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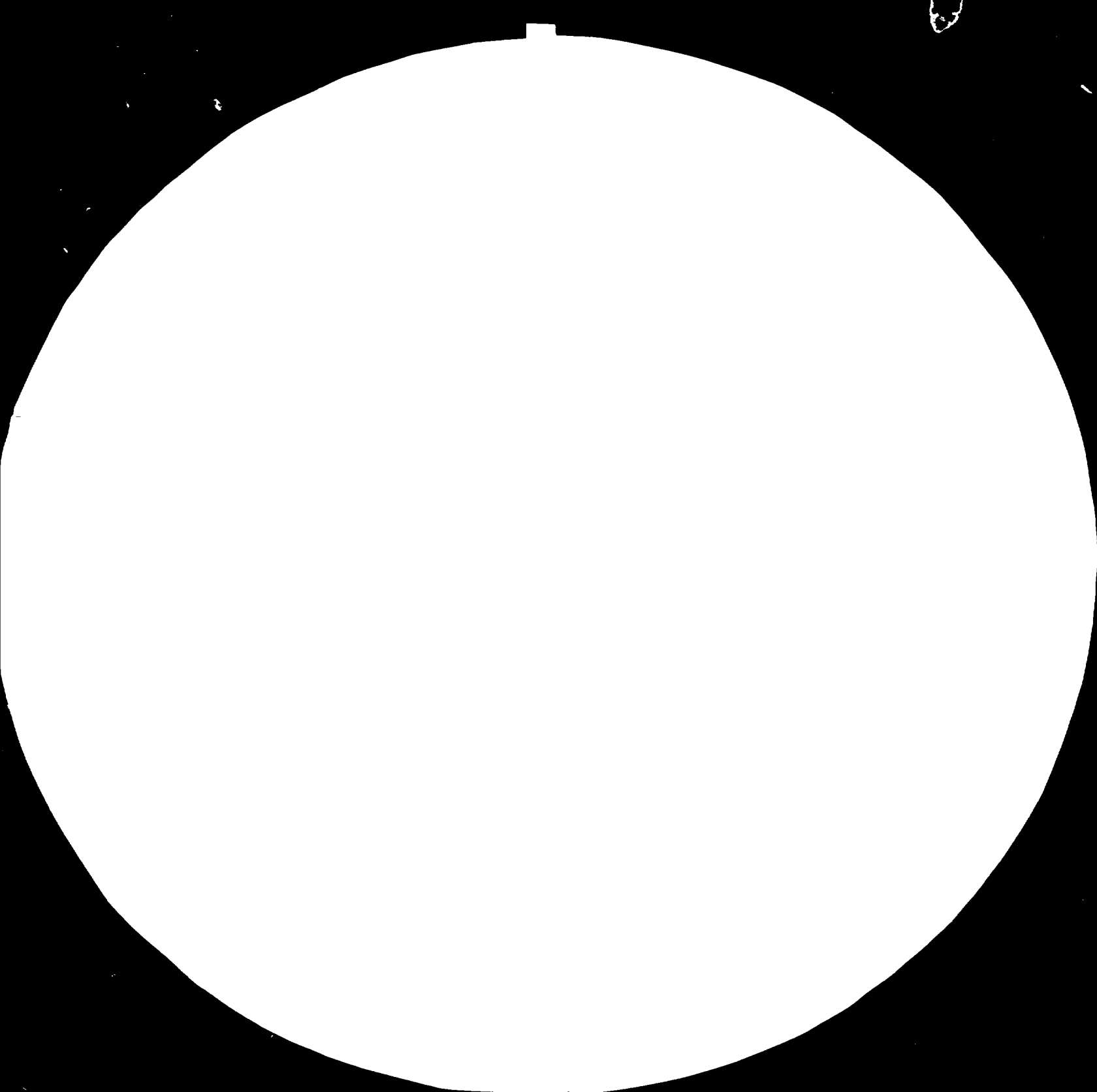

