An interim report on char tests at the Fuel Research Institute

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SYNOPSIS

In a search for suitable reductants for the electro-metallurgical industry, the Fuel Research Institute is conducting investigations into the charring of coals and the properties of the chars produced. This paper gives a selection of the results obtained as an illustration of the work being done. The research is proceeding.

SAMEVATTING

In 'n soektog na geskikte reduktante vir die elektro-metallurgie bedryf is die Brandstofnavorsingsinstituut besig met ondersoeke na die verkoling van steenkool en die eienskappe van die verkoolsel wat verkry word. Hierdie verhandeling gee 'n keur van die resultate wat verkry is ter illustrasie van die werk wat gedoen word. Die navorsing gaan voort.

Introduction

As the supply of metallurgical coke for use as a reductant in the electro-metallurgical industry is becoming limited and expensive, the manufacture of char was commenced in the mid-1950s. The Fuel Research Institute immediately showed interest, and investigated the operation of the travelling-grate Coker Stoker[1].

Realizing that the use of char would become of ever-increasing importance, the Institute looked into various other possibilities and in 1965/66 it was recommended to the Fuel Research Board that the Institute's carbonization facilities should be extended. The choice had fallen on a rotary carbonizer of the Salem–Brosius type. Negotiations were entered into with the manufacturer, and it was finally agreed that the pilot plant should be of 3 m internal diameter and that the plant would be used only for experimental and research purposes. The carbonizer, also known as the pancake oven, was duly erected.

A description of the plant and a discussion of the trial runs in the carbonizer were presented at the symposium 'Coal in the Seventies'[2].

Research work continued, and included investigative work on a contract basis on behalf of sponsors. In fact, as this rotary carbonizer erected at the Fuel Research

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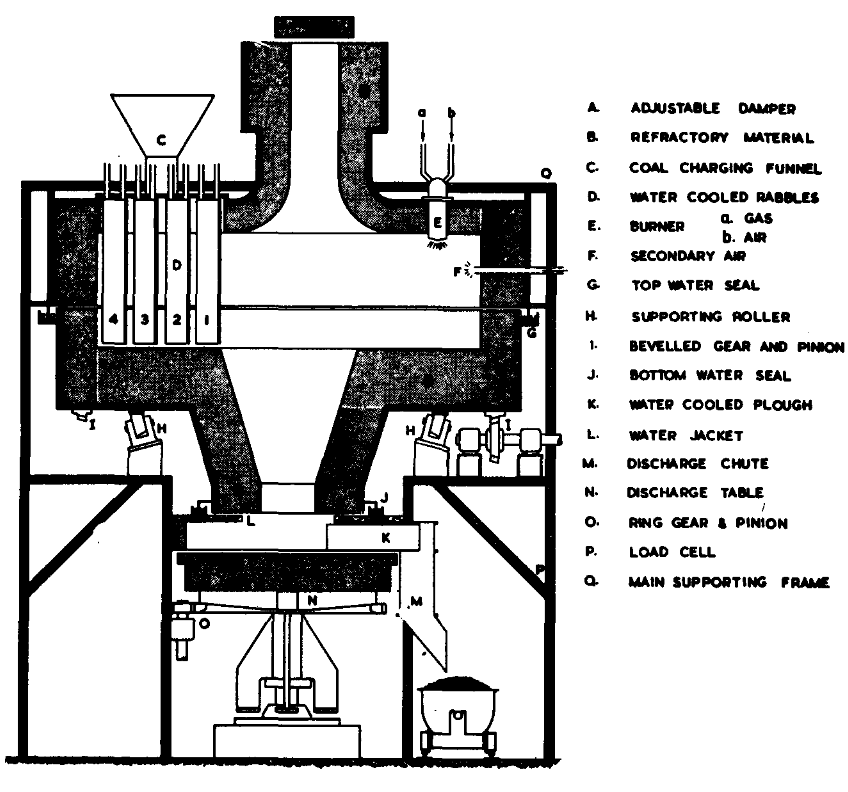

