

Report Title:

**PHASE II CALDERON PROCESS TO PRODUCE
DIRECT REDUCED IRON
RESEARCH AND DEVELOPMENT PROJECT**

Report Type:

QUARTERLY

Reporting Period Start Date: **04/01/2005** End Date: **06/30/2005**

Principal Author(s): **ALBERT CALDERON**

Report Issue Date: **07/29/2005**

DOE Award No.: **DE- FC22 -95PC92638**

Submitting
Organization(s)

CALDERON ENERGY COMPANY

500 Lehman Avenue

Name & Address

P.O. Box 126

Bowling Green, OH 43402

(1)

(2)

(3)

(4)

(5)

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

QUARTERLY TECHNICAL PROGRESS REPORT

PHASE II CALDERON PROCESS TO PRODUCE DIRECT REDUCED IRON RESEARCH AND DEVELOPMENT PROJECT

CALDERON ENERGY COMPANY
COOPERATIVE AGREEMENT NO. DE-FC22-95PC92638

Reporting Period: 4-1-05 to 6-30-05

Date of Report: 7-29-05;

Phase II Award Date: 6-23-00; Anticipated Completion Date: 12-03-05

Total Project: \$ 14,732,316.00 Total DOE Share This Action: \$6,457,000.00

Contracting Officer's Representative (COR): John Stipanovich;

Project Director: Albert Calderon

Assistant Project Director: Reina Calderon

Abstract

This project was initially targeted to the making of coke for blast furnaces by using proprietary technology of Calderon in a phased approach, and Phase I was successfully completed. The project was then re-directed to the making of iron units. In 2000, U.S. Steel teamed up with Calderon for a joint effort which will last 42 months to produce directly reduced iron with the potential of converting it into molten iron or steel consistent with the Roadmap recommendations of 1998 prepared by the Steel Industry in cooperation with the Department of Energy by using iron ore concentrate and coal as raw materials, both materials being appreciably lower in cost than using iron pellets and coke.

TABLE OF CONTENTS

Executive Summary	Page 1
Experimental	Page 2
Results and Discussion	Page 3
Conclusion	Page 5
References	Page 6

Executive Summary

The commercialization path of the Calderon technology for making a feedstock for steelmaking with assistance from DOE initially focused on making coke and work was done which proved that the Calderon technology is capable of making good coke for hard driving blast furnaces. U.S. Steel which participated in such demonstration felt that the Calderon technology would be more meaningful in lowering the costs of making steel by adapting it to the making of iron - thus obviating the need for coke.

U.S. Steel and Calderon teamed up to jointly work together to demonstrate that the Calderon technology will produce in a closed system iron units from iron concentrate (ore) and coal competitively by eliminating pelletizing, sintering, coking and blast furnace operation. If such process steps could be eliminated, a huge reduction in polluting emissions and greenhouse gases (including CO₂) relating to steelmaking would ensue. Such reduction will restructure the steel industry away from the very energy-intensive steelmaking steps currently practiced and drastically reduce costs of making steel.

The development of a technology to lower U.S. steelmaking costs and become globally competitive is a priority of major importance. Therefore, the development work which Calderon is conducting presently under this Agreement with the U.S. Department of Energy becomes more crucial than ever.

During the 2nd quarter of 2005 which the present report covers, five test runs were conducted; they numbered from #I-179 to #I-183. In addition, analytical results were received from U.S. Steel relating to the metallization of Calderon's iron/carbon material produced in Test Run #I-178, drum C, which are encouraging in view of the work that had been done by Iscor, the largest steel company in South Africa.

Experimental

Table 1 shows the test run numbers, the dates at which time they were started; the length of each test, and the number of pushes of each test. The total number of hours was about 300 hours and the number of pushes around 3350. The main objective of these runs was to conduct tests of 60 hours each with experimental work to accomplish two goals:(i) work towards the 72 hour tests at reasonably steady state with 80% metallization; and (ii) overcoming the problem of the sliding gate sticking which was referenced in the “Conclusion” section of the previous report.

TABLE 1

Objectives	Test Run #	Date Started	Duration	Number of Pushes
Run for 80% Metallization	179	April 5	61 hrs: 00 mins.	700
Run for 80% Metallization	180	April 12	59 hrs: 00 mins.	665
Run for 80% Metallization	181	April 19	58 hrs: 45 mins.	659
Run for 80% Metallization	182	April 26	59 hrs: 45 mins.	664
Run for 80% Metallization	183	May 3	59 hrs: 45 mins.	664

Total number of hours - 298 hrs: 15 mins.

