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FINAL REPORT ON THE TEST WORK CARRIED OUT ON THE DIRECT REDUCTION OF RED MUD (A BY-PRODUCT OF ALUMINIUM INDUSTRY FROM HUNGARY)

JULY - 1991

ENGINEERING AND PROJECTS DIVISION

SPONGE IRON INDIA LIMITED

HYDERABAD - 500 028.

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1.0 INTRODUCTION

United Nations Industrial Development Organization (UNIDO) under the project No. DP/HUN/86/005 "Test Work On The Direct Reduction Of Red Mud, a By-Product Of Aluminium Industry" awarded the test work to Sponge Iron India Limited (SIIL) vide contract No. 90/117. The contract was awarded in response to the proposal submitted by SIIL vide their letter No. SI/S&P/RD/7858/193/90 dt. 28.05.1990.

1.1 In terms of the contract the scope of work of SIIL is as follows:

1.1.1 Processing, beneficiation, agglomoration etc. of Hungarian red mud for direct reduction tests, covering its physical, chemical, metallurgical and mineralogical analysis and related test work.

1.1.2 Direct reduction test on laboratory scale aimed at transformation and subsequent magnetic seperation of the iron-oxide content of red mud.

1.1.3 Compilation of test results covering 1.1.1 & 1.1.2 above.

1.1.4 Preperation of a detailed report based on 1.1.1 to 1.1.3 above and data/results with recommendations for evolving appropriate flow sheet for recovery of iron oxide and other useful minerals from red mud.

1.2 100 kgs. of red mud was received from Hungarian Academy of Sciences through UNIDO in the last week of August 1990. As per the directions of UNIDO suitable non-coking coal available with SIIL was used as reductant for these tests. After receipt of red mud sample, detailed

schedule of test work was drawn and accordingly the work was undertaken.

1.3 This report discusses the details of tests conducted on red mud in combination with Manuguru coal of Singareni Collieries, as reductant. The report also indicates the optimum test conditions as also the test results of laboratory rotary furnace test conducted at SIIL Test Centre on this set of raw materials.

2.0 TEST OBJECTIVE

2.1 The prime objective of the test work is to explore the possibility of reducing the iron oxide to metallic iron with a view to recover the iron from red mud. Accordingly the main objective of the test work at the SIIL Test Centre is to determine by laboratory and bench scale tests for finding the suitability of Hungarian red mud and available non-coking coal (Mangurul as reductant for production of reduced red mud by Direct Reduction Process and to assess the main technical parameters and product quality of reduced red mud for further industrial processing.

2.2 Keeping in view the above prime objective and the scope of contract, a detailed schedule of test work was drawn up which is enumerated below:

2.2.1 To analyse the as recieved Hungarian red mud sample chemically to determine its various constituents like Fe, TiO2, and other elements.

2.2.2 To determine physical properties such as moisture content of as recieved samole, screen analysis, bull density etc.

2.2.3 To carry out reduction tests in laboratory rotary furnace to ascertain the reducibility characteristics of the red mud and to determine optimum test parameters.

3.0 TEST MATERIAL

3.1 Hungarian Red Mud

100 kgs.of Red mud sample was received from Hungarian Academy of Sciences at SIIL test centre in last week of August 1990. The as recieved sample was wet having a moisture content of 25% . The chemical analysis of as received sample is given at table-1. The as recieved sample was air dried for a week in open atmosphere the moisture content of the sample was reduced to 2% . The air dried sample with 2% moisture was taken for further testing. The flaky type formed red mud sample was crushed to form final powder. The physical properties of the red mud sample is given in table-2.

3.2 COAL

Coal from Manguru Mines of Singareni Collieries Company Limited which is being used in SIIL plant for production of Sponge Iron has been considered as reductant in the proposed test work. The chemical and physical properties of the coal samole used in the tests is presented in table 3 & 4.