Fig. 1—The rotary carbonizer

TABLE I

TESTS IN THE 7kg COKE OVEN

	Matla No 5 seam					
Coal feed						
Proximate analysis (dry basis)						
Ash, %	10,8					
Volatile matter, %	35,3					
Fixed carbon, %	53,9					
Product char						
Temperature, °C	600	800	1000	600	800	1000
Conditions	Reducing			Oxidizing		
Proximate analysis (dry basis)						
Ash, %	16,6	15,9	16,0	16,6	16,0	15,9
Volatile matter, %	6,5	5,8	1,5	7,1	4,1	1,5
Fixed carbon, %	76,9	78,3	82,5	76,3	79,9	82,6
Performance indexes						
FCR, %	92,8	98,7	103,3	92,1	100,1	104,1
VMD, %	88,0	88,8	97,1	86,9	92,2	97,1
CE, %	81,7	87,7	100,3	80,0	92,3	101,1
Yield, %	65,1	67,9	67,5	65,1	67,5	67,9
Reactivity						
After 15 min, $cm^3/g.s$	3,09	2,96	2,49	3,25	3,15	2,84
After 75 min, $cm^3/g.s$	3,33	3,04	3,36	3,28	3,12	3,40
Resistivity						
Ω. $mm^2/m \times 10^3$	6420	12,7	2,85	166	3,49	3,10
Micum test						
Mean size, mm	16,5	17,5	19,2	16,7	16,7	17,3
50 rev M5	16,0	10,5	11,8	13,0	12,9	10,1
Mean size, mm	11,2	12,9	13,5	12,0	11,8	13,0
MMSS, %	68	74	70	72	71	75
100 rev M5	21,8	15,1	16,6	18,3	17,7	14,5
Mean size, mm	10,2	11,9	12,3	10,7	10,9	11,9
MMSS, %	62	68	64	64	65	69

TABLE II

TESTS IN EXPERIMENTAL COKE OVEN – PROXIMATE ANALYSIS, PERFORMANCE INDEXES, REACTIVITY, AND RESISTIVITY

	Springbok No. 5 Seam		
Coal feed			
Proximate analysis (dry basis)			
Ash, %	11,9		
Volatile matter, %	32,7		
Fixed carbon, %	55,4		
B. S. swelling no.	2½		
Product char	+40	40 x 25	25 x 10
Proximate analysis (dry basis)			
Ash, %	15,6	18,0	16,0
Volatile matter, %	0,9	0,9	0,8
Fixed carbon, %	83,5	81,1	83,2
Performance indices			
FCR, %	115,0	96,8	111,7
VMD, %	97,9	98,2	98,2
CE, %	112,6	95,0	109,7
Yield, %	76,3	66,1	74,4
Reactivity			
After 15 min, $cm^3/g.s$	0,57	0,71	0,81
After 75 min, $cm^3/g.s$	1,05	1,22	1,36
Resistivity			
Ω. $mm^2/m \times 10^3$	0,168	0,183	0,179

Institute was the only pilot-scale version in the world, the manufacturer also made use of the facilities for carrying out investigations.

The growing electric-smelting industry gave rise to concern about the future availability of coals for charring, and the Char Committee was formed to coordinate investigations into potential feedstocks and suitable types of processes. The Char Committee outlined a national development programme on reductants for the electric-smelting industry in South Africa, in which the involvement of the Fuel Research Institute would concern processes for the production of char and char properties.

The Institute duly began investigations into the properties of char, and some of the results are reported here. It must be stressed that these should be regarded only as interim results. As the research project has not yet been completed, the results cannot be evaluated or discussed in depth. It is hoped that a complete account of the work, together with the conclusions drawn from it, will be published at a later date.

Studies on Formchar

Modern mining methods result in an over-production of duff, and most of the char breeze arising from the production of char is discarded. In normal usage, both these small-sized materials lead to a variety of problems. If they could be agglomerated, say by briquetting followed (if necessary) by a carbonization or charring step, a useful fuel or reductant could be produced.

With this in mind, the Fuel Research Institute started its research on char. The aim initially was the production, not of formcoke, which would have to withstand rigorous treatment in the blast furnace, but of formchar, which, since the burdens in electric furnaces are not so great, would not have to comply with such stringent strength requirements. If suitable formchar could be produced, further developments might well lead to the production of formcoke.

In the preliminary work, char, blends of char and coal, and coal were briquetted, with pitch as the binder. Briquettes were also charred in the rotary carbonizer.