Total number of pushes - 3352

Total weight of ore concentrate used - 8,799 lbs.

Total weight of steam coal used - 6,285 lbs.

Results and Discussion:

To determine the degree of metallization on the fly, the practice of grinding samples continued as previously done and explained in previous reports; see photograph 1. Four samples would be taken every hour after reaching steady state (18 hrs. from ignition) and six grinds would be performed on each sample. The number of sparked grinds would be considered as metallized and the number of unsparked grinds would represent the unreduced or over-reduced material. Table 2 shows the number of samples taken during each test run, and the number of grinds that sparked as compared to the number of grinds that did not spark.

TABLE 2

Test Run Number	Number of Samples	Sparked Grinds	Unsparked Grinds	Total Grinds	% of Grinds Metallized (Sparked)
179	44	1019	133	1152	88.45%
180	40	772	188	960	80.42%
181	40	873	130	1003	87.04%
182	40	824	111	935	88.12%
183	42	840	158	998	84.17%

Test Run #179 was conducted the same as Test Run #178. In order to increase metallization the dwell time of Test Run #180 was lengthened. This change developed pushing problems by virtue of material sticking again. During test #180 at push #98 the pushing pressure started rising more than normal which is between 80 psi and 300 psi; it registered a pushing pressure of 625 psi. At push #100 it registered at 615 psi and at push #120, it registered at 980 psi; at push #131, it registered at 249 psi, at push #164 it registered at 810 psi; it continued fluctuating abnormally until it stalled at push 263. The lance was moved out to home position to give relief, this did not help. The material at the discharge was poked to get it unstuck.

After several tries the material at the discharge end of the reactor was loosened and the ram of the pusher began functioning again. It was concluded that the dwell time of the lance within the core which had been lengthened in an attempt to improve metallization in the reactor, was the cause for the aggravated sticking experienced since no other change was made between Test Run #I-179 and #I-180. The dwell time was reset as that of Test Run #179 and testing resumed normally. There was a loss of 55 minutes to the operation. Following the sticking problem the rest of Test Run #I-180 operated smoothly until shut down. Test Run #181, #182, and #183 were uneventful and were shut down on schedule.

The problem experienced with the gate sticking which was reported in the previous report was corrected by introducing in the practice that every ten minutes the sliding gate be cracked-open 3" inches and immediately shut in order to break-up any build-up between the gate itself and the housing within which it is contained. This small change proved to be effective during the five runs.

The results of the material sent to U.S. Steel, Drum "C" from Test Run #178, were received and the metallization was determined to be a composite average of 56.3% after five crushings; see Exhibit 1 attached. In view of the due diligence work done by Calderon 56.3% metallization is no cause for discouragement.

To secure intellectual property protection Calderon filed for patent protection for its technology for making iron in many countries including South Africa; a patent was recently granted to Calderon from South Africa; see Exhibit 2 attached. The U.S. patent had been granted in 2002.

In 1995 a U.S. patent was issued to Mr. Fourie bearing No. 5,411,570 for a steelmaking process which was assigned to Iscor, the largest steelmaker in South Africa. Iscor is the

owner of the “IFCON” technology to make steel direct. In Fourie’s patent a portion of which is attached and marked Exhibit 3, it is disclosed on line 65, Column 5, an example (denoted by “Example III (Without Hot Metal)”) that the charging of 87 tonnes of hot (700°C) 65% metallized sponge iron and 20 tonnes of cold scrap metal and the furnace operated at a power rating below 30MW to produce more than 90 tonnes of steel/hour; it is to be noted that lines 13 through 18 (Column 6), Exhibit 3, page 2 states the following: “It can be seen that although the lower metallization of the sponge iron of this example compared to that of Example II allows much higher production rates in the shaft furnace producing the sponge iron, it does not significantly alter the production rate or treatment cost for the process performed in furnace 10.” By adding 700°C to 87 tonnes of 65% metallized sponge iron, Iscor was capable of replacing 83 tonnes of 91% metallized sponge iron (see lines 48 and 49, Column 5).