3.3 Desulphariser (Lime Stone)

Small quantity of desulphariser is to be used in the reduction tests to restrict pickup of sulpher from coal in the metallised product of red mud during reduction tests. Lime stone used in the SIIL plant has been considered as desulphariser for the tests. The properties of the lime stone used as desulpheriser in the reduction tests are presented in table-5.

4.0 DESIRED TECHNICAL QUALITY REQUIREMENTS OF RAW MATTERIALS TO BE USED IN DIRECT REDUCTION PROCESS USING ROTARY KILN:

4.1 Iron bearing ore, Coal and Limestone are the basic raw materials required for the production of pre-reduced material in the rotary kiln process based on 100% coal operation. As the processing of iron bearing material for reduction in rotary kiln is sensitive to the characteristics of raw materials with regard to size distribution and other chemical parameters, bench scale testing forms the first essential step in determining the suitability of the raw materials and deciding about the process parameters.

4.2 IRON BEARING MINERAL (Hungarian Red Mud)

For better reduction and enrichment of the desired elements in the reduced product, the basic ore should have iron content of the order 50% with low gangue components and low levels of impurities such as sulphur and phosphorus. The requirement of iron content in the mineral arises from the fact that higher the iron content, the better the reduction. Low level of gangue is required as there is no removal of gangue in the direct reduction process is envisaged. Further gangue requires additional melting power and appropriate limestone additions to remove it as slag in the smelting stage. After reduction of iron oxide the weight of the mineral reduces to the extent of removal of oxygen the other mineral present improves proportionality.

The sulpher and phosphorus content are also of utmost importance while selecting the ores keeping in view the specification of the final metal to be produced. Suitable precautions are to be taken for desulphurisation in the rotary kiln, as the reduced material tends to pick up the sulphur from coal in the absence of desulphurisor.

4.3 Coal

The main chemical characteristics of the coal which influence its suitability as the reductant are reactivity, proximate analysis comprising of fixed carbon, ash and volatile matter, melting characteristics of coal ash under reducing conditions, the total sulphur and the different forms of sulphur present.

4.3.1 Coals of higher reactivity are preferable as they permit the operation of the kiln at the lower temperatures and at high throughput rates.

4.3.2 The ash in coal should be as low as possible as it occupies the effective kiln volume reducing the space available for iron bearing materials. The volatile matter in coals should be of the order of 30% so as to heat the ore to the reduction temperature within the shortest possible time. The fixed carbon should be of the order of 40 to 45%.

4.3.3 The melting characteristic of coal ash is of utmost importance while evaluating coals for direct reduction application. As the coal ash forms low melting compounds with fine reduced material, it is desirable to have softening point of coal ash in excess of 1200 deg.C under reducing conditions. The kiln operating temperature in the reduction zone is so chosen that it is lower than the ash softening point by 100 - 150 C to minimize the formation of accretions.

4.3.4 The sulphur content in the coal, in the form of organic and inorganic compounds, also merits careful consideration. Part of organic sulphur gets volatilized in the pre-heating zone of the kiln and increases the sulphur load in the waste gas system. Inorganic sulphur bond to ash released in the reduction zone along with the utilization of carbon and gives rise to sulphur pick up in the reduced material in the

absence of the desulphuriser. In short the total sulphur in coals should be low, preferably below 1%.

4.3.3 However, coals having high percentage of fixed carbon with low volatile matter like anthracite, could also be considered as effective reductant through blending with bituminous or sub-bituminous coal or in combination with oil or natural gas. Alternatively, such coals could also be used by maintaining higher operating temperatures when the reactivity of the coal improves. The related problems of ash softening and subsequent fusion at higher operating temperatures are absent if the ash content is low.

4.4 Limestone

Limestone is used in the process, as a desulphuriser as the coal used for reduction contains sulphur. Limestone containing an average of 45 percent of CaO has been observed to be adequate for this requirement. The size distribution of limestone also needs to be considered as it is observed that the desulphurising ability of finely granulated limestone is very good. The size range of 1 to 3 mm is found to be very effective in rotary kilns.