TABLE III

TESTS IN EXPERIMENTAL COKE OVEN – MICUM TEST

	Springbok No. 5 seam gas nuts		
Product char			
Temp., °C Flue	1150		
Charge centre	1080		
Sieve analysis, %			
(mm round holes)			
x 80	2,6		
80 x 60	4,6	+40 mm = 23,6 %	
60 x 40	16,4		
40 x 30	21,2	40 x 25 mm = 27,7 %	
30 x 25	6,5		
25 x 20	9,8		
20 x 15	18,0	25 x 10 mm = 40,6 %	
15 x 10	12,8		
10 x 5	4,7		
5 x 0	3,4		
Mean size, mm	30,4		
Bulk density, kg/m³	550		
Micum test	+40 fraction	40 x 25 fraction	25 x 10 fraction
Mean size, mm	58,3	33,3	17,1
50 rev M10	11,8	7,8	—
M5	8,1	5,7	8,0
Mean size, mm	31,1	27,3	13,8
MMSS, %	53	82	80
100 rev M10	15,8	11,3	—
M5	11,8	8,8	12,1
Mean size, mm	28,1	25,4	12,7
MMSS, %	48	76	74

In addition to the usual tests, compressive strength tests were carried out on briquettes.

Results

As an illustration of the work being carried out by the Fuel Research Institute in its charring programme, a selection of results is given in tabular form.

Table I: Tests in the 7 kg Coke Oven

Table I gives the proximate analysis of a coal that was treated at three temperature levels under both reducing and oxidizing conditions. The proximate analyses of various chars, with their performance indexes, reactivity, resistivity, and Micum-drum results, are also listed.

Table II: Tests in Experimental Coke Oven — Proximate Analyses, Performance Indexes, Reactivity, and Resistivity

Table II lists the proximate analysis of the coal feed and of the product char, together with the performance indexes, and reactivity and resistivity values.

Table III: Tests in Experimental Coke Oven — Micum Test

Table III shows the sieve analysis of the char and the Micum test results on three selected size ranges.

Table IV: Rotary Carbonizer Tests — Sieve Analyses

Table IV shows the sieve analyses of three coal samples, as well as the sieve analyses of chars produced in tests conducted at three temperature levels on each of the three coals: 800, 1000, and 1200°C.

Table V: Rotary Carbonizer Tests —Proximate Analyses, Performance Indexes, Reactivity, and Resistivity

Table V gives the proximate analyses of the feed coals and of the chars produced, as well as performance indexes, reactivities, and resistivities.

Table VI: Rotary Carbonizer Tests — Micum Tests

Table VI gives the results of the Micum tests on the

TABLE IV

ROTARY CARBONIZER TESTS – SIEVE ANALYSES

	Springbok No 5 seam, gas nuts	Blesbok No 5 seam, gas nuts	Matla No 5 seam
Coal feed			
Sieve analysis, %			
(mm, round holes)			
x 60	—	—	1,3
60 x 40	7,2	5,3	17,7
40 x 30	24,6	11,9	21,1
30 x 25	20,2	14,7	8,7
25 x 20	19,8	21,1	16,1
20 x 15	14,7	28,4	23,0
15 x 10	5,7	11,9	7,3
10 x 5	1,8	3,3	2,4
5 x 0	6,0	3,4	2,4
Mean size, mm	25,8	22,4	28,3

	Springbok			Blesbok			Matla		
Product char									
Roof temperature, °C	800	1000	1200	800	1000	1200	800	1000	1200
Sieve analysis, %									
(mm, round holes)									
x 40	0,4	0,3	0,2	0,5	0,2	—	2,5	0,3	0,4
40 x 30	7,1	8,1	6,5	8,2	8,8	3,7	8,0	2,3	2,2
30 x 25	10,9	16,1	15,1	13,9	14,8	12,3	13,7	8,4	3,5
25 x 20	24,6	19,6	20,0	19,8	20,0	17,8	16,5	21,6	13,7
20 x 15	24,6	25,1	28,4	28,3	26,0	30,0	25,3	34,9	34,2
15 x 10	13,9	15,1	7,1	16,8	15,0	20,3	18,3	18,9	27,2
10 x 5	6,4	5,8	8,8	6,7	6,8	7,6	8,4	7,9	10,3
5 x 0	12,1	9,9	13,9	5,8	8,4	8,3	7,3	5,7	8,5
Mean size, mm	18,0	18,8	17,9	19,1	18,9	17,2	18,9	17,3	15,4
Bulk density, kg/m³	381	420	420	371	437	409	402	384	384

