evaluate the suitability of the ore and the coal for the pellet process. The report covers examination of the composition and the coking properties of the coal and examination of the ore. Pellets have been produced from ore and coal including Portland cement or sulfite lye as binders. The strength of the pellets were tested at various temperatures, and their reducibility has been examined.

II. CONCLUSIONS.

The Nova Scotia coal has favourable coking properties for use in pellets.

The concentrates should be further ground to get a suitable fineness for making pellets. Coal and concentrate of correct fineness, including 3 to 5 % Portland cement as a binder give pellets of good quality, and these pellets may then be smelted without difficulty. Pellets with 1,5 % evaporated sulfite lye as a binder are not so strong, but may probably be used as a raw material for the smelting process.

The reduction rate of the pellets was found to be as normal for hematite pellets. The reduction rate of these pellets is high compared with the reduction rate of sintered pellets with a reducing agent of the same reactivity.

No difference has been found between the behaviour of the Wabush and the Julian concentrates. Smelting test results on the Wabush type, should consequently also be valid for the Julian ore.

III. PRINCIPLES

The intimate mixture of ore and reducing agent in the ore/coal pellets, always causes a high rate of reduction, independent of the mechanical strength of the pellets. We therefore regard the strength of the pellets to be the most important quality criterion for electric smelting. Pellets including coal, get their strength at elevated temperatures from the coke grid formed during the carbonization of the coal. The strength therefore depends on the coking properties of the coal. We have found that coals with high swelling indices and high Gray King coke indices give pellets of good quality.

We normally add cement as a binder. After hardening, the cement bonded pellets will be strong enough to withstand handling by belt conveyors and by weighing and charging equipment. The cement also makes the pellet strong enough to withstand handling at lower temperatures in the shaft or smelting furnace.

Sulfite lye may also be used as a binder. In this case, the pellets are not stored but completely dried to make them sufficiently strong for transport and charging.

IV. RAW MATERIALS

The raw materials used are listed below:
Julian concentrate, our ref. no. 7349 A

Wabush concentrate, our ref. no. 7349 B
Nova Scotia coal, " " " 7348
Norwegian rapid hardening Portland cement of standard composition.
Evaporated sulfite lye, "Totanin".

V. PROCEDURE.

A. EXAMINATION OF THE IRON CONCENTRATES.

The iron content of the concentrates was determined by chemical analyses.

The particle size distribution of the concentrate as received was determined by sieve analyses. To get a suitable grain size for pelletization the concentrates were ground in a laboratory ball mill for 90 minutes. The granulometry of the ground products was determined by sieving on a 200# U.S. sieve, and by determining the specific surface area, (air permeability method developed at the Royal Technical University of Sweden. This method is generally adopted in Sweden).

B. EXAMINATION OF THE COAL.

The composition of the coal was determined by proximate analyses according to the A.S.T.M. standard methods D 271-44. The sulphur content was determined by chemical analysis. To examine the distribution of the coal's sulphur between coke and volatiles, the sulphur content of a sample calcined at 1050°C, was also determined.

The swelling index and the Gray King Coke index of the coal were determined according to the proposed international standard methods. (Second proposed draft ISO-recommendation for the determination of the Gray King coke type of coal, document ISO/TC 27,365, March 1958. Revised draft ISO-proposal for the determination of crucible swelling no. of coal, document ISO/TC 27, 483, September 1959).

Based on the content of volatiles, the swelling index and Gray King coke index the coal has been classified according to the proposed international classification system.

The reactivity of the carbonized coal was determined according to a method developed in this laboratory. The coal sample was calcined at 1050°C, and a - 20+40 # U.S. fraction sample was prepared. A fixed volume of this fraction was placed in the middle of a vertical tube furnace, which was kept at 1000 ± 1°C. At this temperature a slow stream of CO_2 was passed through the coke bed. The degree of CO_2 converted to CO was measured. Assuming the Boudouard reaction to be of the first order, $Y = -\ln(1-x)$, where X is the degree of conversion of CO_2, is an expression of the reaction rate at 1000°C, which we denote as reactivity. Due to the wide range of ash contents and volume weight figures for various reducing agents, we recalculate the reactivity to correspond to a sample containing 5 g fixed carbon.

To make it suitable for pelletization the coal was ground in a laboratory ball mill for 90 minutes. The grain size of the milled coal was determined by sieving on a 200 # U.S. sieve.