Based on the numbers of Iscor, Calderon estimates that its material metallized to 56% would require 88.38 tonnes of material at a temperature of 942°C to make 90 tonnes of steel per hour. Calderon is capable of delivering hot material at 1000°C without difficulty; see photograph 2.

Conclusion

In view of these findings, Calderon has requested a meeting with U.S. Steel to explore the possibility of venturing with Iscor by virtue that it has a technology and Calderon has a technology, in both the U.S. and in South Africa, and these technologies appear to be complimentary to each other. Such an approach will get DOE’s Program of making feedstocks for steelmaking off-dead-center and produce hot metal based on low cost ore concentrate and cheap steam coal consistent with the 1998 Steel Industry Technology Roadmap, page 11, and

also, consistent with the potential benefits outlined in the last two paragraphs of page 754 (Exhibit 4) of the “The Making, Shaping and Treating of Steel, 11th Edition, Steelmaking and Refining Volume”.

Submitted by:

Albert Calderon
Project Director

References -

U.S. Patent No. 5,411,570 - Issued to Fourie, Assigned to Iscor

U.S. Patent No. 6,409,790B1 - Issued to Calderon, Assigned to Calderon Energy

South African Patent WO 02/075002 A1, Assigned to Calderon Energy

“The Making, Shaping and Treating of Steel, 11th Edition,
Steelmaking and Refining Volume”, Page 754

From: "David M Rohaus" <DRohaus@uss.com>
To: <acalderon@bghost.net>
Cc: "Kevin L Zeik" <KZeik@uss.com>
Sent: Tuesday, May 10, 2005 3:28 PM
Attach: April 05 Sample analysis-02725.pdf; Run I-178 Drum C (Apr - 05).xls
Subject: Sample Analysis

Mr. Calderon.

apologize for taking this long to get back to you.

We've analyzed the drum of material you sent us a little over a month ago and found the metallization rate to be about 56%.

Upon receiving the sample, the material was initially screened to 1/4 inch and the undersize was then crushed and screened 4 more times before a representative samples of both the +1/4 inch and -1/4 inch material was sent to the chem lab. The first sheet in the attached work book contains the results of each crushing and screening cycle.

The attached adobe file contains the results of the sample analyses. Sample #1 is the -1/4 inch results.

The chem results where combined with the weight results to calculate the metallization rate. The calculations are shown on the second sheet in the workbook.

As before, we assumed the uncrushable material was essentially pig iron and we also assumed that the amount of material that could not be crushed to less than 100 mesh by the chem lab was also pig iron.

I believe that the metallization of this sample is higher since you screened it before sending it to us. As I believe I mentioned before, I think that the product collected after screening should be at least 80% metallized before we consider the effect of recycling the undersized material.

Please call if you have any questions.

Thanks.

(See attached file: April 05 Sample analysis-02725.pdf)(See attached file: Run I-178 Drum C (Apr - 05).xls)



Clark Analytical Chemistry Lab
 4000 Tech Center Drive
 Monroeville, PA 15146
 Phone: (412) 825-2400 Fax: (412) 825-2407

05/10/2005
Final

Report of Test Results
 Crawford - Calderon

Contact: Crawford/Rohaus
Address: Crawford/Rohaus
 U.S. Steel Technical Center
 Cost Center - 4701
 MS A-60

Tracking Sheet Number: 05-02725
Customer P.O. Number: 345585
Date Received: 04/21/2005

Test Name	Test Method	Analyte	Result	Units	Test Date
Sample No: 0510511 Customer ID: 2005-00-0003 #1					
Major Oxides (XRF)	13-014/13-010	SiO2	10.46	wt. %	05/05
	13-014/13-010	Al2O3	4.45	wt. %	05/05
	13-014/13-010	CaO	1.81	wt. %	05/05
	13-014/13-010	MgO	2.56	wt. %	05/05
Minor Oxides (XRF)	13-014/13-010	MnO	0.32	wt. %	05/05
COI	13-016	Change on Ignition	+ 4.94	wt. %	05/05
Sample Preparation		Passing 100 mesh	116.15	g	05/05
		Retained on 100 mesh	17.23	g	05/05
Iron, metallic	14-006	Metallic Iron	26.27	wt. %	04/28
Total Fe (wet chem)	14-017	Total Iron	62.67	wt. %	04/28
Carbon & Sulfur	E1019	Carbon	9.76	wt. %	05/05
	E1019	Sulfur	0.40	wt. %	05/05
Sample No: 0510512 Customer ID: 2005-00-0003 #2					
Major Oxides (XRF)	13-014/13-010	SiO2	12.30	wt. %	05/05
	13-014/13-010	Al2O3	5.26	wt. %	05/05
	13-014/13-010	CaO	1.94	wt. %	05/05
	13-014/13-010	MgO	2.99	wt. %	05/05
Minor Oxides (XRF)	13-014/13-010	MnO	0.35	wt. %	05/05
COI	13-016	Change on Ignition	+ 13.80	wt. %	05/05
Sample Preparation		Passing 100 mesh	88.23	g	05/05
		Retained on 100 mesh	110.73	g	05/05
Iron, metallic	14-006	Metallic Iron	34.31	wt. %	04/28