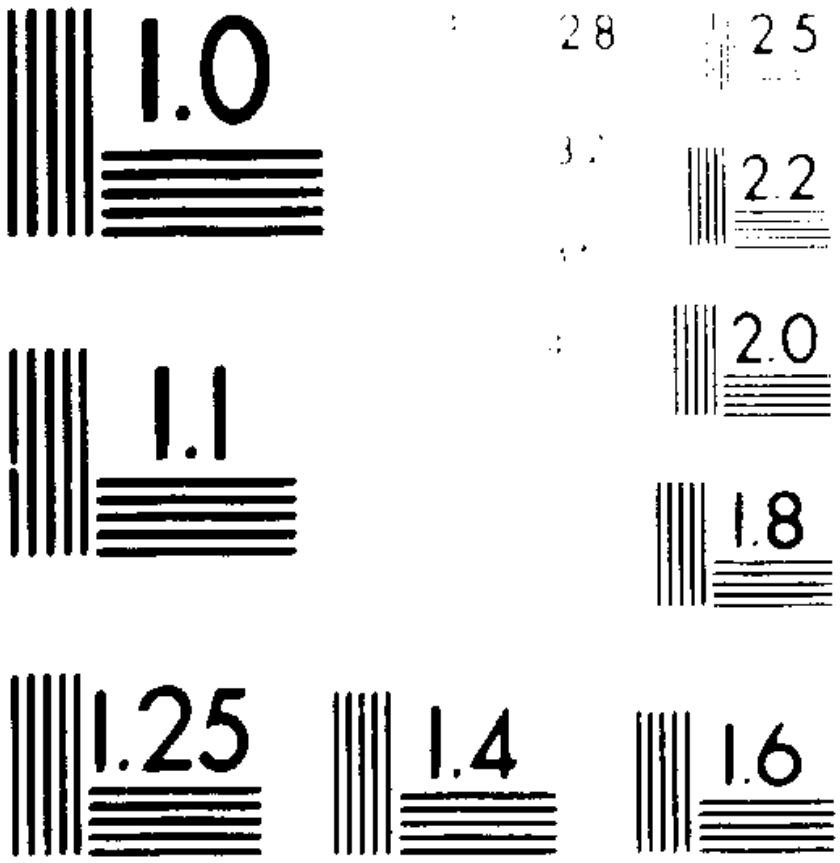

MICROCOPY RESOLUTION TEST CHART

13519

DRAFT FINAL REPORT ON TESTING OF PAKISTAN COALS AND INDIAN IRON ORES FOR SPONGE IRON PRODUCTION

CONTENTS

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SIIL

DRAFT FINAL REPORT ON TESTING OF PAKISTAN COALS AND INDIAN IRON ORES FOR SPONGE IRON PRODUCTION

1.0 INTRODUCTION

1.1 United Nations Industrial Development Organisation (UNIDO) vide their Contract No.82/74, Project No. DP/PAK/79/020 awarded the work relating to carrying out investigations on the feasibility of using Pakistan Coals for production of sponge iron (Master Plan for the Iron and Steel Industry in Pakistan).

1.2 In terms of the Contract the scope of work is as follows:

Phase I: Bench Scale Tests covering determination of proximate analysis, calorific value sulphur content, ash softening temperature, reactivity of Pakistan Coals and study of their behaviour as reductant with Indian Iron Ores in the Laboratory Rotary Furnace and Short Rotary Kiln.

Phase II: If the Bench Scale Test results are found satisfactory, a demonstration test in the 100 tonnes per day capacity kiln of SIIL, with the selected coal sample, would be carried out so as to produce approximately 50 tonnes of sponge iron of suitable quality for steelmaking in Electric Arc Furnace.

1.3 Hospet Iron Ore of India is to be considered for testing suitability of Pakistan Coal as a reductant. This arrangement was considered acceptable as some quantity of iron ore from this region is being imported by Pakistan for their Steel Plants based on the conventional Blast Furnace route.

2.0 TEST PROGRAMME

The results of the Phase-I test programme carried out at SIIL Test Centre were discussed in the interim report (copy enclosed).

2.1.0 The following salient observations (already indicated in the interim report) emerged from the above test work.

2.1.1 The high sulphur content in Pakistan Coals is contributing to the high sulphur pick-up by sponge iron. Even by addition of high amounts of desulphurizer (9 to 15%) the sulphur pick-up could not be controlled within the acceptable levels of 0.03 max. in sponge iron.

2.1.2 Use of large quantities of desulphurizer to control sulphur pick-up in sponge iron is not considered desirable as it would have an adverse affect on the throughput. Further the

low ash softening temperatures (1150-1180°C) of Pakistan Coals also do not permit usage of higher proportions of desulphurizing agent.

2.1.3 High sulphur content in coal would also lead to generation of sulphur dioxide in large percentages in the waste gases which would have to be treated before letting out into the atmosphere. This would involve elaborate and extensive waste gas handling and treatment plant.

2.1.4 For production of quality steel though the use of sponge iron, sulphur levels of 0.03% and below are required to be established in bench scale samples in the first instance before attempting production of sponge iron in bulk scale.

3.0 CONCLUSION

3.1 From the above findings of the Phase-I tests, it can be concluded that it is not feasible to produce acceptable quality of sponge iron (Sulphur levels not more than 0.03%) for steelmaking.

3.2 The results also confirmed very low ash fusion characteristics of coals which would be more pronounced if higher proportions of desulphurizer are used on commercial scale operations. In view of this it is considered not advantageous to carry out bulk scale tests in the 100 TPD Rotary Kiln, as sponge iron produced would not be suitable for industrial use in steelmaking.

