INITIAL OPERATIONAL EXPERIENCE WITH ITAKPE IRON ORE IN DIRECT REDUCTION STEEL PRODUCTION AT DSC LTD.

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1.0 INTRODUCTION

The Itakpe iron ore was originally conceived for use in the Blast Furnace process at Ajaokuta Steel project because of the low iron (Fe) content and high acid gangue ($SiO2 + Al_2O_3$) level in the ore. The Delta Steel Plant based on the Direct Reduction Process was to source its required high grade iron ore from Nimba Miferqui (Guinea) deposit in which Nigeria was to have a large share capital. But as Nimba ore project did not materialize, Delta Steel Company had to depend, at the initial stage, on Libe rian ore and later, on the use of ore from Brazilian sources for its operation.

However with the worsening economic situation in Nigeria and the devaluation of the Naira agianst major international currencies, it was becoming increasingly difficult to sustain importation of ores from foreign countries. This contributed to a reduced capacity utilization within the steel sector, and time was therefore ripe to look inwards for a solution to the problem.

It was at this point that the Federal Ministry of Power and Steel mandated a tripartite team of Delta Steel Company (DSC), National Iron Ore Mining Project (NIOMP) and National Metallurgical Development Centre (NMDC) to explore the possibility of using Itakpe iron ore for DSC operations. The first part of this work as reported else where [1,2,3] resulted in the production of superconcentrate with Fe content, 67.4% from a crude ore feed of Fe content 36.8%. The suitability of the superconcentrate for the Direct Reduction process was confirmed through extensive pilot plant studies and bas ket tests. The data obtained from the tests aided the finalization of the design of the superconcentrate unit of the 2.6MT/year ore beneficiation plant at Itakpe mines. It may be noted that even though the equipment for the superconcentrate unit

It may be noted that eventhough the equipment for the superconcentrate unit had since been supplied to site they were yet to be installed owing to funds constraint. This situation still left DSC with the problem of having to import superconcentrate from foreign source amidst dwindling financial resources. Moreover, with the delay in the commissioning of the Blast Furnace (BF) at Ajaokuta Steel Project there was an accumulation of over 100,000 tonnes of BF grade concentrate which virtually filled the stockyard and was therefore threatening further operations at the beneficiation plant.

In order to resolve this dilemma, the study team explored the possibility of blend ing high grade Brazilian Iron Ores with the BF grade Itakpe ore (Fe = 62.68%). Al though it was found that the blend of 1:2 of Itakpe/Brazilian ores produced the desired results, this option appeared unattractive since it was still laden with the problem of having to rely on importation of ore for DSC operations. Thus the blending scheme was discarded and further work was found necessary not only to prevent DSC from grinding to a halt due to lack of foreign exchange but also to make avenue for NIOMP to remain in operation. At this point encouraged by a strong support from the Federal Ministry of Power and Steel, DSC and NIOMP embarked on additional and the last phase of the study which was to upgrade the Itakpe ore of BF quality to that acceptable for use in DSC Direct Reduction Plant.

The focus of this paper therefore is to report on this last phase of the study on Itakpe iron ore and also to relate the operational experience with some 50,000 tonnes of the ore so far supplied and used in DSC.

2.0 QUALITY REQUIREMENTS FOR DIRECT REDUCTION PROCESS

The major chemical change between iron ore and the direct reduced iron (DRI) is the absence of most of the chemically bonded oxygen originally present in the ore. The degree of metalization which expresses the ratio of metallic iron to the total iron content in the reduced iron represents the main parameter for assessing the DRI quality. For meeting this requirement, the ore material must have appropriate chemical, physical and reduction characteristics.

2.1 Chemical and Physical Characteristics

The iron oxide feed with iron content more than 66% and gangue, less than 3.5% is required for Direct Reduction Process. Although lump ores can be used as iron oxide feed, the limited availability of high grade natural ores in the world has led to frequent use of oxide pellets feed as adopted in DSC too.
It is expected that the pellets must have a minimum strength of 2,000N/pellet and should have average size of 12mm. The specification is to allow for trouble free operation, good quality steel and yield.

