

# Problems and prospects of raw materials for ferro manganese industry with special reference to manganese ores

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## Abstract

*This paper deals with the various problems of raw material resources, grade and ferro manganese production in the country. Methods such as exploration of new resources, blending and beneficiation of low-grade ores and reduction in consumption of Fe-Mn for steel production have been suggested for proper utilisation and conservation of manganese ore reserves.*

## Introduction

Ferro manganese is the most important ferro alloy used in steel industry and its consumption in the world exceeds all other ferro alloys combined. In India approx. 15 to 16 kg of ferro manganese is consumed for every tonne of steel produced, as against around 6 kg of standard grade ferro manganese consumed in industrially advanced countries.

USSR is the biggest producer of ferro alloy in the world. There is a trend towards ore producers moving into the ferro alloy production thereby going in for value added products. The major constraint here is energy. From this point of view the future ferro-alloy industry's growth can be expected in the countries having enough reserves of manganese ore like South Africa, Australia, Brazil, Mexico and India.

## Requirements of manganese ores for Fe-Mn Production

Specifications for manganese ore required by Indian ferro manganese producers are given in Table - 1. The important factors governing

the selection of manganese ore for the production of Fe-Mn are :

- Manganese/iron ratio
- Manganese content of the ore
- Phosphorus content
- Content of slag forming constituents like silica and alumina.

Smooth and efficient furnace operation in the manufacture of Fe-Mn depends to a great extent on the physical nature of the raw-material burden.

Taking into account gas flow, heat transfer and reduction, one sees that the ideal burden for the electric furnace should have relatively small particle size with a narrow range, and as few fines as possible. This assumes not only better preparation at the mines but also screening near the furnace. Generally, higher quantity of fines in the burden is known to increase power consumption because of disturbed heat and mass transfer and also gives rise to irregularity in furnace operation.

As the size of the electrodes increases, with increasing furnace capacity, the smelting zone around the electrodes does not increase, in the same proportion. For this reason the velocity of

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TABLE — 1

Specifications for manganese ore required by Indian ferro-manganese producers.

Producer	Chemical composition percent					
	Mn	Fe	SiO <sub>2</sub> + SiO <sub>2</sub>	SiO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub>	P	S
FACOR	45-48	8(max)	8(max)	—	0.16 (max)	—
Khandelwal Ferroalloys Ltd.	44-48	10	5	—	0.15 (max)	—
Universal Ferroallied Chemicals	a) 46-48	7.5(max)	9(max)	—	0.15 (max)	—
	b) 42-44	10	12(max)	—	0.15 (max)	—
	c) 40-42	10-12	15(max)	—	0.10 (max)	—
	d) 44-46	9.5	9(max)	—	0.15 (max)	—
VISL	42 (min)	10(max)	5(max)	—	0.10 (max)	0.05(max)
TISCO	48 (min)	7.5	—	10(max)	0.11	—
Jeypore Sugar Co..	46-48	8	9	—	0.15	—

gas flow around the electrode in a bigger furnace is much higher than that in a smaller one. This explains as to why smaller furnaces can probably run satisfactorily while still taking substantial proportion of fines. But, today as the trend is towards larger and larger furnaces the size specifications are bound to become more and more stringent. In India, smaller furnaces use materials screened on 3 mm screen in dry season and on 4-6 mm screens in the wet seasons. The fines generated in wet season are stacked separately and rescreened on 3 mm in the dry season and used up systematically. The bigger furnace at M.E.L. Chandrapur used 6 mm and 8 mm screens in dry and wet season respectively earlier. But later, when because of reduced demand of Fe-Mn in the market, the furnace was operating on reduced loads, screening of -6 mm material on 4 mm screen was done and earlier stocks were used thus without noticeable operational problems.

#### Ferro-Manganese - Indian Scene :

##### Production Processes :

High carbon ferro manganese can be pro-

duced either in blast furnace or in electric furnace. Under Indian conditions the coke consumption for making a tonne of standard HC Fe-Mn can be 2500 Kg. and 650 Kg. for blast furnace and electric furnace respectively. The alloy produced in a blast furnace using indigenous materials analyses typically as follows :

Mn%	70-75
C%	5.5-7.00
P%	0.55-0.70
S%	0.027
Si%	0.55

The above chemistry compares very unfavourably, regards 'P' with the ASTM and IS Standards. For this reason, all ferro manganese in India is now produced in submerged arc electric furnaces of capacities ranging from 9 to 33 MVA.