SIIL

INTERIM REPORT ON TEST WORK ON PAKISTAN COALS

INTRODUCTION:

Test work was taken up on Bench Scale and Demonstration scale on coal from Pakistan for Sponge Iron Production using Indian Iron Ore at the request of United Nations Industrial Development Organisation (UNIDO) (Reference request for proposal No. P 82/38 and project No. DP/PAK/79/020).

As outlined in the proposal submitted by SIIL, the work involved is to be completed in two phases. Phase-I includes bench scale tests covering determination of proximate analysis, calorific value, sulphur content, ash softening temperature, reactivity and a study of the behaviour of the coal as a reductant with Indian Iron Ore, in the salvis tube furnace and in the Short Rotary Kiln. The phase-I experimentation was completed in two stages. In the first stage, the proximate analysis of the coals from various regions of Pakistan and Salvis Tube tests were taken up. In the second stage, detailed salvis tube and short rotary kiln tests were completed. The present report covers findings from the I phase experiments.

The second phase i.e., Demonstration test in a 100 tonnes per day kiln is to be carried out with the selected coal and ore aimed at producing approximately 50 tonnes of good quality sponge iron suitable for conversion to steel in Electric Arc Furnace.

Hospet iron ore was considered for testing reduction behaviour of Pakistan coal as some quantity of iron ore from this region is being exported to Pakistan and used for smelting in the Integrated Steel Plant near Karachi.

A review of the summary of characteristics of Pakistan coals provided in substantive terms of reference indicated that in the Bench Scale experiments, there will be a need to study the effect of high sulphur level in Sponge iron product. Therefore a few experiments were planned on optimization of proportion of desulphurizer so that sulphur pick up by sponge iron would be minimal.

TEST OBJECTIVES:

The prime objective of the test work was to test the suitability of Pakistan coal for sponge iron production in a rotary kiln. Further it was also aimed at producing approximately 50 tonnes of good quality sponge iron in the demonstration kiln, suitable for conversion to steel in Electric Arc Furnace.

The Bench scale tests have been carried out to fulfill the following objectives.

a) To determine proximate analysis and sulphur content of reductant coal samples.

b) To determine calorific value of reductant coal samples.

c) To determine Reactivity of coal which has a bearing on the reduction temperatures to be maintained in the kiln.

d) To determine ash softening and fusion characteristics of reductant coals.

SAMPLES:

The coal samples for test work were received totally in 8 drums. The identification marks mentioned on the drums were retained and the same have been used for the purpose of this test work.

TEST RESULTS:

Proximate Analysis: All the reductant samples received were analysed to determine proximate analysis. The proximate analysis was carried out on dry basis as per procedure outlined in Indian Standard IS: 1350 (Part-I)-1969. The results of proximate analysis are presented in Table - I. Proximate analysis values indicated that coals mainly fall under the classification of lignites. The ash percentage, volatile matter and fixed carbon are generally found to be acceptable for sponge iron production.

Sulphur Content: All the reductant samples were analysed by the Gravimetric Method as per the procedure outlined in Indian Standard: IS: 1350 (Part-III) - 1969. The sulphur content of all the samples were found to be in the range 4 to 6 per cent as can be seen from results presented in Table-II. The sulphur content of all samples were found to be on the high side endangering the risk of high sulphur pick-up by sponge iron when considered as reductant for sponge iron production. High sulphur content of coals necessiated study of the behaviour of reductant coals with varying proportions of desulphurizer i.e., limestone. Also studies were taken up for establishing the nature of sulphur whether organic or inorganic, which would help in determining the extent of sulphur pick up by sponge iron.

Calorific Value: The Gross Calorific Value of all the reductant coal samples presented in Table-III were determined by using Gallenkamp Adiabatic Bomb Calorimeter. The values were found to be within acceptable limits.

Reactivity of Reductants: The reactivity of coals was determined at 1000 C by the weight loss method. The results of reactivity tests are presented in Table-IV. Coals

appeared to fall under lignite classification and showed high reactivity of 4.32 to 5.50 cc of CO per gram carbon per second. This would facilitate operating the kiln and lower material bed temperature of the order of 900°C to 950°C.

Melting Characteristics of Reductant Ashes:

The three stages of melting characteristics of reductant ashes namely softening point, melting point and flowpoint were determined for all the samples of coals in the Leitz Heating Microscrope and are presented in Table - V . The plates 1 to 5 show the photographic views of ash samples during heating indicating various stages of melting. The ash softening temperature for most of the samples was around 1150°C. Some samples such as 2/2 Lakara coal field, 1/2 coal, Baluchistan had relatively narrow range of melting i.e., the difference in temperature between flow point and ash softening point. The overall ash melting behaviour of all samples indicates that safe operating temperatures for bed would be 900°C to 950°C and for gas phase it would be 1050°C in the reduction kiln.