5.0 **LABORATORY AND BENCH SCALE TEST RESULTS**

5.1 Beneficiation Studies

The red mud was subjected to washing with an aim to beneficiate the red mud in terms of upgradation of iron content by removing other constituents like Silica, Alumina and Alkali bound material.

5.1.1 The as received red mud powder was soaked in a container with frequent stirring to dissolve any free alkalies present. If free alkalies are present they dissolve in water resulting increase in PH value of water. But after six hours of soaking in water there is no considerable increase in PH value. From this test, it was inferred that the alkalies present cannot be seperated as they are chemically associated with other elements.

5.1.2 Secondly the red mud was washed in slow stream of water with an aim to seperate various constituents present in the red mud by Gravity method. By this method it is possible to seperate Silica and Alumina if present in their free forms.

5.1.3 The washing was carried out on an inclined surface with tables provided. It was observed that the material is uniformly washed away in the slow stream of water without leaving any distinct seperation based on the specific gravity. From this experiment it was concluded that the different constituents in the red mud are not in their free forms and they cannot be seperated by physical beneficiation methods.

5.2 Pelletisation

[illegible] pellets [illegible] prepared in the pellet[illegible] [illegible] was [illegible] the required [illegible]

5.2.2 The as received red mud sample after drying was taken and subjected to agglomeration by way of pelletising. The red mud was pelletised in a laboratory type Disc Pelletiser using binders such as Cement, and Hydrtsted lime . After homogenisation first seeds are developed and later they are converted to pellets in the disc Pelletiser by spraying the required amount of water. The red mud powder agglomerated into well defined and spherical pellets. These pellets are dried in open air for 24 hrs, the red mud pellets were having good green strength which could be directly used in laboratory rotary furnace. The pellets of size range 3mm to 20mm were taken for testing to find their reducibility character.

5.3 Chemical Analysis of Hungarian Red Mud Sample

The Red mud sample was analysed as per the standard analytical procedure. Various constituents such as Fe (Total), Fe (Met.), FeO, Fe_2O_3, TiO_2, SiO_2, Al_2O_3, CaO, Na_2O, KO, MgO, P, S were determined and the results are presented in Table-1.

5.3.1 Iron content

The total iron content present in the Red mud sample was of the order 30.16%. The detailed analysis to find different forms of iron present in the red mud revealed that most of iron is in its Fe_2O_3 form. The analysis results shows that FeO content is 1.44% and Fe_2O_3 content is 41.52%. As can be seen from the chemical analysis of the red mud only small quantity of iron is associated with the oxygen in magnetite form.

5.3.2 Gangue content

While carrying out reduction tests of the iron bearing material Silica, Alumina content do not undergo any change and they are called gangue material. The gangue content in the red mud as analysed is of the order 14.32%, in which SiO_2 constitutes 10.02% and Al_2O_3

constitutes 16.14%. The total gangue content in the red mud is very much on higher side compared to the prime iron ores. Higher percentage of SiO2 and Al2O3 is disadvantage factor for reduction of iron oxide and also for recovery of iron from the red mud.

5.3.3 Impurities

The impurities normally present in the iron bearing material (Red Mud) is phosphorous and sulphur. As can be seen from the chemical analysis the impurities level in the red mud is on higher side. The sample is having sulphur and phosphorous of the order 0.09% and 0.035% respectively. The chemical analysis results shows that the red mud sample contains Na2O, K2O, and V2O5 which are 4.58%, 4.46% and 0.003% respectively.

5.3.4 Physical properties of red mud sample

The as recieved red mud sample was in wet condition for carrying out further tests the sample was air dried. The sample on air drying formed cake like flaky mass and on crushing this mass became dry powder of size lessthan 0.5 mm. The red mud powder samole was reddish in colour. The physical properties of the red mud samole and its screen analysis are presented in table - 2.