Basically, the selection of a particular process route for the production of high carbon ferro manganese will depend largely upon local circumstances. For example, if an integrated steel maker decides to produce HC Fe-Mn, the

selection may be somewhat different. The availability of a suitable B.F., a supply of low phosphorous coke, an adequate supply of oxygen and shared labour and overheads can help this route become cost competitive. Added to this is the crucial capital cost of the installation which in an integrated plant can be written off.

#### **Choice of different slag practices :**

In normal practice, the largest possible quantities of Manganese is recovered from the ores, into the metal and slag, by following the high manganese slag practice, wherein the fume losses are restricted to about 2-3%. The apparently higher consumption of the manganese ore in this process is due to planned usage of slag for silico-manganese production. If silico manganese is not produced in the electric furnace in conjunction with the ferro manganese, then the adoption of this particular slag practice shall be considered contrary to the interest of conservation. Under Indian conditions, however, the adoption of high MnO slag practice is difficult because of :—

- Poor Mn/Fe ratio of the ore
- High 'p' in the ore and coke
- High slag volume because of higher gangue content of ore and high ash of coke, and
- Requirement of minimum levels of Mn and maximum limit of 'p' in the alloy in keeping with ASTM and or IS Specifications.

On the contrary, the discard slag practice which offered solution earlier, is running into difficulty, because of relatively higher power consumptions and higher power tariffs. Some manufacturers have found semiflux or 25-30% MnO slag practice, which is a half way between the high MnO and discard slag practices, more economical considering all aspects.

#### **Resources of manganese ores :**

##### *India's position :*

The installed capacity of ferro manganese in the country with seven units is 2,32,400 tonnes per annum while the maximum production is

@ 2,00,000 tonnes per annum. This means a demand of high grade Mn. Ore for ferro manganese production at 0.5 million tonnes per annum. There is an expected increase of this demand to about 0.7 million tonnes per annum by 87-88. Against this background the reserve position as detailed in Table - 2 may be seen. Though, the present reserves are indicated at 116 million tonnes the additional reserves developed has not given proportionate increase in the high grade low phos. manganese ore for ferro manganese production. The high grade ores namely + 46% Mn suitable for ferro manganese production is shown as 17.28 million tonnes. However, as more than 12.66 million tonnes come from M. P. Maharashtra, most of which is high phos. material the resource position for ferro manganese production appears to be very discouraging. It would be, therefore, necessary that ways and means are found out for meeting the increasing demand. This can be achieved by (1) Reducing the quantity of ferro manganese consumption in the steel industry (2) Unearthing more high grade reserves in the country in places where detailed exploratory work has not been done so far (3) Utilisation of high grade manganese ore fines by agglomeration (4) Beneficiation of low grade ores for reduction of Fe and phosphorous content (5) Suitable blending of different types of ores to get the required grade for ferro manganese production.

#### **Beneficiation of low grade manganese ores**

Indian Mn. ores can be classified into four broad groups from beneficiation point of view namely :

- Quartzitic ores
- Garnetiferous ores
- Ferruginous ores, and
- High phosphorous ores

Garnetiferous ores do not respond well to ore dressing technique. Electrostatic separation is possible but the feed size imposes restriction. Flotation has been unsuccessful. Quartzitic ores

**TABLE — 2**  
*Manganese reserves of India recoverable reserves as on 1-1-1975*  
 ( with 25% Mn cut-off grade )

Region	+46%Mn	(Quantity - million tonnes)		Total
		35 to 46%Mn	25 to 35%Mn	
Bihar-Orissa	4.62	8.40	17.96	30.98
M. P./Maharashtra	12.66	6.32	1.66	20.64
Andhra Pradesh	—	—	1.24	1.24
I) Bellary Dist.	—	4.90	8.36	13.46
II) Simoga-Tumkur-Hassan, Chitradurg	—	0.22	2.26	2.48
Narth Kanara	—	—	4.19	4.19
Goa	—	—	3.28	3.28
Gujarat-Rajasthan	—	3.03	0.18	3.21
<b>Total :</b>	<b>17.28</b>	<b>22.87</b>	<b>39.33</b>	<b>79.48</b>

are generally amenable to beneficiation by simple gravity separation processes.