Reduction Tests in Laboratory Salvis Tube Furnace:

Reduction test was carried out with Hospet ore at the standard test temperature of 1000°C with 3 hours of retention time. The reducibility index, metallisation level and the decrepitation of ore during reduction are presented in Table-VI The metallisation levels & Reducibility index values obtained indicated that ores have good reducibility and it is possible to reduce ore completely at 1000°C with 3 hours of retention time. High metallisation values attained indicated that desired level of metallisation i.e., 92±2% could be obtained at lower temperature. Hence a few additional experiments were carried out at temperatures of 850 & 900°C. The results of these tests are presented in Table-VII . The

results indicate that Pakistan coal being mainly of lignite type and hence more reactive, the desired metallisation level (92±2%) could be obtained at bed temperature around 900°C to 950°C.

Optimization of Desulphurizer (Limestone):

Inorder to study the effect of desulphurizer on sulphur pick up in sponge iron and optimise the proportion of limestone addition, reduction tests were carried out with varying proportions of locally available limestone. The proportions of limestone were varied from 0 to 15 per cent. The results are presented in figure 1 . The results indicate that while sulphur levels could be brought down with increase in limestone proportion, it may be difficult to achieve desirable standard level of 0.03% maximum with Pakistan coals. Further relatively low ash softening temperatures of Pakistan coals (1150°C - 1180°C) may not permit usage of higher proportions of desulphurizing agent.

Reduction Tests in Short Rotary Kiln:

Reduction tests on short rotary kiln have been taken up and two tests have been completed. The initial results have confirmed the behaviour exhibited in salvis tube tests. Further tests to study particle size of coal and ore and mixing behaviour are in progress.

Discussion & Review of Test Results:

i) From a review of the test results it can be seen that the behaviour of Pakistan coal as Reductant with respect to metallisation levels achievable in sponge iron in the temperature range 850 to 1000°C was found to be satisfactory.

Also the high reactivity of the coal facilitates maintenance of lower operating temperatures in the actual plant operation.

ii) High volatile matter in the coal has enhanced the decrepitation rate of the iron ore and the percentage of iron ore fines generated is higher by 7 percent in comparison to the results obtained on same ore with subbituminous Manuguru coal of India.

iii) However, high percentage of sulphur in coal is giving rise to higher levels of sulphur in sponge iron which is not desired in subsequent steel making. Considerable refining would be required to bring down sulphur level in steel making stage. Therefore it is felt that while using sponge iron obtained using Pakistan coal as reductant " External Desulphurizing Techniques" such as Ladle Refining may have to be employed in order to bring down sulphur levels in the molten steel.

High sulphur levels also necessiate use of higher proportion of desulphurizer (limestone) for controlling sulphur pick up by sponge iron.

iv) Pakistan coals being of lignite type which are more reactive compared to bituminous & sub-bituminous coals their consumption is likely to be more when used as reductant as well as a source of heat in rotary kiln direct reduction processes.

v) High sulphur levels would give higher amount of sulphur dioxide gas in waste gas. Therefore waste gas cleaning systems would require adequate design to take extra load of SO_2 in order to minimize SO_2 levels in gases let out in accordance with Internaltional stipulations on rollution Control.

vi) On the basis of bench scale tests carried out so far it c ld be concluded that Pakistan coal is suitable as reductant for direct reduction, if the problem of high sulphur in sponge iron is taken care of in subsequent melting stage through adoption of modern ladle desulphurizing techniques. This could be further studied in the phase-II programme when demonstration tests would be taken up.

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Table No. 1

Proximate Analysis of Coal (on dry basis)

Sample Mark	Volatile matter %	Ash %	Fixed Carbon %
Lakara Coal Field 2/2	46.73	8.90	44.37
Upper Seam of degari-Beluchistan 4/4	42.86	14.28	42.86
Degari-Beluchistan 4/3	45.74	12.90	41.26
SOR- Range Beluchistan 4/2	50.26	5.55	44.19
4R*	44.72	7.54	47.74
Thimpur Mines	39.35	8.05	52.60
SOR-Beluchistan	46.80	9.87	43.33
1/2 coal	47.55	17.98	34.47

* Identification Mark/source not clear.

SIIL

Table No. II

Sulphur content of Samples

Sample Mark	Sulphur (on dry basis) %
Lakara Coal field $2/_2$	4.29
Upper seam of Degari-Beluchistan $4/_4$	5.97
Degari-Beluchistan $4/_3$	4.88
SOR- Range Beluchistan $4/_2$	4.50
4R*	4.37
Thimpur Mines	4.80
SOR - Beluchistan	4.62
½ coal	4.55

* Identification Mark/source not clear.