5.4 Properties of Reductant used (Manguru Coal, Singareni Collieries Co.Ltd, India)

5.4.1 Proximate Analysis:

The proximate analysis of the coal samples for determination of the fixed carbon, volatile matter and ash was carried out as per standard procedure. The average results of the analysis carried out are presented in table-3.

From the table it could be seen that the volatile matter is 27.90%, fixed carbon is 46.40% and ash is 25.70%.

5.4.2 Sulphur Content:

The sulphur content of the coal is one of the important characteristics for the evaluation of the suitability of the coal to be used as reductant for direct reduction of iron bearing minerals. The sulphur in coal is normally composed of inorganic/pyritic sulphur, Sulphate sulphur and organic sulphur. The presence of organic sulphur contributes to the sulphur pickup in the sponge iron in the absence of desulpharizer. The total sulphur in the coal sample was analysed by gravimetric method. The different forms of the sulphur in Manguru coal were also analysed and the results of these chemical analysis are presented in the table-3. The total sulphur in the coal was 0.88%. With the organic sulphur of the order of 0.48% , it could be observed that the sulphur content in product could be controlled well below acceptable limit with usage of limestone (Blast Furnace grade) as desulpharizer.

5.4.3 Calorific Value

The average gross calorific value of the Manguru coal sample was observed to be of the order of 5320 Kcal/Kg which is considered optimum for the specified purpose. The calorific value of the reductant was determined in an adiabatic Bomb Calorimeter.

5.4.4 Chemical Analysis of the coal ash

The chemical composition of the coal ash influence the softening characteristics of the coal ash. Higher concentration of silica and alumina are generally in line with higher softening temperature. However, higher concentration of the iron oxides in the ash lowers the softening point considerably. The analysis of the coal ash for the determination of SiO_2, Al_2O_3, CaO and MgO was carried out and the results are tabulated in the table-4. The results of the chemical analysis of the coal indicate that the ash is acidic in nature and predominantly of silica with a value of more than 50%.

5.4.5 Melting Characteristics of coal ash

In the rotary kiln process the kiln is to be operated at a temperature of 1050 deg.C to get the desired degree of reduction and this requires coals with relatively higher ash softening temperatures of the order of 100 - 150 deg.C above the kiln operating temperatures. The melting characteristics of the coal ash is determined in a LEITZ HEATING MICROSCOPE and the points of important observation are the softening or the initial deformation point, the melting or hemispherical point and the flow point . The behaviour of Manguru coal was found to be extremely good and the initial softening point itself was observed to be 1220 deg.C. It is felt that this could be attributed to lower concentration of sulphate sulphur in the coal ash. The test results of the melting behaviour of the coal ash are indicated in the Table-4.

5.4.6 Reactivity of coal

Reactivity of the coal refers to the amount and the rates of carbon monoxide generation through the well known Boudouard reaction. This is an important factor in the rotary kiln operation since the generation of the carbon monoxide required for the reduction of the iron ore is formed in situ and is a function of the temperature in the kiln. The reactivity of the coal is determined by weightloss method. The test results carried out on Manguru coal indicate the reactivity as 0.19 c.c. of carbon monoxide per gram of carbon per second.

5.5 REDUCIBILITY TESTS IN LABORATORY ROTARY FURNACE

5.5.1 Reducibility tests are carried out in order to determine the behaviour of iron bearing red mud and coal during the reduction and to predict the behaviour of these input materials in rotary kiln for commercial operation. In the laboratory rotary furnace

reduction tests, operating conditions of the rotary kiln are simulated. The test results indicate the behaviour of the iron bearing mineral i.e red mud and coal under reducing conditions and establishes the reducing properties based on which the suitability of the iron bearing minerals and coals for use in rotary kilns could be determined and the operating parameters are found to achieve the desired levels of product quality in the actual operations. The reducibility tests on red mud samples were conducted with Manuguru coal as reductant.