2.2 Reduction Characteristics

The iron oxide characteristics at reduction condition include reducibility, reduction degradation and clustering tendencies. High reducibility leads to high degree of metallization which in most cases is desirable.
Reduction degradation and clustering result in unstable and inefficient operation. In addition to these characteristics, it is required that matching operating conditions must

be found for optimum performance.

3.0 EXPERIMENTATION

3.1 Materials and Equipment

Itakpe ore (Fe < 63%, SiO_2 > 7%) samples were used in the various pilot plant tests. The ore was taken from a stock of 400 tonnes of Itakpe ore originally earmarked for blending with imported Brazilian ores before the idea was discarded. The average chemistry of the ore is shown in Table 1. Lime hydrate containing an average of 75% CaO was employed as a binder.

3.2 Experimental Procedure

Studies carried out were aimed at upgrading the Itakpe iron ore in terms of the iron and gangue contents. Then it was required to prove the suitability of the ore in plant operations through trial tests followed by optimisation of the necessary operating conditions.

Table 1. Composition of Itakpe Iron Concentrate

Parameters	DSC Specification	Itakpe Concentrate (Before Improvement)
Chemical Properties		
Fe (total)	66 - 67	62.28
S1O2 + Al2O3	2.7 - 3.5	11.10
CaO	0.1	0.17
P	0.05 max.	0.011
L.O I	1.20 max.	0.21
Physical Properties		
≤ 45 microns (%)	30max	3.8

4.0 COMMERCIAL RUNS

Actual plant trial runs and full scale operations with the improved ore consignments (Fe > 65%, gangue < 5.49%) were carried out in the iron and steel making facilities of DSC. The improvement in the quality of the Itakpe ore supplies was based on results of the laboratory studies which showed that the + 500 microns grain sizes of Itakpe ore concentrate gave quality level which was close to DSG specification.

By applying the above concept, the key operating parameters of the beneficiation plant at Itakpe were adjusted to produce iron ore concentrates of predominantly + 500

microns sieve sizes and the quality consequently improved.

Increased erosion of the Furnace refractory linning was also studied by adding crushed used Magnesium Oxide (MgO) bricks in the steel bath.

5.0 RESULTS AND DISCUSSION

5.1 Upgrading of Itakpe Ore

During the course of the laboratory study in DSC a relationship between grain size distribution and iron and silica (gangue) contents was observed for Itakpe iron ore. This relationship was exploited which greatly facilitated the improvement of the ore quality for DSC plant operation. Table 2 illustrates the relationship between Itakpe iron ore grain size and the iron and gangue contents.

Table 2. Relationship between grain size concentrate composition.

Parameters	NIOMP Sieved Concentrate Sample (%) (a)		DSC Reconstructed Sieved Concentrate Sample (%) (b)		
	- 500 microns	+ 500 mirons	- 200 microns	200 - 500 microns	+ 500 microns
Fe	63.8	66.20	58.40	63.47	65.26
$S_1O_2+Al_2O_3$	8.64	4.97	15.22	8.82	5.49
CaO	0.11	0.17	0.28	0.22	0.22
P	0.026	0.018	0.147	0.063	Not done
L.O I	0.07		0.09	0.08	

As may be seen from the NIOMP sieved sample in Table 2, column (a), further amplified by the DSC's reconstructed sieved sample in column)b), the + 500 microns grain size gives Fe and gangue levels which approached the quality requirements of DSC as indicated in Table 1. The range of these values are, for Fe, 65.26 - 66.20% and for the gangue, 4.97 - 5.49%. Similarly, the - 500 microns sieve size showed poor quality characteristics particularly the -200 microns which gave Fe content of 58.4% and a very high gangue level of 15.22%.

The grain size gradation principle was therefore employed as a guide by NIOMP to adjust the beneficiation plant parameters. Thus, by starting with BF grade ore (Fe - 63% and gangue - 8%), it was possible to obtain higher quality ore with Fe 65% minimum and gangue content of less than 5% which could be utilized at DSC.

As pelletisability and reducibility of the Itakpe ores had been conclusively proved [3] in earlier studies in this programme, it was considered superfluous to perform any further pilot tests for this purpose.