SIIL

Table No. III

Gross Calorific Values of samples.

Sample Mark	Gross Calorific value Kcal/Kg.
Lakara coal field $2/_2$	6233
Upper seam of Degari-Beluchistan $4/_4$	5765
Degari - Beluchistan $4/_3$	5981
SOR-Range Beluchistan $4/_2$	6133
4R *	6280
Thimpur Mines	6312
SOR - Beluchistan	5840
1/2 coal	5610

* Identification Mark/source not clear.

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Table No. IV

Reactivity of Samples

Sample Mark	Reactivity cm^3 of CO gas/g_c-sce.
Lakara Coal field $2/_2$	4.75
Upper seam of Degari-Beluchistan $4/_4$	4.50
Degari-Beluchistan $4/_3$	4.70
SOR - Range Beluchistan $4/_2$	5.50
4R*	4.65
Thimpur Mines	4.32
SOR - Beluchistan	4.74
½ coal	4.80

* Identification Mark/source not clear.

SIIL

Table No. V

Ash Softening temperatures of samples

Sample Mark	Softening (Initial deformation Point°C	Melting(Hemi-spherical) point°C	Flow point °C
Lakara Coal field $2/_2$	1140	1180	1200
Upper seam of Degari-Beluchistan $4/_4$	1135	1230	1335
Degari-Beluchistan $4/_3$	1150	1200	1250
SOR-Range Beluchistan $4/_2$	1160	1220	1250
4R*	1240	1300	1330
Thimpur Mines	1150	1295	1360
SOR-Beluchistan	1130	1180	1235
½ coal	1140	1200	1220

* Identification Mark/Source not clear.

SIIL

Table No. VI

REDUCTION TESTS IN SALVIS TUBE ROTARY FURNACE AT 1000°C

Iron Ore	Reductant source	Reduction Temp. °C	Metallisation	Reducibility Index	Decrepitation behaviour			Process Degradation Index.
					-1 mm	-3 mm	-5 mm	
Hospet ore	Pakistan coal (Lakara coal field 2/2)	1000	93.50	95.44	15.22	27.18	66.31	60.19
Hospet ore	Pakistan coal (Lakara coal field 2/2)	1000	91.83	94.26	17.14	28.57	62.86	57.83
Hospet blend	Pakistan coal (Lakara coal field 2/2)	1000	75.96	83.13	20.56	29.78	62.40	58.62
Kudremukh pellets	Pakistan coal (Lakara coal field 2/2)	1000	91.95	94.35	19.40	24.62	32.08	43.82
Hospet blend	Pakistan coal (Lakara coal field 2/2)	1000	92.87	94.99	14.90	23.41	55.32	55.03
Hospet blend	Pakistan coal (Lakara coal field 2/2)	1000	95.11	96.57	11.21	18.69	48.60	49.96
Hospet blend	Pakistan coal (Lakara coal field 2/2)	1000	96.30	97.40	16.66	27.19	55.26	53.54

SIIL

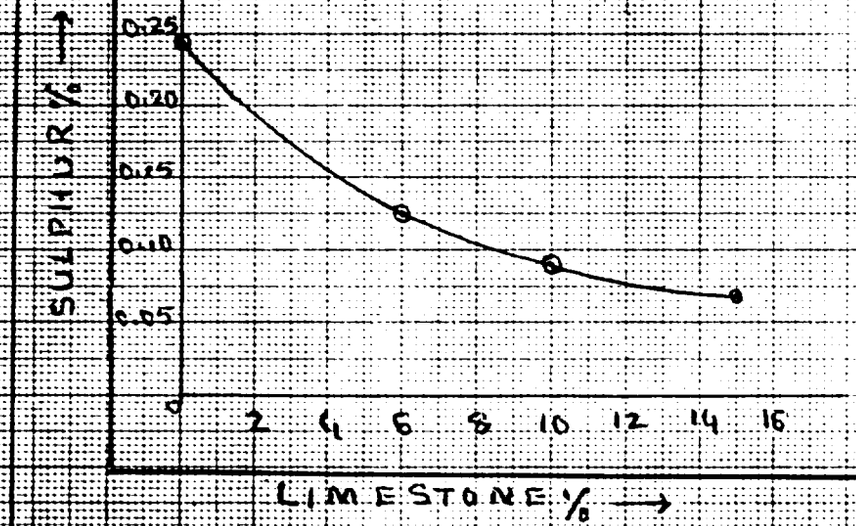
Table No. VII

REDUCTION TESTS IN SALVIS TUBE ROTARY FURNACE AT 900°C & 850°C

Iron ore	Reductant source	Reduction Temp. °C	Metallisation	Reducibility Index	Decrepitation behaviour			Process Degradation Index.
					-1 mm	-3 mm	-5 mm	
Hospet blend	Pakistan coal (Lakara coal field 2/2)	900	89.79	92.83	24.24	37.37	69.69	63.69
Hospet blend	Pakistan coal (Lakara coal field	850	68.63	77.98	17.89	27.64	53.66	49.08