3.5.2 The reducibility tests are conducted in an electrically heated rotary furnace normally at a reduction temperature of 1000 °C and for a retention time of 3 hours. Based on the comparitive study of Bench and Demonstration scale tests on known ores and coals, the test parameters/conditions for the laboratory rotary furnace have been developed by SIIL. Number of laboratory rotary furnace tests have been conducted on Hungarian red mud in combination with Manguru coal to determine the optimum operating parameters for achieving good metallization in the kiln.

3.5.3 In order to achieve higher degree of reduction the laboratory rotary furnace tests were conducted at various test conditions. The metalization levels achieved with red mud powder in combination with Manuguru coal even at higher temperatures and higher carbon to iron ratios were low. The details of the test results with red mud powder and Manuguru coal at various test conditions are given in tables 6 to 12. As can be seen from the test results the metallisation varied from 31.2% at 1000 °C reductant temperatures to 56.8% at 1100 °C.

3.5.4 The tests were conducted on sized red mud flakes which were formed on drying the wet sample. The reducibility results in laboratory rotary furnace tests on sized flaky red mud sample with Manuguru coal is

given in table- 14. Even at higher reduction temperature of 1080° C and with high retention time of 5 hours the metallization obtained was low of the order 52.78% for the red mud flaky samples.

5.5.5 In view of not achieving high degree of metallisation with red mud powder it was considered to pelletise the red mud powder and use the pellets for reduction study. The red mud powder was pelletised in a disc pelletiser using 2 to 3% of cement and hydrated lime as binders. The green pellets of size 3 to 20 mm were taken for reducibility tests in combination with 3 to 12 mm size Manuguru coal. For studying the reducibility of red mud pellets the tests were conducted at extreme conditions i.e at 1080° C, C/Fe ratio of 0.7 and a retention time of 5hrs. The test results are detailed in table - 15. The metallisation achieved for pellets is 64.03%.

5.6 DEGREE OF METALLIZATION

5.6.1 The degree of metallization aimed for red mud was more than 85%. The first experiment was conducted on dry red mud powder at normal operating condition viz a reduction temperature of 1000° C and retention time 3 hours and a C/Fe ratio of 0.5. For [illegible] 41.20% was acheived with red mud powder.

as reductant and condition of the [illegible]

Keeping in view above limitations the final reduction temperature for the red mud tests along with Manuguru coal as reductant was kept at 1080° C. At a

reduction temperature of around 1030 °C and 3 hours retention time it was possible to achieve an average metallization of 56.9% for red mud powder, 52.78% for red mud flaky sample and 54.03% for red mud pellets. The details of metallization levels achieved at various test conditions are presented in table- 16.

6.0 FINDINGS

6.1 The laboratory and bench scale tests conducted on Hungarian red mud samples revealed that it is difficult to achieve higher degree of metallization of the order of 85% at normal operating conditions.

6.2 It is observed from the results of reduction tests conducted on the Hungarian red mud samples that its reducibility character is poor and even at higher reduction temperature of 1150°C and higher retention time of 5 hrs., the metallization obtained is only 56.5%.

6.3 Sub-bituminous coals having a fixed carbon of 45% is considered suitable as reductant.

6.4 From the Laboratory tests conducted on Hungarian red mud in combination with Manguru coal following operating parameters are suggested for reducing the red mud with suitable coal in commercial operation for production of prereduced red mud (metallization of about 56%).

i)	Reduction Temperature	:	1080°C
ii)	Retension time	:	5 hours
iii)	C/Fe ratio	:	0.70

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 The laboratory tests on Direct Reduction of Hungarian red mud in combination with Manuguru coal showed that it requires higher reduction temperatures of the order of 1180 C and a retention time of 5 hrs. for achieving a metallisation of 56%.

7.2 Since further higher reduction temperature cannot be applied in rotary kiln based Direct Reduction process using coal as reductant it is concluded that the Hungarian red mud shall yield a metallisation of the order of 56% with total iron content of 42.16% in the product.

7.3 As the metallization levels achieved are low and total iron content in the reduced red mud is of the order 42.16% ,it is suggested that red mud after reduction can be subjected to smelting in a suitable Electric Arc Furnace for recovery of iron.