Following these positive results, DSC entered into contractual agreement with NIOMP for commercial movement of the ore from Itakpe to DSC.

5.2 Utilization of Itakpe Ore for DSC Operations

A typical chemistry of the improved quality Itakpe ore is as shown in Table 3. A rough assesment of the chemistry of the ore indicates the problems likely to be encountered in the overall utilization in steel making are centered on the level of acid gangue (SiO_2 + $Al2O_3$) in the ore. High SiO_2 in the ore (above 2.5%) increases the swelling tendency during the reduction process. Al_2O_3 content is not known to constitute a problem in reduction operation.

With respect to steel making, high acid gangue is detrimental to the life of the furnace refractory lining. It's effect has to be contained by using additional flux. Thus in the overall, high acid gangue content in the ore leads to generation of high slag volume with attendant increase in power consumption.

The total gangue of 4.73% in Itakpe ore as against Midrex maximum specification of 3.5% is high, therefore a successful utilization of the ore was to include, as a necessity, steps to accommodate this level of gangue.
The programme for the utilization of Itakpe ore was carried out in two phases.

The first phase involved the processing of blends of Itakpe ore with recycled materials (oxide fines and dumped ground ore) which had accumulated over time.

Table 3. Typical Chemistry of Improved Itakpe Ore

Parameters	%
Fe	65.77
Fe_2O_3	94.05
SiO_2	3.93
Al_2O_3	0.80
CaO	0.13
LOI	0.17
H_2O	2.36

5.3 Pelletization of Itakpe Iron Ore in DSC

The iron ore was pelletized in the Pellet Plant - a process which involves dry grinding, mixing, balling, firing and final product screening operations. To achieve the required specific area (SSA) of the ground ore of 1850 - 2500 cm^2/g necessary for successful balling, the grinding ball size distribution was adjusted as shown in Table 4. This grinding ball size distribution produced average specific surface area of 1873 cm^2/g for prime Itakpe ore and 1833 cm^2/g for the blends. These corresponded to 82.38% and 77% of < 45 microns grain size for the prime ore and the blends respectively.

The ground ore mixed with average of 3.2% hydrated lime and pelletized gave typical results shown in Table 5. The physical properties of the fired pellets were good except for the high proportion of the oversize (+ 16mm). This was considered as a process problem and not intrinsic in Itakpe ore. Later operations with better adjustment of process parameters led to the control of + 16mm size materials within acceptable limits.

5.4 Direct Reduction of Oxide Pellets Derived From Itakpe Ore

As expected, the reduction behaviour of the oxide pellets confirmed earlier pillot tests which proved good reducibility of pellets from Itakpe iron ore. Processing the pellets from both prime and blended materials showed that the oxide pellets were easily reducible at a comfortable reduction temperature of 760°C with moderate fines level. Table 6 shows the average properties of the derived DRI during the two phases of production.

The Fe^{met} which gives the level of metallic iron was below the DSC specifiction by virtue of the chemistry of the ore characterized by high gangue level. It was therefore clear that accommodating this level of gangue in the steel making process would require a careful choice of production strategy.

5.5 Making Steel with DRI derived from Itakpe Iron Ore

The utilization of DRI from Itakpe Iron Ore in Steel Making Shop (SMS) did not pose any serious unanticipated problems. Table 7 shows the performance indices of Itkape DRI during the steel making operations. The energy used to melt 100 tonnes of DRI was 67.46 Mwh for prime ore, 73.56 Mwh for blend with recycled materials and 53.09 Mwh for imported ore

Table 4. Ball Size Distribution For Grinding of Itakpe Ore

Ball Size (mm)	% by wt.
50	7.5
40	20.5
30	72

Total Ball Weight about 165 Tonnes.

Table 5. Physico - Chemical Properties of Pellets derived from Itakpe iron ore.