C. PRODUCTION OF PELLETS.

Pellets were produced batchwise in a laboratory drum pelletizer. The pellets prepared in the laboratory, have previously proven to be of the same quality as pellets produced continuously in the disc pelletizer at our pilot plant, provided the raw materials are identical.

The charge compositions are listed in appendix 1.

D. TREATMENT OF PELLETS

The cement bonded pellets were stored for 3 or 5 days, depending on the amount of binder, and subsequently heat treated as described below. Pellets with sulfite lye as a binder were dried in an air stream at 70°C for about 1 hour.

The pellets were heat treated at temperatures from 700 to 1000°C in closed but, untight steel sheet boxes. During the treatment the volatiles escape, and a reaction takes place between the carbon and the iron oxide. The escaping gases protect the pellets against atmospheric oxygen. On cooling the boxes, a slight reoxidation may take place. Pellet strength will, however, not

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be influenced by this effect.

To determine the rate of reduction the pellets were heat treated at temperatures from 700 to 1000°C in a container of heat resisting steel, shown in appendix 2. To protect the pellets against oxidizing gases, purified nitrogen was led into the container during the complete heating and cooling cycle.

Heating was in both cases carried out in high capacity furnaces. Both types of containers were inserted at operating temperatures. For strength measurements, the time at the temperature in question was 60 minutes, while 30 minutes were applied in the reduction test.

E. EXAMINATION OF THE PELLETS.

Green pellets were tested for strength. Such testing was repeated after storage or drying and after heat treatments.

Strength figures were obtained by two different methods. The crushing strength was determined in an apparatus applying constant rate of load increase until rupture. Strength values reported are means of 10 single measurements. The drop strength was taken as the height from which a number of pellets can be dropped to give 50 % breakage.

The pellets heat treated under protecting gas in the steel container were analysed on metallic iron, bivalent iron and total iron. The degree of oxidation was calculated according to the formula

$$\text{Degree of oxidation} = \frac{Fe^{3+} + 2/3\ Fe^{2+}}{Fe_{(tot)}} \cdot 100\ \%$$

VI. RESULTS.

Appendix 3 and 4 give the results of the examinations of the ores and coal, respectively.

The strength figures obtained on the pellets are presented in appendix 5.

Analyses of the reduced pellets are given in appendix 6.

VII. DISCUSSION

A. RAW MATERIALS

1. Concentrates

The total composition of the ore has not been examined by us. We have, however, been informed through our New York office that the concentrate contains about:

6,0 % SiO_2
0,6 % Al_2O_3
0,3 % CaO
0,2 % MgO

The cement added as a binder, consisting of about 65 % CaO, 20 % SiO_2, 6 % Al_2O_3 and 3 % MgO, will thus furnish the charge with some of the necessary slag constituents.

The ore as delivered, is too coarse for pelletizing and should be ground to a specific surface of 7000 to 10000 cm^2/cm^3. The samples used in the laboratory examinations might have been coarser, and still been suitable for pelletization.

No difference is found between the behaviour of the Wabush and the Julian concentrates in the pellets. The results obtained on smelting the Wabush ore, should therefore also be valid for the Julian concentrate which is the raw material in question for the planned steel work.

2. Coal

The coal has favourable coking properties for good pellet strength.

The sulphur content of the coal is high. % sulphur in coke produced in the laboratory, is the same as in the coal. This means that 1/3 of the sulphur is distilled from the coal with the volatiles.

The estimated coal consumption is 300 kg pr. ton of pig iron (175 kg fixed carbon/950 kg Fe). The rest of the carbon which is necessary for reduction should be added as coke.

To evaluate the reactivity of the coal, the reactivity ranges for different reducing agents are listed in appendix ~~3~~ 4. The Nova Scotia coal thus has a good reducing power.

B. STRENGTH OF PELLETS.

As stated previously we regard the strength of the pellets to be a very important criterion on their quality. Pilot plant smelting tests have shown that a compression strength of about 20 kg is the lowest permissable limit to secure good furnace performance. Consequently, the cement bonded pellets are strong enough, while the pellets bonded with sulfite lye lie close to the lower limit. These pellets also have a rather low drop strength at 800°C.

5 % cement give enough strength for transportation and charging, 3 % seem, however, to be too low. By a conservative estimate the consumption of cement should be between 4 and 5 %.