7.4 Keeping in view the lower iron content in the product it is recommended that smelting tests on the reduced red mud sample may be conducted in a Submerged type Arc Furnace to recover iron as liquid metal and other elements as slag. SIIL is obtaining a laboratory type Submerged Arc Furnace shortly and the feasibility of smelting these reduced red mud sample can be taken up as separate programme which would eventually meet the final aim. that is recovery of iron and other elements from the red mud.

SPONGE IRON INDIA LIMITED
Test Centre

CHEMICAL ANALYSIS

Reference: HUNGARY RED MUD

Table- 1

$Fe(T)$	:	30.16	L.O.I.	:	10.02
Fe^{+2}	:	1.12	SiO_2	:	10.08
FeO	:	1.44	Al_2O_3	:	16.14
Fe^{+3}	:	29.01	CaO	:	5.85
Fe_2O_3	:	41.52	MgO	:	0.05
Fe(M)	:	---	Sulphur	:	0.09
Metn.	:	---	Carbon	:	---
Phos.	:	0.035	TiO_2	:	5.38
Na_2O	:	4.58	P_2O	:	4.46
			V_2O_5	:	0.003

Physical properties of as recieved red mud sample

Table- 2

1.	Colour	:	Brick Red
2.	Bulk Density	:	1.185 T/M3
3.	Moisture Content	:	25%

4. Screen Analysis

Screen Size	Weight Fraction (%)
+ 0.3 mm	16
+ 0.15 mm	61
+ 0.1 mm	18
+ 0.075mm	2
- 0.075mm	1

TABLE - I

Chemical analysis of reductant used in the tests (Manuguru Coal)

I. Proximate analysis (Dry basis)

Ash	25.70 %
Volatile matter	27.90 %
Fixed Carbon	46.40 %
Moisture	4.80 %

II. Ash chemical analysis

SiO2	59.50 %
Al2O3	25.40 %
Fe2O3	8.20 %
CaO	1.40 %
MgO	0.85 %

III. Sulphur analysis in Coal

Organic sulphur	0.4821 %
Pyritic sulphur	0.38 %
Sulphate sulphur	0.016 %
Total sulphur	0.8781 %

Physical properties of reductant used in the tests (Mavuzwi Coal)

Screen Analysis

Table- 1

Screen size	Weight fraction %
+ 12 - 15 mm	12.90
+ 10 mm	28.27
+ 9 mm	15.45
+ [illegible] mm	20.40
+ 3 mm	22.48

II. Gross calorific value 5700 k-cal/kg

III. Ash softening characteristics

Softening point	1320 °C
Melting point	1335 °C
Flow point	1390 °C

IV. Reactivity : 2.1 cm^3 co/gm carb sec

Properties of limestone (desulphuriser) used in pot tests

Table 3

1. Chemical analysis

Constituent	Weight %
CaO	47.2
Fe(t)	1.7
MgO	1.51
S	0.06
SiO2	5.33

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 6

Test No. 1

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.5

Reduction Temp. : 950 °C

Retention time hrs. : 3 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 16.7

Reducibility Index : ---

Process Degradation Index : ---

-Oxide feed % : ---

-Reductant % : ---

Decrepitation Behaviour

Size

- 1 mm : Feed Size < 9.5mm.

- 3 mm :

- 5 mm :

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm					
5 - 10mm	40.21	6.7	16.7	1.1	0.12
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 33.00

Ash : 72.00

Volatile Matter : 6.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 7

Test No. 2

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.5

Reduction Temp. : 1000° C

Retention time hrs. : 3 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 31.20

Reducibility Index : ---

Process Degradation Index : ---

-Oxide feed % : ---

-Reductant % : ---

Decrepitation Behaviour

Size		
- 1 mm	:	Feed Size
- 3 mm	:	0.3mm.
- 5 mm	:	

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm	38.54	12.01	31.20	0.55	0.14
5 - 10mm					
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 27.00