EFFECT OF LIMESTONE AS PERCENTAGE OF IRON ORE FEED ON DESULPHURISATION

(COMPOSITE VALUE OF "% S" IN +1MM SPONGE IRON PRODUCT)



LIMESTONE %	SULPHUR %
0	0.247
6	0.128
10	0.093
15	0.069

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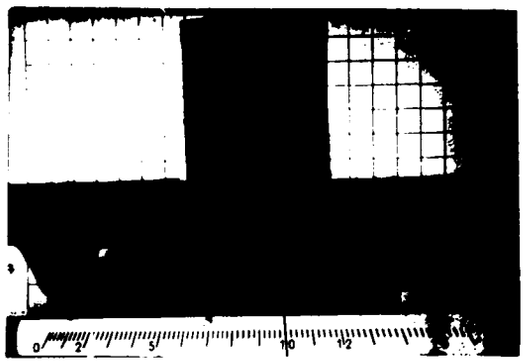
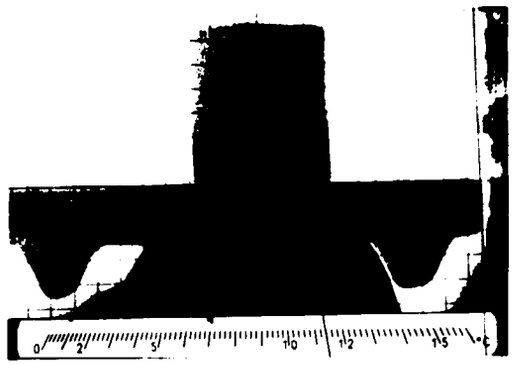
FIG-1

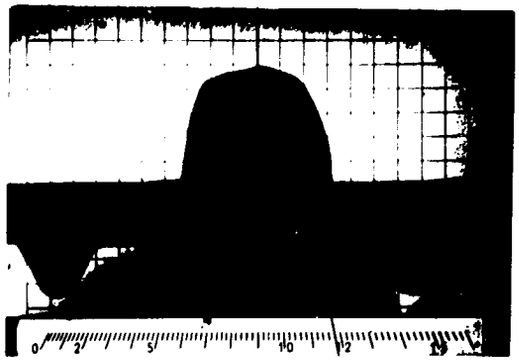
SPONGE IRON INDIA LIMITED

TEST CENTRE

ASH SOFTENING CHARACTERISTICS OF PAKISTAN COAL(LAKARA COAL FIELD2/2)







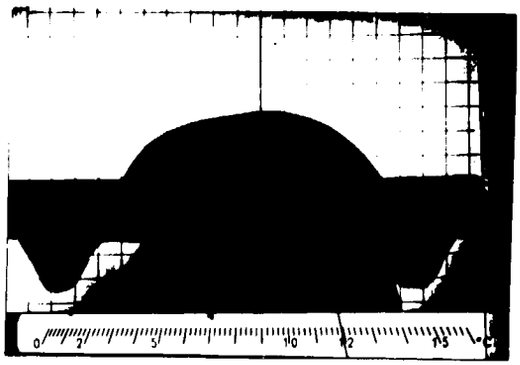


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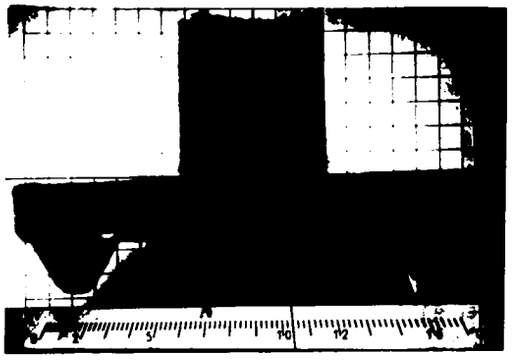
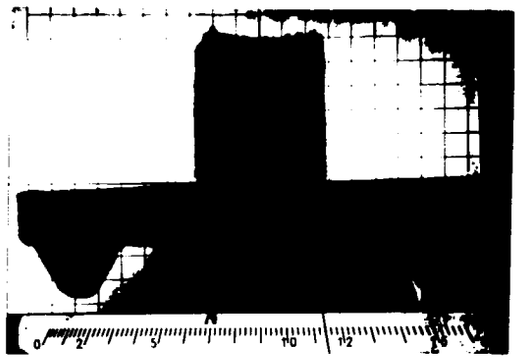
PLATE NO. 1