Parameters **Green Pellets**	Prime Ore	Blend of Ore and Recycled Materials	DSC Specification
Moisture (%)	8.10	7.56	7-8.0
Drop No (D/P)	5.7	5.88	4.8 min.
Cold compression Strength (N/P)	11.22	9.28	9.0 min
Fired Pellets Physical Prop.			
CC Strength (N/P)	4560.50	4592	2000
+ 16mm (%)	21.41	12.35	5.0 max.
6.3 - 19mm (%)	95.05	96.15	92.0 min.
Tumble Index (%)	94.51	95.94	93.0 min
Abrasion Index (%)	3.95	2.89	5.0 max.
Firing Temp. (°C)	1300	1300	1300
Chemical Prop			
Fe. tot (%)	65.10	64.32	66.0 min.
Fe_2O_3 (%)'	93.21	92.09	94.0 min.
$SiO_2 + Al_2O_3$ (%)	4.57	4.75	3.5 max.
CaO (%)	2.13	1.99	1.5 - 1-7
MgO (%)	Trace		2.0 max.
S (%)	00001		0.001
P (%)			0.03
Basicity	0.51	0.42	0.60

The liquid yied from DRI was 78.36% for the prime ore, 76.36% for the blend and 83.10% for imported ore. Extrapolating from the yield data, the minimum energy required to produce 100 tonnes of steel was found as 86.09Mwh for Itakpe ore, 95.99 Mwh for the blend and 63.89% Mwh for imported ore. The differences in energy requirement for the production of 100 tonnes of liquid steel are as the result of the different gangue levels within the ores. The higher energy requirement for the blend than the prime ore was due to extra gangue mainly silica incorporated into the materials during the various stages of gathering them together.

Table 7 also shows the slag basicity for the DRI derived from Itakpe ores, its blend with recycled materials as well as for imported ore. The basicity is an index of acidity of the slag. The lower the basicity the more acidic the slag and so the greater the wear on the refractory lining of the furnace. The chemical properties of the DRI

derived from Itakpe ores naturally demand an increase in the quantity of lime addition. As showm in Table 7 the slag basicity for Itakpe ore based DRI varied from 1.30 - 1.63 which was below the required minimum basicity of 2. The slag therefore showed a high level of acidity, and this was after the lime addition was increased from the standard 6 tonnes to 8 tonnes in a bid to strike a basicity value with a minimum refractory damage.

To achieve a slag basicity of 2 and above, it was estimated that a lime dosage of 10 tonnes minimum, was required. This would result in a slag volume of more than two slag pots, additional energy consumption and invariably an increased pressure on the slag moving equipment. The implication of the extra requirements would be a substantial cost differential between imported ore and the Itakpe ores in DSC.

Table 6. Physico - chemicla properties of DRI derived from Itakpe ore.

Parameter	Prime Ore	Blend of Ore and Recycled Materials	DSC Specification
Chemical Prop. (%)			
Fe_{total}	88.30	84.87	90 min.
Fe_{met}	81.20	79.40	82 min.
Deg. Met	92.00	94.2	88 min.
Fe O	9.10	7.03	2.0 - 9.4
CaO	1.22	1.86	2.5 max.
$SiO_2+Al_2O_3$	5.42	5.83	3.6 max
C	2.08	1.24	1.1 - 2.0
MgO	Trace	0.04	max
P	N.D		0.03 max
S	0.006		0.03 max
Physical Properties			
CCStrength (N/DRI)	970	11.88	700 min.
Grain Size (%)			
(9.5 - 16mm)	89.5	87.17	90 min.
Tumble Index (%)	83.33	85.33	80 min.
Abrasion Index (%)	6.67	6.0	6.0 max.
Fines Level	6.27	9.1	6.0 max.
Reduction Temp. (°C)	760	760	760 - 850

Table 7. Some Performance Indices of DRI from Itakpe Iron Ore in SMS

Pamater	Prime Ore	Blend of Ore and Recycled Materials	Imported Iron Ore
Energy to melt 100t DRI (Mwh)	67.46	73.56	53.09
Liquid Steel Yield (%)	78.36	76.63	83.10
Slag Volume (No of Slag Pots)	2	2	1
Slag Basicity	1.30	1.63	1.98
(Lime in Tonnes)	(8.0)	(8.0)	(6.0)

It was therefore necessary to take some measures to minimize the refractory wear as well as find a trade - off between the costs of such measures and their resulting effects i.e higher energy consumption and increased demand on slag moving equipment.