Ash : 66.00

Volatile Matter : 7.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 8

Test No. 3

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.55

Reduction Temp. : 1020 °C

Retention time hrs. : 3 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 34.10

Reducibility Index : ---

Process Degradation Index : ---

Decrepitation Behaviour

Size		
- 1 mm	:	Feed Size
- 3 mm	:	0.5mm.
- 5 mm	:	

-Oxide feed % : ---

-Reductant % : ---

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm	40.21	13.73	34.1	0.98	0.13
5 - 10mm					
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 28.00

Ash : 65.50

Volatile Matter : 6.50

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE- 9

Test No. 4

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-6 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.55

Reduction Temp. : 1040 °C

Retention time hrs. : 3 1/2 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 43.06

Reducibility Index : ---

Process Degradation Index : ---

Decrepitation Behaviour

Size

- 1 mm : Feed Size
- 3 mm : 0.3mm.
- 5 mm :

-Oxide feed % : ---

-Reductant " : ---

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm					
5 - 10mm	40.21	17.32	43.06	1.01	0.175
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 21.00

Ash : 73.00

Volatile Matter : 6.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 10

Test No. 5

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.65

Reduction Temp. : 1050 °C

Retention time hrs. : 4 Hrs.

III. Test Results

Average Metallication (+1 mm)% : 53.30

Reducibility Index : ---

Process Degradation Index : ---

-Oxide feed % : ---

-Reductant % : ---

Decrepitation Behaviour

Size		
- 1 mm	:	Feed Size
- 3 mm	:	0.5mm.
- 5 mm	:	

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn. Carbon	sulphur
- 1 mm				
1 - 3 mm				
3 - 5 mm	41.33	22.04	53.30	0.98	0.14
5 - 10mm				
10 - 15mm				
+15mm				

V. Proximate Analysis of Non-magnetic product (dry)%

Fixed Carbon : 21.50

Ash : 71.00

Volatile Matter : 5.50

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 11

Test No. 6

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.70

Reduction Temp. : 1050 ^{o}C

Retention time hrs. : 4 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 54.81

Reducibility Index : ---

Process Degradation Index : ---

-Oxide feed % : ---

-Reductant % : ---

Decrepitation Behaviour

Size		
- 1 mm	:	Feed Size
- 3 mm	:	0.5mm.
- 5 mm	:	

IV. Grainsizewise Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm					
5 - 10mm	41.69	32.85	56.80	1.1	0.15
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 23.00

Ash : 69.50

Volatile Matter : 7.50

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 12

Test No. 2

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD (POWDER)

Reductant : Manuguru Coal(-3 mm)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.70

Reduction Temp. : 1080 °C

Retention time hrs. : 5 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 56.80

Reducibility Index : ---

Process Degradation Index : ---

Decrepitation Behaviour

Size
- 1 mm : Feed Size
- 3 mm : 0.5mm.
- 5 mm :

-Oxide feed % : ---

-Reductant % : ---

IV. Grainsizewise Analysis of Magnetics (%)

Size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm					
1 - 3 mm					
3 - 5 mm	42.44	24.10	56.80	0.94	0.13
5 - 10mm					
10 - 15mm					
+15mm					

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 24.00

Ash : 69.00

Volatile Matter : 7.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 13

Test No. 8 (Confirmation Test Of NO.7)

I. Input Raw Materials

Iron bearing mineral	:	HUNGARY RED MUD (POWDER)
Reductant	:	Manuguru Coal(-3 mm)
Desulphuriser	:	SIIL Limestone(-3 mm)

II. Test conditions

C/Fe	:	0.7
Reduction Temp.	:	1080^{3} C
Retention time hrs.	:	5 Hrs.