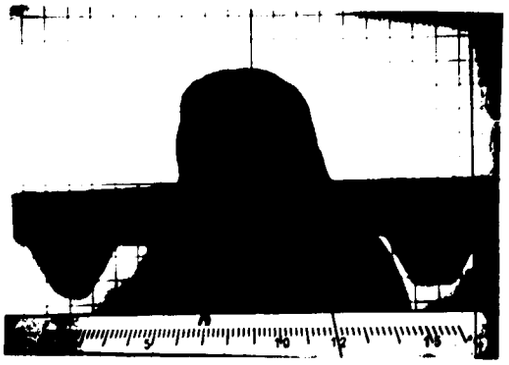
SPONGE IRON INDIA LIMITED

TEST CENTRE

ASH SOFTENING CHARACTERISTICS OF PAKISTAN COAL(1/2 COAL)







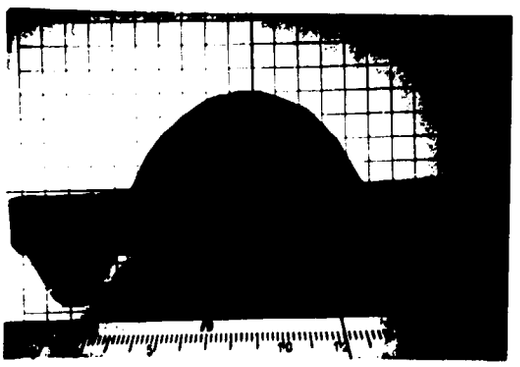


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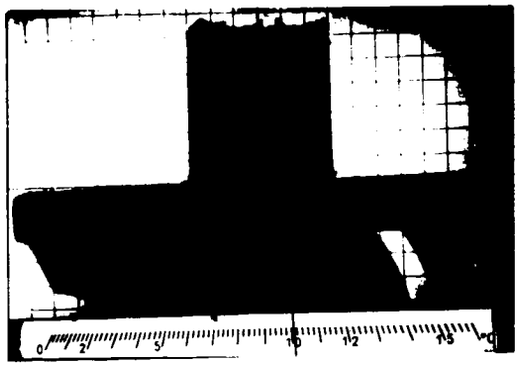
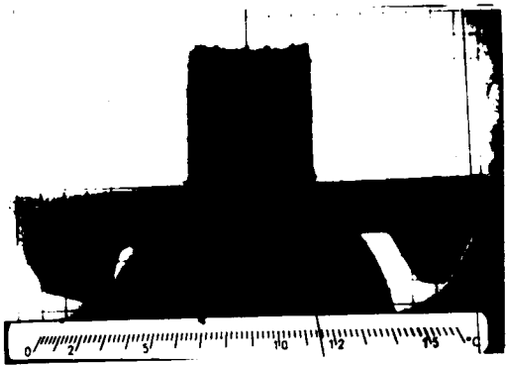
PLATE NO. 2

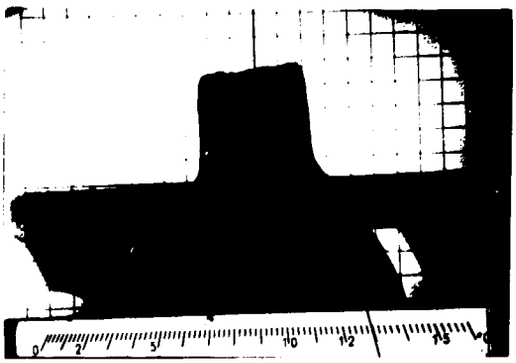
SPONGE IRON INDIA LIMITED

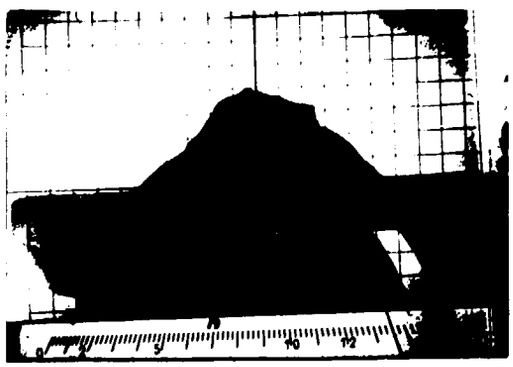
TEST CENTRE

ASH SOFTENING CHARACTERISTICS OF PAKISTAN COAL(THIMPUR MINES)