Test Name	Test Method	Analyte	Result	Units	Test Date
Sample No: 0510512	Customer ID: 2005-00-0003 #2				
Total Fe (wet chem)	14-017	Total Iron	71.26	wt. %	04/29
Carbon & Sulfur	E1019	Carbon	2.87	wt. %	05/05
	E1019	Sulfur	0.45	wt. %	05/05

This report shall not be reproduced except in full, without the written approval of Clark Laboratories.

Approved By: _____ **Date:** _____

end of report

Calderon Data Sheet

4/8/05

Drum ID	Run I-178 Drum C
Drum Weight	32.96
Product Weight	351.33

After First Crush

Plus 1/4 Inch Weight	290.65
Minus 1/4 Inch Weight	59.87
Uncrushable	0.0
Total	350.52

After Second Crush

Plus 1/4 Inch Weight	148.88
Minus 1/4 Inch Weight	200.61
Uncrushable	0.15
Total	349.64

After Third Crush

Plus 1/4 Inch Weight	93.32
Minus 1/4 Inch Weight	256.22
Uncrushable	0.15
Total	349.69

After Fourth Crush

Plus 1/4 Inch Weight	61.76
Minus 1/4 Inch Weight	287.63
Uncrushable	0.15
Total	349.54

After Fifth Crush

Plus 1/4 Inch Weight	46.86
Minus 1/4 Inch Weight	302.47
Uncrushable	0.15
Total	349.48

Sample was crushed in the big jaw crusher for the first crusher
The second third fourth and fifth crush was in the small jaw crusher

Apr-05						
.						
Run I -178 Drum C	Weight, lb.	%				
Uncrushable	0.15	0.04				
+1/4 Inch	46.86	13.41				
- 1/4 Inch	302.47	86.55				
Total	349.48	100.00				
Uncrushable*		Chemistry Assumed to be that of Feb 18, 2003 Test				
Fe Total	95.60					
Fe Met**	95.60					
(**assumed all metallic)						
C	0.022					
S	0.514					
+ 1/4 Inch	+100 Mesh	-100 Mesh	Composite			
%	44.30	55.70	100.00			
Fe Total	95.60	71.26	82.04			
Fe Met	95.60	34.31	61.46			
C	0.022	2.870	1.608			
S	0.514	0.450	0.478			
- 1/4 Inch	+100 Mesh	-100 Mesh	Composite			
%	13.00	87.00	100.00			
Fe Total	95.60	62.67	66.95			
Fe Met	95.60	26.27	35.28			
C	0.022	9.760	8.494			
S	0.514	0.400	0.415			
Overall						
	Wt. Fraction, %	Fe Total	Fe Met	% Met	C	S
Uncrushable	0.04	95.60	95.60	100.00	0.022	0.514
+1/4 Inch	13.41	82.04	61.46	74.9	1.608	0.478
- 1/4 Inch	86.55	66.95	35.28	52.7	8.494	0.415
Composite	100.00	68.99	38.82	56.3	7.57	0.42



PATENTS ACT, 1978

CERTIFICATE

In accordance with section 44 (1) of the Patents Act, No. 57 of 1978, it is hereby certified that

CALDERON ENERGY COMPANY OF BOWLING GREEN, INC.

has been granted a patent in respect of an invention described and claimed in complete specification deposited at the Patent Office under the number

2003/7071

A copy of the complete specification is annexed, together with the relevant Form P2.