Ferruginous ores can be beneficiated by reduction roasting followed by low intensity magnetic separation. IBM has done extensive work on samples from Keonjhar and Sundergarh districts. A composite of 21 samples assaying 38.85% Mn, 16.41% Fe (Mn/Fe - 9.55) Weight pct. yield of concentrate was 59.5% with Mn. yield as high as 80%.

#### Dephosphorisation of Mn Ores

Fe-Mn industry cannot accept a Manganese ore with more than 0.15% P and hence one may classify all such Mn ores as being high phosphorous. A limited quantity of high phos ores is currently being mined for suitably blending with low phosphorous variety. MOIL is not able to cater to the Phos. limitations of the industry. MOIL parcels of Mn. ores have Phos. from 0.16 to 0.17 pct. which can be used only in conjunction with other low 'p' ores. However, there appears a commercial scale possibility of beneficiation of such high Phos. ores for phosphorous removal which should be explored.

#### Work by IBM

Reduction of Phos. content in high phosphorous Mn. ore attracted IBM's attention and in the year 1968 systematic work on a large number of samples from Maharashtra & Madhya Pradesh was undertaken. A quick method to determine the amenability of the ore samples to Phos. removal was evolved. The study showed that when phosphorous is present as free apatite, it was possible to reduce it. Pilot plant campaign involving two stages floatation on South Tirodi samples assaying 39.62% Mn, 16.45% SiO<sub>2</sub>, 8.32% Fe, 1.6% Al<sub>2</sub>O<sub>3</sub>, and 0.4% P, yielded a concentrate 47.7% Mn, 12.66% SiO<sub>2</sub>, 9.68% Fe, 0.89% Al<sub>2</sub>O<sub>3</sub> and 0.12% P with a manganese recovery of about 68%. Agglomeration studies on these concentrates were then proposed.

#### Work by NML

Some of the R&D investigation results on high 'P' Manganese ore samples studied at NML are shown in Table - 3. It can be seen that Phos. could not be lowered appreciably by following conventional ore dressing methods.

TABLE — 3

Summary of beneficiation studies on low grade Mn ore done at NML

State & Locality	Assay% Mn	ROM Ores Fe	Yield% Mn	Assay% Mn	Conc. Produced Fe	Dist% Mn
<b>Orissa</b>						
1. Tisco	26.8	28.8	26.7	58.1	4.5	57.9
2. Sambalpur	38.5	17.5	49.5	57.9	6.1	74.5
3. Barajamda	35.7	9.2	50.6	47.1	6.1	66.7
4. Joda West	27.2	24.2	32.0	52.5	7.3	61.8
<b>Maharashtra</b>						
1. Moil-1	43.1	6.1	81.3	47.6	6.4	89.8
2. Tirodi-B	29.7	13.8	61.3	42.1	17.0	86.9
3. Tirodi-D	29.5	9.5	48.4	47.9	12.4	78.6
4. Khandelwal Ferro-alloys Co., Mn Ore fines.	36.0	9.0	61.5	48.1	8.1	83.4
<b>Madhya Pradesh</b>						
1. Balaghat	29.2	7.8	37.8	47.7	10.4	61.8
2. Jhabua	28.8	5.9	45.1	40.0	4.2	62.7
<b>Andhra Pradesh</b>						
1. Kodur (Eluvial)	33.9	4.5	50.2	44.8 P-O 29	—	66.3
2. Kodue (Bed Ore)	33.5	13.9	43.5	50.3 P-O,25	6.3	65.3
3. Chipurupalli	25.8	10.9	36.8	48.9 P-O.17	7.9	69.8
4. Marrivalusa (Salur)	28.6	12.7	27.0	50.1	6.3	47.3
5. Kodur (Dumps)	24.3	12.9	29.2	46.3 P-O.20	6.1	55.6
<b>Karnataka</b>						
1. Nagri-Joida	34.7	13.6	49.1	57.4 P-O.062	—	81.2
2. Bandur	30.2	21.9	31.5	52.6	7.2	54.9
3. Amritapura	29.9	6.9	33.0	55.1	—	60.9
4. Kumsi	34.4	5.4	65.9	46.2 Insol	9.2	88.5
	SiO <sub>2</sub> -35.5		62.6	47.5 "	4.9	87.8