Some encouraging results were obtained by studing the chemistry of refractory erosion and the use of Mgo bricks and dolomite in steel production.

5.6 Minimizing Wear of Furnace Refractory Lining

5.61 Understanding the chemistry of Refractory Erosion

To combat the wear on refractory lining, a fair knowledge of the slag chemistry is required. The correlation [4] between the acid gangue level in DRI and the resulting slag wieght in Electric Arc Furnace is shown in Figure 1. It is known that the degree of slag attack on basic refractories is slag - basicity dependent. The more basic the slag, defined by the value of CaO/S_1O_2, the less the attack on refractories. It is therefore possible to estimate and quantity the degree of attack by a careful analysis of both the slag chemistry and the composition of the charged materials.

Since the refractory linings are MgO - based, the quantity of MgO in slag obviously reflects the degree of damage done to the refractory walls.
About 95% of MgO found in slag is known to result from slag - induced dissolution, whilst the balance 5% results from mechanical damage and contribution by input materials. It is envisaged that at a given temperature, dissolution will continue until the slag is saturted with MgO. Further, it may be assumed by intuition[5] that MgO dissolution rate will be fastest at the begining of slag formation (i.e between power on and melt down) and will diminish with time. More than 60% damage done to refractory walls via dissolution incidentally occurs within this period whilst the balance occurs during tap periods mainly due to high temperatures (1600°C - 1700°C) and longer contact with

slag. It is usually difficult to determine with precision the MgO solubility limit in slag by virtue of so many variables in slag composition and the very quasi - equillibrium conditions prevalent in the furnace. However Tromel[4] showed that the solubility of MgO in slag is appreciable at basicities of less than 2 and is highly influenced by the level of FeO present in the slag.

As shown [6] in Figure 2, for basicities greater than 2, the solubility of MgO reduces significantly and becomes less dependent on the level of FeO. The beneficial effect of FeO may be traced to its foaming propensities causing the submersion of powerful arcs in foam and thus shielding the refractory walls from intense arc radiation.

5.6.2 Refractory Erosion Control

Remedial measures based on raising CaO/S_2O_2 value via excess adddition of lime may have its draw - back in the sense that the solubility of CaO, in slag is not indefinte but limited by the saturation of slag with dicalcium silicate, $2CaOSiO_2$. Once saturated with dicalcium silicate further lime addition remains undissolved and engulfed in dicalcium silicate globules in the slag. The undissolved lime in slag does not participate in the inhibition of refractory dissolution but wil only present false basicity value for the slag.

However it is known that addition of MgO in slag can further increase the solubility of dicalcium silicate by providing extra chemical driving force via shifting liquidus isotherin to higher concentration of CaO[5]. Estimates from Figure 2 give the solubility values for MgO in slag to be 9% at slag basicity of 2 and 10% at the basicity of 1.5. This implies that reduction of slag erosion of basic refractory lining would involve pushing CaO/S_1O_2 value beyond 2. This would be costly and therefore, not desirable.

What was therefore considered more cost effective in this work was to satisfy the affinity of slag for MgO at low basicity either by reverting to the use of dolomitic lime (CaO.MgO) or introducing ground MgO bricks extraneously into the furnace to a point of saturation to discourage further migration of MgO from the refractory lining into the slag.

Table 8 shows the data on steel making process with preliminary addition of crushed MgO bricks to three consecutive heats, Nos 543478 - 543480, of 110 tonnes of steel each. Analysis of the data showed interesting results.

Table 8 Effect of addition of MgO bricks on intensity of Refractory Wear.