In testimony thereof, the seal of the Patent Office has been affixed at Pretoria with effect

from the **24th** day of **November 2004**

.....
Registrar of Patents

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
26 September 2002 (26.09.2002)

PCT

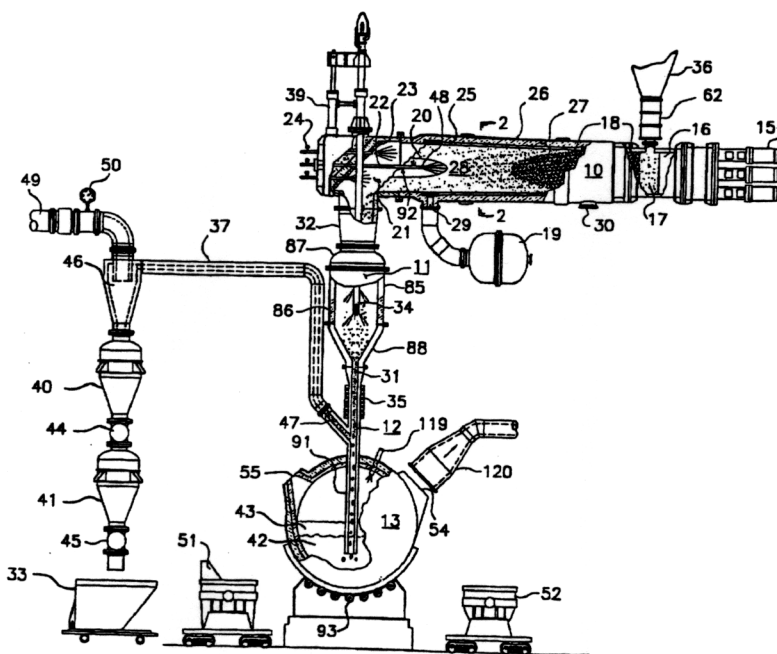
(10) International Publication Number
WO 02/075002 A1

- (51) International Patent Classification⁷: **C21B 13/14**
- (21) International Application Number: PCT/US02/06109
- (22) International Filing Date: 28 February 2002 (28.02.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
09/808,963 16 March 2001 (16.03.2001) US
- (71) Applicant: **CALDERON ENERGY COMPANY OF BOWLING GREEN, INC.** [US/US]; 500 Lehman Avenue, Bowling Green, OH 43402 (US).
- (72) Inventors: **CALDERON, Albert**; 1065 Melrose, Bowling Green, OH 43402 (US). **LAUBIS, Terry, James**; 14377 Powell Road, Portage, OH 43451 (US).
- (74) Agents: **SCHURR, Donald, A.** et al.; Marshall & Melhorn, LLC, Four SeaGate - 8th Floor, Toledo, OH 43604 (US).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR PRACTICING CARBONACEOUS-BASED METALLURGY



(57) Abstract: An energy efficient, coal-based method and apparatus, a reactor (10) that are environmentally friendly which produce under pressure metallized/carbon product and molten metal directly from abundant coal or other carbonaceous material, and low cost fines (or ore concentrate) wherein the molten metal is devoid of gangue material and possesses the inherent advantage of retaining the sensible heat for subsequent processing.

I Claim:

1. A method for thermally processing a metallic oxide with a carbonaceous material in one or more chambers, wherein each of the one or more chambers has a charging end and a discharging end, to produce a hot metallized/carbon product which is subsequently melted in a melter to make a molten metal and a molten slag, comprising:

feeding the metallic oxide and the carbonaceous material to the charging end of said one or more chambers and forcing the metallic oxide and the carbonaceous material toward the discharging end of said one or more chambers;

injecting an oxidant in such a way as to utilize at least a portion of the energy contained in said carbonaceous material to release thermal energy and produce pressurized reducing gases to reduce the metallic oxide to form a hot metallized/carbon product;

discharging said hot metallized/carbon product from said one or more chambers into the melter;

heating the metallized/carbon product in the melter to produce a hot pressurized off-gas, a molten metal and a molten slag; and

segregating the off-gas, the molten slag and the molten metal.