TABLE V

ROTARY CARBONIZER TESTS – PROXIMATE ANALYSES, PERFORMANCE INDEXES, REACTIVITY, AND RESISTIVITY

	Springbok No 5 seam			Blesbok No 5 seam			Matla No 5 seam		
Coal Feed									
Proximate analysis (dry basis)									
Ash, %		12,1			9,5			10,4	
Volatile matter, %		33,6			33,8			39,0	
Fixed carbon, %		54,3			56,7			50,6	
Total sulphur, %		0,6			0,5			0,55	
Phosphorus, %		0,004			0,005			0,003	
Product char									
Roof temperature, °C	800	1000	1200	800	1000	1200	800	1000	1200
Proximate analysis (dry basis)									
Ash, %	16,9	16,9	17,6	14,0	14,7	14,8	16,7	15,8	15,7
Volatile matter, %	5,9	1,7	1,3	3,6	2,0	0,8	5,0	3,2	2,9
Fixed carbon, %	77,2	81,4	81,1	82,4	83,3	84,4	78,3	81,0	81,4
Performance indexes									
FCR, %	101,8	107,3	102,7	98,6	94,9	95,5	96,4	105,4	106,6
VMD, %	87,4	96,4	97,3	92,8	96,2	98,5	92,0	94,6	95,1
CE, %	88,9	103,4	99,9	91,4	91,3	94,1	88,7	99,7	101,4
Yield, %	71,6	71,6	68,8	67,9	64,6	64,2	62,3	65,8	66,2
Reactivity									
After 15 min, $cm^3/g.s$	1,88	1,86	0,88	1,95	2,16	0,44	3,70	3,24	2,25
After 75 min, $cm^3/g.s$	1,84	1,97	1,12	1,77	1,91	0,69	3,90	3,79	3,16
Resistivity									
$\Omega . mm^2/m \times 10^3$	1810	2,33	1,53	12,1	4,44	1,10	14,3	3,47	1,83

TABLE VI

ROTARY CARBONIZER TESTS – MICUM TESTS

	Springbok No 5 seam, gas nuts			Blesbok No 5 seam, gas nuts			Matla No 5 seam		
Roof temperature, °C	800	1000	1200	800	1000	1200	800	1000	1200
+25 mm fraction									
Mean size, mm	30,9	30,2	29,4	30,7	30,5	29,3	31,8	Low yield in this size. No Micum tests done.	
50 rev M10	11,2	10,2	12,0	11,2	10,4	9,6	13,2		
M5	9,2	7,0	7,2	7,6	7,0	6,0	9,2		
Mean size, mm	20,0	19,7	17,7	18,0	18,1	17,8	20,7		
MMSS, %	65	65	60	59	59	61	65		
100 rev M10	16,8	15,4	16,8	17,2	15,6	13,6	19,2		
M5	14,0	11,2	11,2	12,0	11,4	9,2	14,8		
Mean size, mm	17,7	17,4	15,8	16,0	16,2	16,0	17,6		
MMSS, %	57	58	51	52	53	55	55		
25 x 10 mm fraction									
Mean size, mm	18,0	17,9	17,9	17,7	17,9	17,3	17,3	17,7	16,6
50 rev M5	8,2	6,0	6,4	6,4	5,6	5,0	6,2	4,8	5,2
Mean size, mm	14,8	14,9	14,2	14,3	14,7	14,5	14,9	14,6	14,0
MMSS, %	80	83	76	81	82	84	86	83	84
100 rev M5	12,8	9,4	10,2	10,4	8,8	8,4	10,8	8,6	8,8
Mean size, mm	13,6	13,8	13,0	13,3	12,8	13,4	13,8	13,3	12,5
MMSS, %	74	77	70	75	72	78	80	75	75

TABLE VII

SOME ANALYSES OF COMMERCIALLY PRODUCED CHARS (FEED: SPRINGBOK AND BLESBOK NO. 5 SEAM COALS)