Heat No.	Lime Charged (Tonnes)	MgO Charged (Tonnes)	Slag Weight (Tonnes)	MgO in slag (Tonnes)	MgO Eroded from Refractory wall
543478	7.2	None	24.5	2.31	2.31
543479	6.3	0.8	23.7	1.65	0.85
543480	7.2	0.8	25.49	2.08	1.28

The Table 8, indicates that for Heat No. 543487 in which 8 tonnes of lime (i.e 7.2 tonnes of Ca O) was charged, a slag weight of 24.5 tonnes was obtained with 2.31 tonnes of refractory erosion (measured in form of MgO), recorded. For Heat No. 54379 where 7 tonnes of lime (i.e 6.3 tonnes of CaO) and 1 tonne of MgO brick (i.e 0.8 tonne of pure MgO) were added, 23.7 tonnes of slag was obtained. In this case the slag contained 1.65 tonnes of MgO out of which only 0.85 tonne was derived from refractory wall due to erosion. From these, therefore, there was an observed decrease in the level of refractory erosion when MgO brick was added to the steel bath as against when only lime was added as flux. This trend continued even for Heat No. 543480 in which the trial was repeated after carrying out extensive repair of the furnace wall with some 3.3 tonnes of MgO slinging mass, some of which must have invariably fallen into the bath and incorporated into the slag.

Thus in Heat No 543480, with addition of 7.2 tonnes of CaO from 8 tonnes of lime and 0.8 tonnes of MgO from 1 tonne of MgO brick, it was observed that in 25.49 tonnes of slag, the MgO was 2.08 tonnes out of which the quantity arising from refractory wall erosion was 1.28. This was still lower than the figure for Heat No. 543478 where no MgO was added to the steel bath.

These preliminary trial results therefore show that migration of MgO from refractory walls to the slag medium can be significantly discouraged by satisfying partially, the affinity of slag for MgO by introducing MgO extraneously into the furnace.

It may however be noted that whilst the use of MgO bricks in steel making has shown a good promise the long term adoption of this option may be marred by inadequate supply of the desired brick base. For this reason DSC is also exploring the use of dolomitic lime which has long been known and applied to combat refractory erosion due to its 30 - 35% MgO content.
The use of dolomite was excluded at the on set of DSC project because of the humid nature of the environment and its associated problem in pneumatic transport system adopted in DSC.

It is therefore envisaged that at the end of this work a new approach would be evolved to arrest refractory erosion, since refractory materials now constitue the biggest off - shore input in DSC operation.

6.0 ECONOMIC CONSIDERATION AND FUTURE POTENTIAL IN THE USE OF ITAKPE IRON ORE

The economic advantage of using a locally sourced ore in the Nigerian steel industries can easily be seen from the cost savings[7] made on basis of 50,000 tonnes of the Itakpe ore so far supplied to DSC. The total cost and freight (C&F) value of Itakpe iron ore at N2300 per tonne is N115 million.

The corresponding C&F value for the imported ore from Brazil at the exchange rate of N83: $1 is approximately N217 million. Thus the savings amount to about N102 million. When it is considered that 50 000 tonnes of iron ore would merely sustain DSC for not more than 20 days at full capacity, then it could be easy to appreciate the gain implied in the use of the local ore.

This is on the one hand. On the other hand, the development of iron ore industry in Nigeria has a great potential for job creation and possibly as future foreign exchange earner via iron ore exportation. Additionally, it will free the steel industries in Nigeria from the usual politics associated with world trade.

It should be mentioned that though there is evidently a substantial cost saving in the use of Itakpe ore as against importation, a lot of room still exists for improving on the production economics. For example the high gangue content in the Itakpe ore leads to increased processing costs. Also the current method of transportation which is mainly by road haulage is time consuming and extremely uneconomic. An alternative mode of using badges via the River Niger though more cost effective, is seasonal.

Thus improvement of the economics of the use of Itakpe ore in steel production would be realised by rapid completion of the Itakpe-Aladja rail project as well as the speedy installation of the superconcentrate plant at Itakpe.

7.0 CONCLUSION

Some 50,000 tonnes of Itakpe iron ore have so far been utilised via the Midrex Direct Reduction route, to produce high quality steel products in DSC.
The ore was originally earmarked for use in blast furnace operations at Ajaokuta, due to its low quality. Therefore its successful utilization is an innovation by Nigerians. The iron ore upgraded in NIOMP was pelletised and fired at 1300°C and reduced at 760°C.