2. A method for thermally processing a metallic oxide with a carbonaceous material in one or more chambers, wherein each of the one or more chambers has a charging end and a discharging end, to produce a hot metallized/carbon product which is subsequently melted in a melter to make a molten metal and a molten slag, comprising:

feeding the metallic oxide and the carbonaceous material to the charging end of said one or more chambers in such a way as to form a core with an annulus surrounding the core for the efficient reaction of the metallic oxide with the carbonaceous material, and forcing the metallic oxide and the carbonaceous material toward the discharging end of said one or more chambers;



US005411570A

United States Patent [19]
Fourie

[11] **Patent Number:** 5,411,570
[45] **Date of Patent:** May 2, 1995

[54] **STEELMAKING PROCESS**

- [75] **Inventor:** Louis J. Fourie, Newcastle, South Africa
- [73] **Assignee:** Iscor Limited, Pretoria West, South Africa
- [21] **Appl. No.:** 258,970
- [22] **Filed:** Jun. 13, 1994
- [30] **Foreign Application Priority Data**
Jun. 16, 1993 [ZA] South Africa 93/4272
- [51] **Int. Cl.⁶** C21C 5/28
- [52] **U.S. Cl.** 75/10.15; 75/10.14;
75/10.16; 75/10.17
- [58] **Field of Search** 75/10.15, 10.14, 10.16,
75/10.17

[56]

References Cited

U.S. PATENT DOCUMENTS

4,010,029 3/1977 McBride 75/10.17

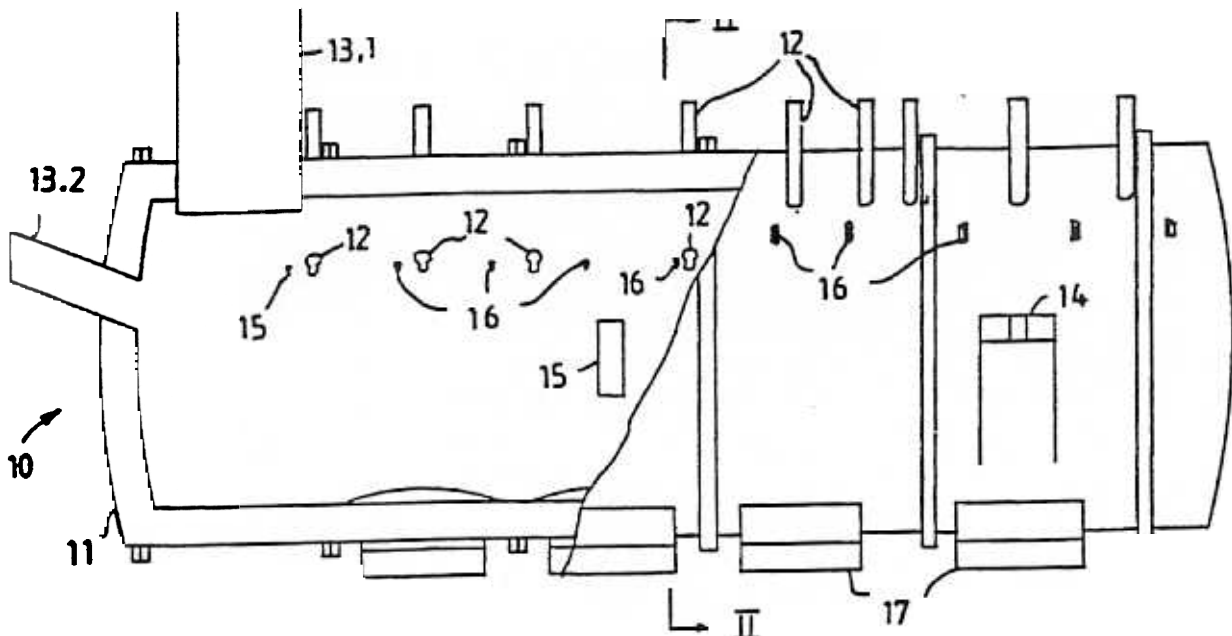
Primary Examiner—Peter D. Rosenberg
Attorney, Agent, or Firm—Nixon & Vanderhye

[57]

ABSTRACT

A method of making steel, by heating in a channel type induction furnace an iron containing burden and carbon, the carbon being included in the burden and/or contained in hot metal; and maintaining the temperature of the liquid product so formed above its liquidus temperature by controlling the amount of heat supplied to the furnace and/or the rate at which the burden is added to the furnace.

20 Claims, 4 Drawing Sheets



said dividing wall 22, the inside of vessel 11 is divided into a primary compartment which extends from inlet 13 about three quarters the length of vessel 11 and a secondary compartment which extends over the rest of the length of vessel 11.