C. RATE OF REDUCTION.

The rate of reduction found by testing pellets of Javelin raw materials, is in very good agreement with the reactivity of the coal.

The % degree of oxidation depends on time- and temperature conditions in the shaft. The best overall results from shaft/electric furnaces will be established in the forthcoming smelting tests in our pilot plant.

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CHARGE COMPOSITIONS FOR LABORATORY TESTS. WEIGHTS IN GRAMS.

Charge No.	1	2	3	4	5	6
Julian concentrate	2470		2435		2385	
Wabush concentrate		2460		2420		2370
Nova Scotia coal	485	475	475	490	465	480
Norwegian rapid hardening Portland Cement			90	90	150	150
Evaporated sulfite liquor	45	45				

The amount of coal in the charges corresponds to 175 kg's fixed carbon pr. metric ton of pig iron (950 kg Fe).
Charges 1 and 2 contain 1,5 % evaporated sulfite liquor, charges 3 and 4, 3 % cement and charges 5 and 6, 5 % cement.

Appendix 1.

Pellet charges of raw materials from Canadian Javelin Limited.	ELEKTROKEMISK A/S OSLO — NORWAY Report no. 2 34 22. November 1961

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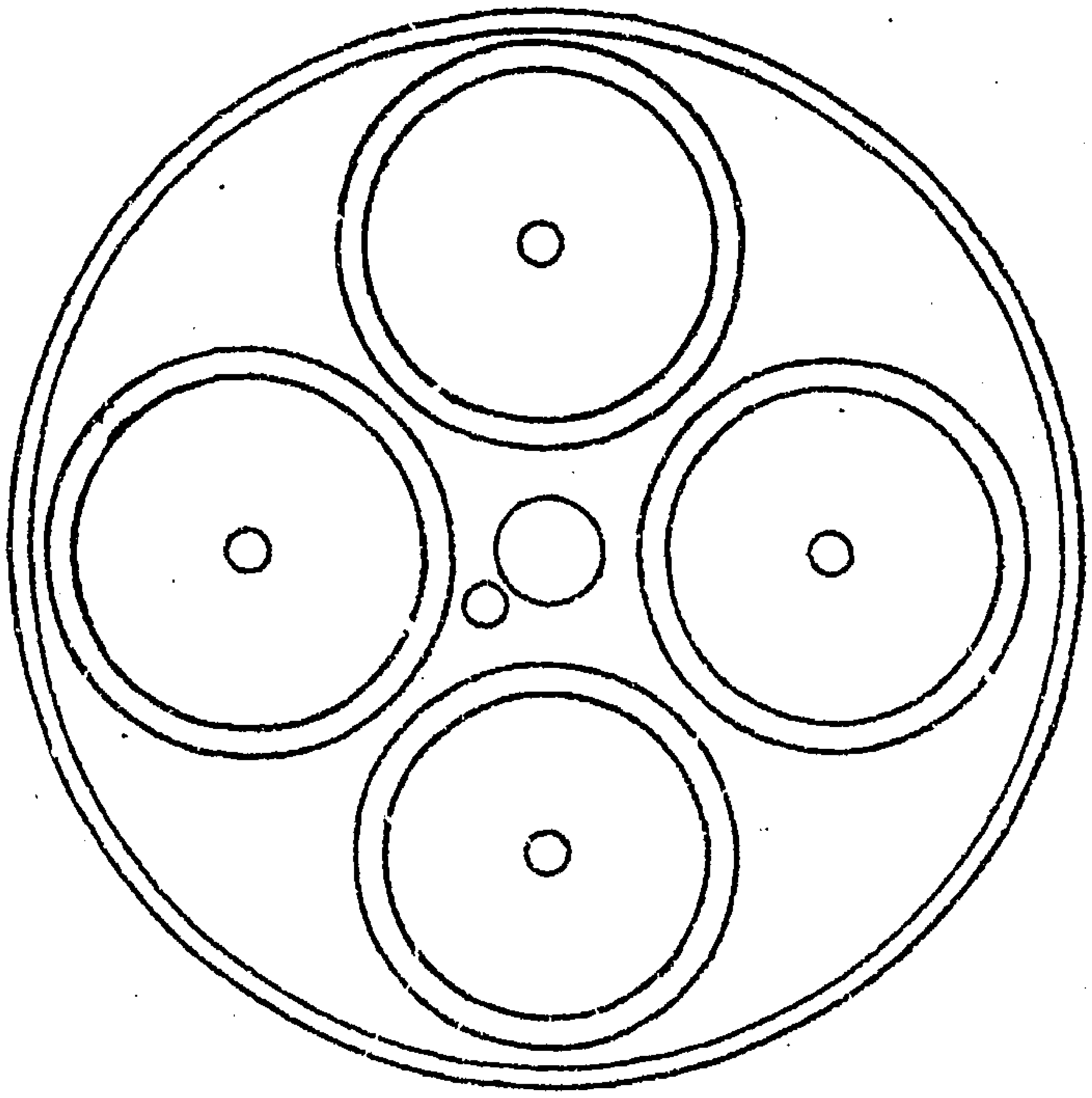