	Char A	Char B
Proximate analysis (dry basis)		
Ash, %	16,9	16,6
Volatile matter, %	1,9	3,8
Fixed carbon, %	81,2	79,6
Micum test on 25 x 10 mm fraction		
50 rev M5	5,6	6,2
MMSS, %	83	87
100 rev M5	8,4	10,3
MMSS, %	76	80
Reactivity		
After 15 min, $cm^3/g.s$	0,85	1,32
After 75 min, $cm^3/g.s$	0,78	1,24
Resistivity		
$\Omega . mm^2/m$	$2,40 \times 10^3$	$1,20 \times 10^4$

40 by 25 mm and 25 by 10 mm char fractions. Note that, for the third coal, Matla, the heat treatment at 1000°C and 1200°C caused a considerable size degradation, so that there was not sufficient 40 by 25 mm char for the Micum tests.

Table VII: Some Analyses of Commercially Produced Chars

Table VII lists some of the properties of commercially produced chars. Comparisons can thus be made between the variuos processes and their products.

Acknowledgements

The author thanks the Fuel Research Board for permission to publish these results. He also thanks his colleagues for their help. Any opinions expressed are those of the author only.

References

1. LA GRANGE, C. C. An investigation into the operation of a travelling grate Coker Stoker. *J. S.Afr. Inst. Min. Metall.*, vol. 57. Oct. 1956. pp. 99–114.
2. WHITE, R. W., MÜLLER, E. F. E., and LA GRANGE, C. C. The pilot scale rotary carbonizer of the Fuel Research Institute as a unit for investigating char production. *ChemSA*, Mar. 1974. pp. 101–104, 112.
3. JOCHENS, P. R. (convenor). Proposed national development programme on reductants for the electric-smelting industry in South Africa. Johannesburg, Char Committee, Jan. 1978.

IPMI awards

The International Precious Metals Institute (IPMI) announced that the recipient of its 1980 Distinguished Achievement Award is Dr Leslie R. Hunt, and the recipient of its first annual Henry J. Albert Award is Dr Chain T. Liu.

Dr Hunt is the creator and editor of the *Platinum Metals Review*, now in its 23rd year of publication. He was the creator of the *Gold Bulletin* and served as its editor until October 1977. These two publications are recognized worldwide for their consistently high standards and are a direct reflection of the unique experience, determination, and continuing personal involvement of Dr Hunt.

Dr Hunt has had a long and distinguished career with Johnson Matthey Co., Ltd, having retired as a Group Executive Director. He has an intimate knowledge of the science, technology, and markets for precious metals and has authored a textbook on *Electrical Contacts*. He has written numerous articles in both *Platinum Metals* and the *Gold Bulletin*, as well as many other periodicals.

Dr Lui, of the Oak Ridge National Laboratory, Oak Ridge, Tennessee, is being recognized for his outstanding theoretical and experimental contributions to the metallurgy of precious metals.

Dr Lui's work has embraced many aspects of physical and chemical metallurgy, and has been marked by keen perception and innovation. Dr Lui was particularly cited for his research and development of precious metals and precious metal alloys needed for critical components in DOE and NASA space programmes. For example, iridium alloys developed by Dr Lui were essential to the performance of nuclear-power sources on board the Voyager 1 and 2 spacecraft, which surveyed Jupiter in 1979.

The Henry J. Albert Award is sponsored jointly by IPMI and the Engelhard Minerals and Chemicals Corporation as a memorial to Dr Henry J. Albert, who served as Technical Director of Engelhard's Cartaret Division and as President of IPMI.

Refining of precious metals

The International Precious Metals Institute (IPMI) plans to conduct an intensive Educational Seminar on the Refining of Precious Metals on 22nd to 24th October, 1980, at the Skytop Lodge, Skytop, Pocono Mountains, Pennsylvania. The Seminar is the third in a series of educational courses being conducted by the Institute with the purpose of serving the technical and educational needs of the precious metals community.

Dr George Foo, Refining Specialist at the Western Electric Research Center, Princeton, New Jersey, is the General Chairman, and he is assisted by Dr Mahmoud El Guindy, of Engelhard Minerals & Chemicals Corp., Anaheim, California.

The Seminar will cover the fundamentals and current practice of precious metals refining. Sessions on the primary and secondary recovery methods will be held, and the international refining situation will be discussed in a featured after-dinner talk.

For further information, contact IPMI Headquarters, Polytechnic Institute of New York, 333 Jay Street, Brooklyn, New York, 11201, U.S.A.