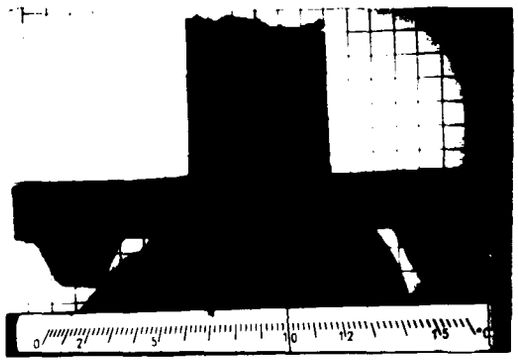
SIIL

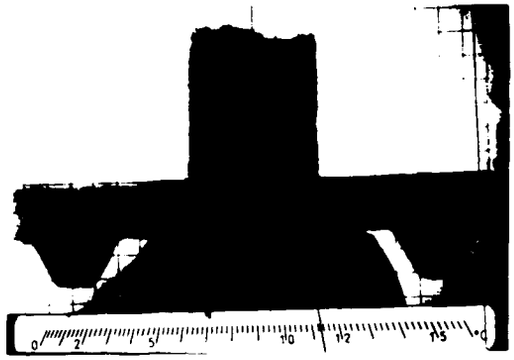
PLATE NO. 3

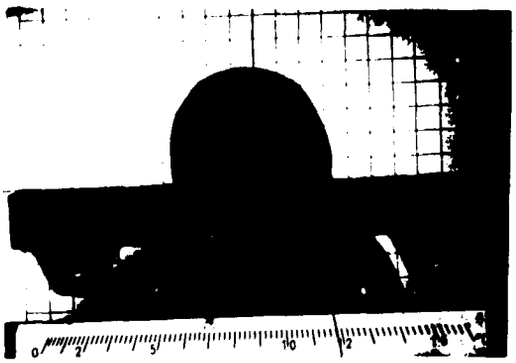
SPONGE IRON INDIA LIMITED

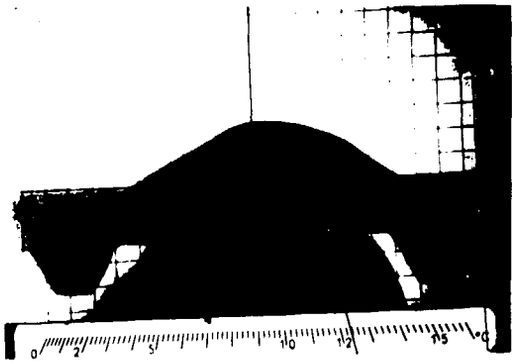
TEST CENTRE

ASH SOFTENING CHARACTERISTICS OF PAKISTAN COAL
(SOR RANGE-BELUCHISTAN)









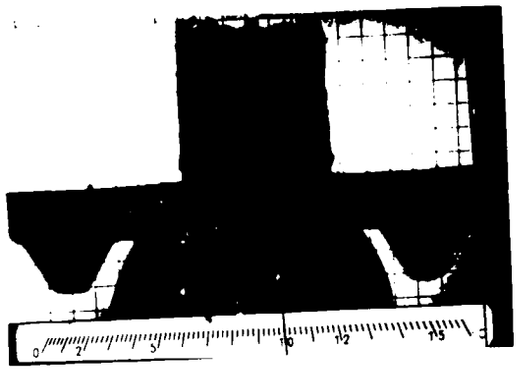
SIIL

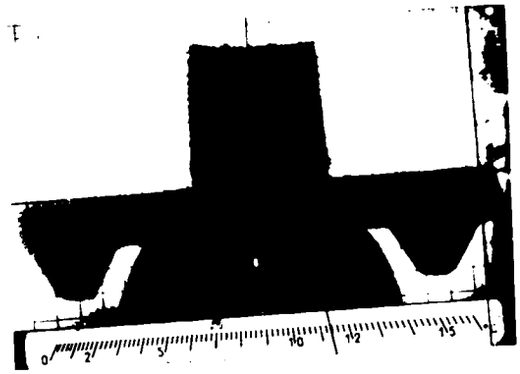
PLATE NO. 4

SPONGE IRON INDIA LIMITED

TEST CENTRE

ASH SOFTENING CHARACTERISTICS OF PAKISTAN COAL
(UPPER SEAM OF DEGARI-BELUCHISTAN 4/4)





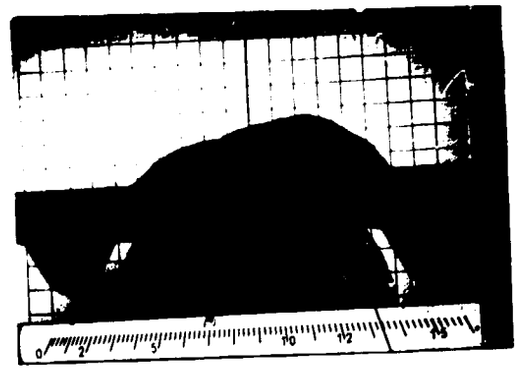


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PLATE NO. 5