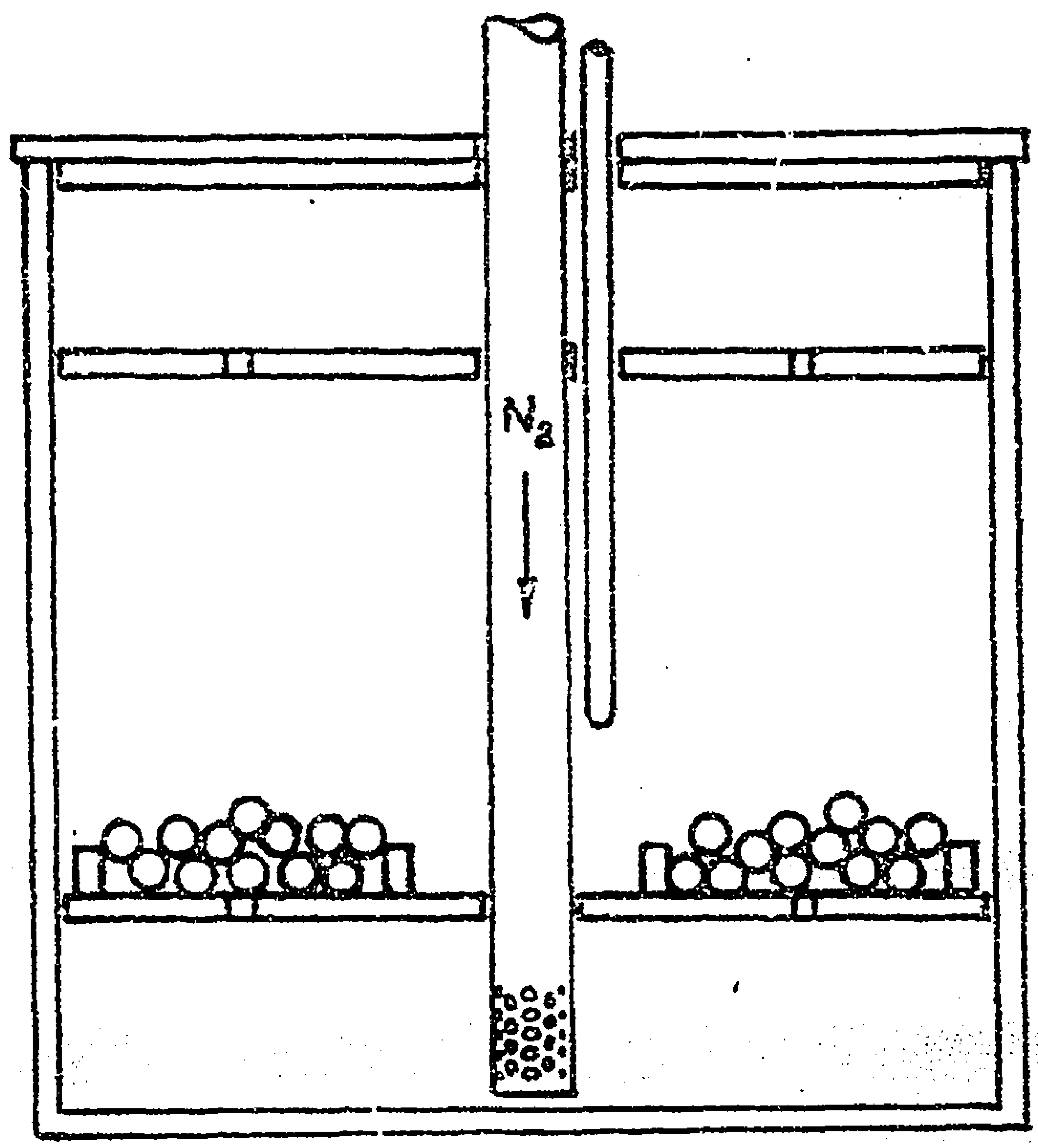

Appendix 2.