Wall 22 serves to prevent mixing of the liquid metal of the primary and secondary compartments when furnace 10 is tilted towards the tapping side. An overflow notch (not shown) is provided in wall 22 in such a position that metal can flow from the primary to the secondary compartment when furnace 10 is in the horizontal position or tilted slightly backwards in a direction away from the tapping position.

The hot metal, scrap steel or solid iron and the major portion of the burden are charged to the aforesaid primary compartment and the steel is tapped from the secondary compartment.

As pointed out above, the flux additives are such that in the primary compartment the slag 20 is rendered relatively acid and in the secondary compartment relatively basic.

The method of the invention will now be described further by means of the following examples.

EXAMPLE 1 (With Hot Metal)

Vessel 11 of furnace 10 is charged with 83 tonne of hot metal, 20 tonne scrap metal and 72 tonne of 65% metallised sponge iron per hour, the latter being at a temperature in the order of 700 degrees C. It will be appreciated that because of the relatively low metallisation of the sponge iron, a very high throughput in the shaft furnace producing the sponge iron is possible.

The furnace is operated at a power rating of below 30 MW to produce 159 tonne of steel per hour. The steel, which is tapped at 1580 degrees C., contains approximately 0,10% C and below 0,015% of P.

The most important consumption rates are as follows:

Electricity	180 kWh/t
Lime & dolomite	50 kg/t
Oxygen	40 kg/t
Refractory repairs	2 kg/t
Gas or oil/fuel	5 kg/t

EXAMPLE 11 (Without Hot metal)

Vessel 11 of furnace 10 is charged with 83 tonnes of cold, 91% metallised sponge iron and 20 tonne of cold scrap metal per hour. The furnace is operated at a power rating of below 30 MW to produce 90 tonnes of steel per hour.

The most important consumption rates are as follows:

Electricity	280 kWh/t
Lime & dolomite	65 kg/t
Oxygen	85 kg/t
Refractory repairs	3 kg/t
Gas or oil (fuel)	25 kg/t
Coke (or other reductant)	11 kg/t

(Instead of fuel and coke, coals of varying volatile content can be used).

EXAMPLE 111 (Without Hot Metal)

Vessel 11 of furnace 10 is charged with 87 tonnes of hot (700 degrees C.) 65% metallised sponge iron and 20 tonnes of cold scrap metal and the furnace operated at

a power rating of below 30 MW to produce more than 90 tonne of steel per hour.

The most important consumption rates are as follows:

Electricity	280 kWh/t
Lime & dolomite	65 kg/t
Oxygen	72 kg/t
Refractory repairs	3 kg/t
Gas or oil (fuel)	7 kg/t
Coke (or other reductant)	59 kg/t

It can be seen that although the lower metallisation of the sponge iron of this example compared to that of Example 11 allows much higher production rates in the shaft furnace producing the sponge iron, it does not significantly alter the production rate or treatment cost for the process performed in furnace 10.

EXAMPLE IV (Iron ore)

Vessel 11 of furnace 10 is charged with 133 tonnes of magnetite ore which had been mixed with 43 tonnes of coal and formed into pellets with 1,33 tonnes of bentonite, while the furnace is operated at a power rating of below 37 MW to produce approximately 93 tonne of steel per hour.

The most important consumption rates are as follows:

Electricity	400 kWh/t
Limestone	118 kg/t
Raw dolomite	93 kg/t
Hot air (1000° C.)	2080 kg/t (produced by exchanging heat with the off gas.)
(Or Oxygen)	490 kg/t
Magnetite ore	1430 kg/t
Coal	465 kg/t

Excess energy from this operation, whether oxygen or preheated air is used, is more than sufficient for generating the electric power required by the induction heaters.

It will be appreciated that the furnace design for this alternative will allow for a greater surface area for heat transfer from the flames and roof to the burden.

It will further be appreciated that this alternative eliminates the need for a direct reduction plant, and that the process transforms iron ore directly to crude liquid steel.

It will be appreciated that the method and apparatus according to the invention provide an integrated arrangement in which steel can be produced and by means of which many of the problems referred to above as being encountered with the conventional type processes can be overcome or at least minimised.

It will be appreciated further that there are no doubt many variations in detail possible with a method and apparatus according to the invention without departing from the spirit and/or scope of the appended claims.