III. Test Results

			Decrepitation Behaviour		
Average Metallization (+1 mm)%	:	56.5			
Reducibility Index	:	---	Size		
Process Degradation Index	:	---	- 1 mm	:	Feed Size (-0.5mm.
			- 3 mm	:	
			- 5 mm	:	
-Oxide feed %	:	---			
-Reductant %	:	---			

IV. Grainsizewise Analysis of Magnetics (%)

size Range			Fe(T)	Fe(Met.)	Meta. Carbon	sulphur
	-	1 mm				
1	-	3 mm				
3	-	5 mm				
5	-	10mm	42.16	23.8	36.5	0.92
10	-	15mm				
		+15mm				

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon	:	21.5%
Ash	:	71.50
Volatile Matter	:	7.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 14

Test No. 9

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD(Lumo Form Std.Size)

Reductant : Manuguru Coal(Std.Size)

Desulphuriser : SIIL Limestone(-3 mm)

II. Test conditions

C/Fe : 0.79

Reduction Temp. : 1080 °C

Retention time hrs. : 5 Hrs.

III. Test Results

Average Metallization (+1 mm)% : 53.78

Reducibility Index : ---

Process Degradation Index : ---

Decrepitation behaviour

Size		
- 1 mm	:	10.15
- 3 mm	:	15.40
- 5 mm	:	25.36

-Oxide feed % : 29.38

-Reductant % : 39.63

IV. Grainsizewise Analysis of Magnetics (%)

Size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm	42.72	24.26	56.80	---	---
1 - 3 mm	40.45	22.67	55.49	---	---
3 - 5 mm	41.89	21.12	51.82	0.75	0.11
5 - 10mm	41.80	22.05	52.65	(composite values)	
10 - 15mm	39.46	20.61	52.27	---	---
+15mm	39.46	20.61	52.27	---	---

V. Proximate Analysis of Non-magnetic product (char):

Fixed Carbon : 20.00

Ash : 73.00

Volatile Matter : 7.00

LABORATORY ROTARY FURNACE TEST RESULTS

TABLE - 13

Test No. 17

I. Input Raw Materials

Iron bearing mineral : HUNGARY RED MUD PELLETS (Fe, Si, Ca)

Reductant : Manuguru Coal

Desulphuriser : SIIL Limestone

II. Test conditions

C/Fe : 0.7

Reduction Temp. : 1050°C

Retention time hrs. : 5 Hrs.

III. Test Results

Average Metallisation (-1 mm)% : 54.03

Reducibility Index : ---

Process Degradation Index : ---

Decrepitation Behaviour		
Size		
- 1 mm	:	15.36
- 3 mm	:	19.54
- 5 mm	:	26.53

-Oxide feed % : 28.17

-Reductant % : 39.46

IV. Granulometric Analysis of Magnetics (%)

size Range	Fe(T)	Fe(Met.)	Metn.	Carbon	sulphur
- 1 mm	42.45	23.45	55.25	---	---
1 - 3 mm	41.89	22.75	54.36	---	---
3 - 5 mm	41.88	22.76	54.36	0.70 (composite values)	0.099 (composite values)
5 - 10mm	40.35	21.72	53.82	---	---
10 - 15mm	40.35	21.12	52.33	---	---
+15mm	---	---	---	---	---

V. Proximate Analysis of Non-magnetic product (char)%

Fixed Carbon : 24.00

Ash : 69.00

Volatile Matter : 7.00

SUMMARY OF LABORATORY ROTARY FURNACE TEST RESULTS

Table-1a

S.NO.	TYPE OF RED MUD	C/Fe RATIO	RADIATION TEMP.(Deg. C)	RETENTION TIME(HR.)	METALLIZATION
1.	POWDER	0.5	950	3	16.7
2.	POWDER	0.5	1000	3	31.2
3.	POWDER	0.55	1020	3	34.1
4.	POWDER	0.55	1040	3.5	43.06
5.	POWDER	0.65	1050	4	53.30
6.	POWDER	0.70	1060	4	54.81
7.	POWDER	0.70	1090	5	56.80
8.	RED MUD FLAKES (7-20 MM)	0.70	1090	5	52.72
9.	RED MUD PELLETS (7-20 MM)	0.70	1080	5	54.03