The physico - chemical properties of the oxide pellets and the DRI produced were largely within DSC specifications. The DRI to liquid metal yield was 78% which was not much at variance with 83% for imported ore.
The succesful utilization of the ore was not without problems. Owing to the high acid gangue of the ore, higher lime dosage was required at steel making stage to neutralize the effect on the basic refractory lining of the EAF vessels.
This resulted in high slag volume and higher energy consumption.

However, with current work to combat the refractory wear phenomenon via extraneous MgO addition, this problem is likely to be minimised in the near future. The cost of producing one tonne of steel with Itakpe ore should be comfortably lower than that for imported ore if adequate measures are taken to circumvent the observed excess refractory wear and high transportation cost of ore from Itakpe to Aladja. These measures include enhanced use of inland waterways and /or completion and utilization of the rail lines now under cosntruction as well as installing at Itakpe the superconcentrate plant whose equipment and machinery had already been delivered to site.

Initial experience with Itakpe ore has shown a lot of promise for the country viz job creation via establishment of ancillary industries, improved capacity utilization in the steel industries, export promotion, general development and improved standard of living.

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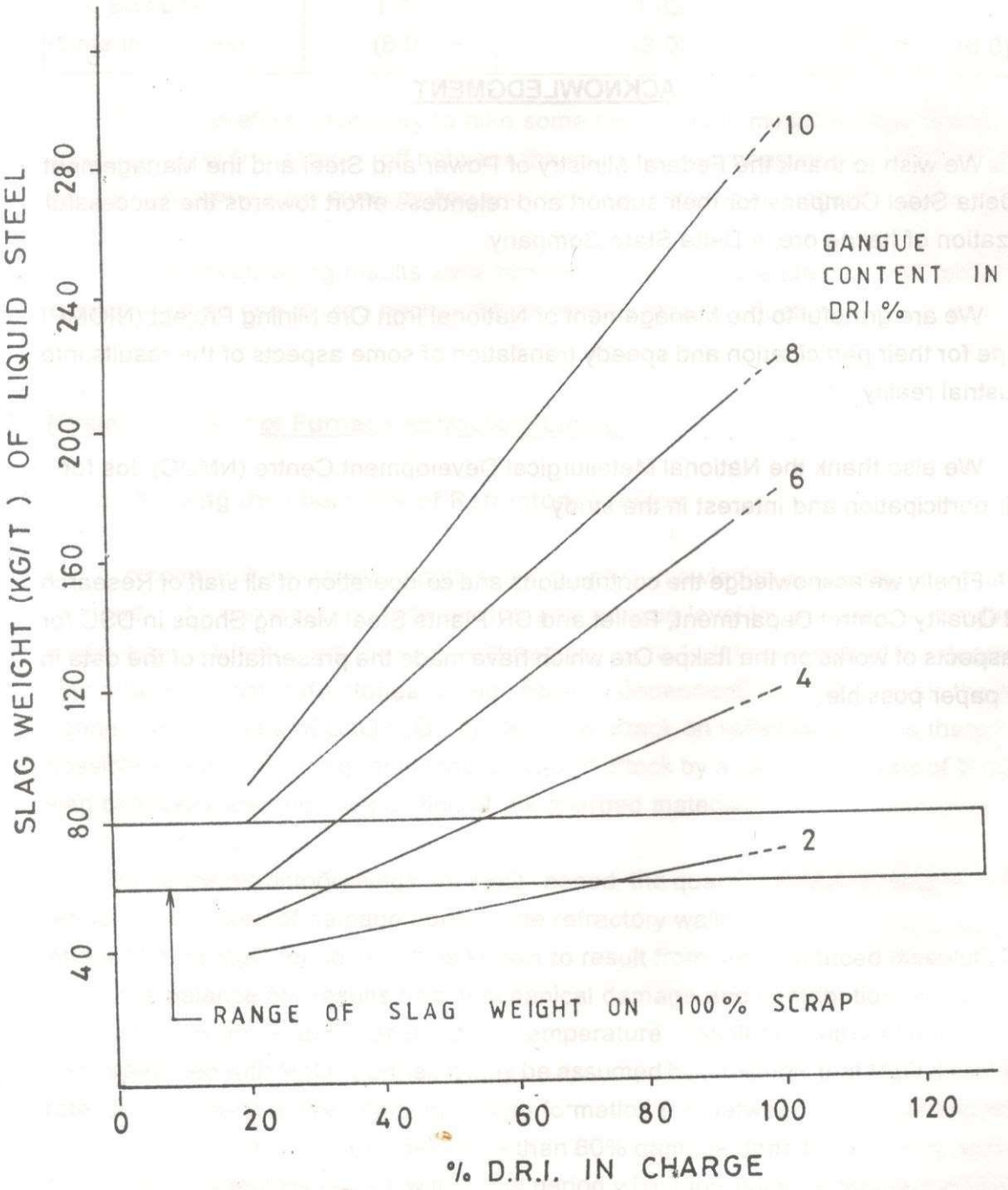