Steel container for treatment of pellets at higher temperatures.

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Iron content of concentrates:

Julian, our ref. no.	7349 A :	64,9 % Fe
Wabush, " " "	7349 B :	66,7 % Fe

Sieve analyses of concentrates as received.

	Wabush	Julian
U.S. sieve no.	7349 B	7349 A
+ 20 #	0,1 % cum	0,8 % cum
+ 50 #	20,1 " "	38,8 " "
+100 #	69,6 " "	78,3 " "
+200 #	96,0 " "	98,1 " "
-200 #	4 %	1,9 %

Sieve analyses and specific surface areas of milled concentrates.

	Wabush	Julian
U.S. sieve no.	7349 B	7349 A
+200 #	23 %	22 %
-200 #	77 %	78 %
Specific surface area	8500 cm^2/cm^3	9700 cm^2/cm^3

Appendix 3.

Examination of concentrates from Canadian Javelin Limited.	ELEKTROKEMISK A/S OSLO — NORWAY Report no. 2734 22. November 1961

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COMPOSITION AND PLASTIC PROPERTIES OF NOVA SCOTIA COAL.

Water content	2,5 %
Proximate analysis	
Ash:	5,5 %
Volatiles:	33,4 %
Fixed carbon:	61,1 %
Sulphur	2,27 %
Swelling index	8
Gray King coke index	10
International classification no.	635
Sulphur content of coal sample calcined at 1050°C :	2,28 %
Reduction of sulphur content: about	1/3.

Reactivity : 1,36

Reactivity ranges for various types of reducing agents

Reactivity range	Reducing power	Typical materials
0,1 - 0,3	Poor	Metallurgical coke
0,3 - 0,7	Medium	Antracite, gas coke
0,7 - 1,0	Good	Low temperature coke
1,0 - 2,0	"	Special cokes
> 2,0	"	Chars

Appendix 4.

Examination of Nova Scotia coal from Canadian Javelin Limited.

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Appendix 5.

Charge no.		1	2	3	4	5	6
Green pellets	Crushing strength, kg.	5,0	5,3	4,4	5,5	5,1	4,5
	Drop strength,cm.	180	190	150	180	195	165
Stored for 3 days	Crushing strength, kg.	-	-	-	-	35,2	42,8
	Drop strength, cm.	-	-	-	-	200	250
Stored for 5 days	Crushing strength, kg.	-	-	17,9	23,8	-	-
	Drop strength, cm.	-	-	165	210	-	-
Dried at about 70°C	Crushing strength, kg.	36,0	42,6	-	-	-	-
	Drop strength, cm.	70	90	-	-	-	-
Heat treated at 700°C	Crushing strength, kg.	52,0	66,8	109	94,4	167	141
	Drop strength, cm.	165	200	>300	>300	>300	>300
800°C	Crushing strength, kg.	28,2	29,4	35,0	48,3	42,6	38,0
	Drop strength, cm.	135	130	210	>300	225	220
900°C	Crushing strength, kg.	22,2	29,2	53,3	45,1	64,8	52,0
	Drop strength, cm.	190	265	>300	>300	>300	>300
1000°C	Crushing strength, kg.	46,7	57,8	>180	160	84,7	69,8
	Drop strength, cm.	300	>300	>300	>300	>300	>300

Strength figures for pellets of raw materials from Canadian Javelin Limited.

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Charge no.	Heat treated at	Analyses % Fe (met)	% Fe^{2+}	% Fe_{tot}	% Fe^{3+}	Degree of oxidation %
3	700°C	0	24,2	57,6	33,4	86,0
4	700°C	0	27,3	59,8	32,5	84,8
3	800°C	0	52,4	62,2	9,6	71,8
4	800°C	0	53,6	62,3	8,9	71,4
3	900°C	25,7	44,8	72,9	2,4	44,3
4	900°C	24,7	48,1	73,1	0,3	44,3
3	1000°C	64,7	16,7	84,6	3,2	16,9
4	1000°C	64,2	20,4	84,6	0,0	16,1

Appendix 6.

Degree of oxidation of pellets after heat treatment.

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