I claim:

1. A method of making steel in a channel-type induction furnace, including the steps of heating in the channel-type induction furnace a burden containing iron and carbon; and maintaining the temperature of the liquid product so formed above its liquidus temperature by controlling at least one of (i) the amount of heat supplied to the furnace and (ii) the rate at which the burden is added to the furnace.

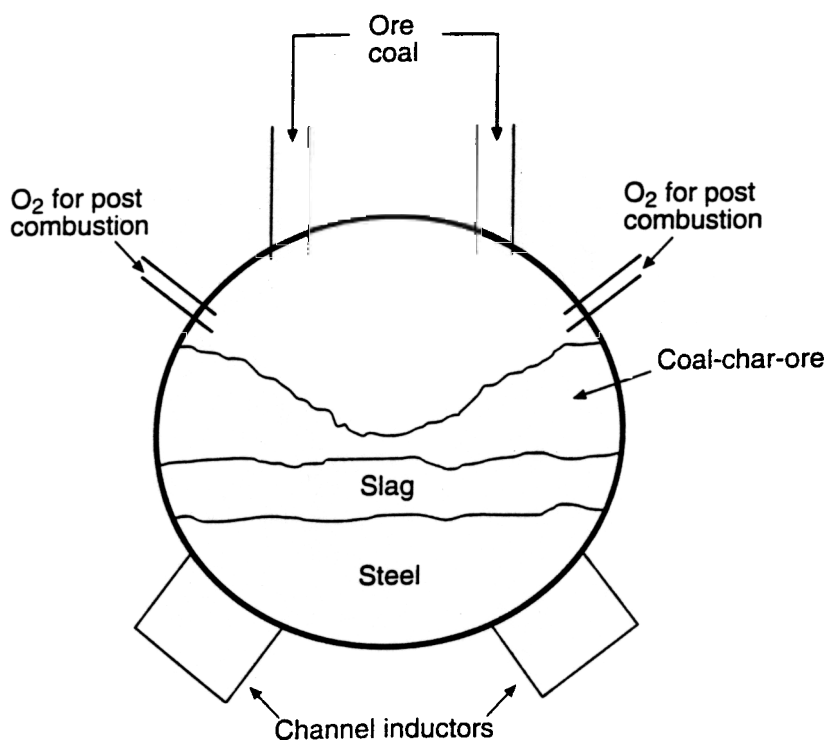


Fig 13.8 Schematic diagram of the IFCON process.

concluded that in order to avoid excessive heat losses the smallest feasible plant would be 45 tons/hour. They invited Nucor to help design such a plant. Whereas the process is theoretically attractive, it is only a concept and to date (1998) no steel has been produced. It requires higher levels of post-combustion than have even been achieved in other processes and the availability of iron carbide at a reasonable cost. If such a process was possible it could be used for other feeds such as HBI or DRI plus carbon, granulated pig iron or liquid hot metal and DRI or HBI.

Another extremely interesting, and possibly revolutionary process, is the IFCON process under development by ISCOR in South Africa. Little public information is available except for its patent.²⁴ A schematic diagram is shown in Fig. 13.8. The process utilizes a channel type induction furnace similar to that used in hot metal mixers. According to the patent, the process can use hot metal and partially reduced sponge iron (direct reduced iron), sponge iron only and, even more interestingly, iron ore and coal to produce steel directly. The latter version of the process would be truly revolutionary and satisfy the long time dream of steelmakers to go from ore to steel in a single reactor.

According to the ISCOR patent²⁴, when using ore, the ore and coal are added to the furnace continuously. Oxygen is added primarily for post-combustion of the CO from reduction and hydrogen from the coal. Post-combustion supplies a significant amount of energy for reduction. Electrical energy is supplied by the channel inductors for melting the reduced iron. ISCOR has operated a pilot plant and is considering a commercial/demonstration plant. No operating information from the pilot plant is available. However, a small pilot plant has been in operation at Pretoria and has run continuously for several campaigns of over one month each and produced steel with 0.03–0.1%C. A semi-commercial plant producing approximately 300,000 tpy is scheduled to begin operation in 1998 in South Africa. If such a process proves feasible it could drastically reduce the capital cost associated with steelmaking by eliminating the coke and sinter plants and combining iron and steel-making in one vessel.



Photograph 1



Photograph 2