Fig. 1. EFFECT OF GANGUE CONTENT IN DRI ON SLAG WEIGHT

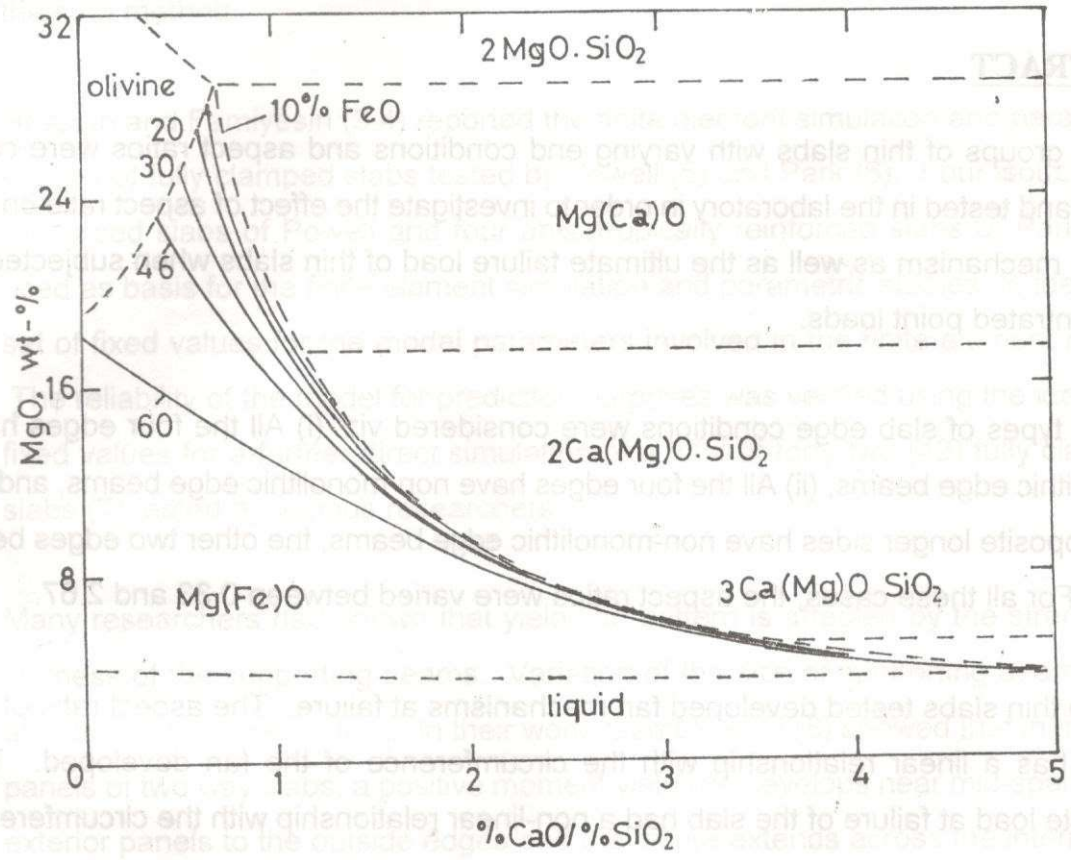


Fig. 2. SOLUBILITY OF MgO AS A FUNCTION OF SLAG BASICITY AND FeO CONCENTRATION