The process of thermal beneficiation developed by Gupta and Co. Workers, consists in the treatment of low grade high 'P' Mn. ores in two stages producing a iron phos. alloy with low Mn. and a phos. free high Mn. slag which could be treated in second stage for producing HC Fe-Mn. This is known as duplexing and both stages can be carried out in electrical furnace.

Total power consumption can be as much as 6000 KWH. Also the intermediate alloy (Spiegeleisen) is not saleable. The process therefore is not economically viable.

#### Work at RRL (Bhubaneswar)

For the last 16-17 years this Laboratory has been engaged in the active R & D efforts on



TABLE — 4

*Reduction of phosphorus content by alkali roasting*

No. of samples	State	District	Locality	Mn %	Fe %	P %	SiO <sub>2</sub> %	Total insoluble %	Phosphorus(P) content after alkali roast*	Phosphorus reduced %
1.	Orissa	Koraput	Kuttinga (high grade)	49.8	8.3	0.421	1.4	3.3	0.122	71.0
2.	"	"	Kuttinga (low grade)	27.2	13.0	0.377	14.1	24.5	0.207	45.1
3.	"	"	Nishikhal	30.1	24.3	0.641	3.3	6.7	0.283	55.8
4.	"	"	Kasipur	39.8	11.8	0.216	5.0	12.7	0.096	55.6
5.	"	Bolangir	Khutpalli	25.0	25.1	0.438	9.0	18.0	0.253	42.2
6.	"	"	Dandapani	33.1	23.0	0.301	7.0	10.3	0.238	21.0
7.	"	Sambalpur	Khandohl	38.1	17.2	0.230	3.6	5.4	0.132	42.3
8.	Andhra Pradesh	Srikakulam	Garbham	33.0	17.7	0.355	9.5	16.8	0.188	47.0
9.	"	"	Kandapalem	34.1	16.5	0.381	8.8	15.1	0.252	34.0
10.	"	"	Duvam	38.0	9.0	0.626	9.2	14.9	0.277	55.7
11.	Madhya Pradesh & Maharashtra	Balaghat	Tirodi	53.3	5.2	0.311	5.6	7.6	0.145	53.3
12.	"	Nagpur	Ramtek	50.2	6.1	0.406	10.6	15.0	0.256	37.0
13.	"	Bhanda	Gelerwahi	48.1	11.3	0.396	12.5	16.8	0.311	—

\*Ore/Na<sub>2</sub>O in the roasting mixture = 10.4. temp. = 32°C. Period 1.5 hrs.

reduction of phos. content of high 'p' Mn. Ores. RRL (B) undertook detailed studies on chemical beneficiation using alkalis and acids. While dilute acid leaching was applicable to most of Maharashtra MP Mn. ores, a different treatment was required for southern Orissa and AP ores. The studies claim to have obtained very satisfactory results. Table - 4 gives reduction of Phos. content of certain ores from Orissa AP, MP and MS by alkali roasting (reproduced from studies on the reduction of Phos. contents of Phosphorous rich Mn. ores of India-RRL. B).

From a study of all the work done on dephosphorisation of Mn. ore so far, it appears that dephosphorisation of Mn. ores in general, is quite possible technologically though one standard beneficiation method to cover all ores may not be possible.

### Agglomeration

While sintering is one of the proven process for agglomeration of high grade Mn. fines it will be essential to locate this sintering plant near the ferro Mn. plant in order to avoid undue fine generation by sinter handling. There are other avenues of agglomeration especially when the beneficiated concentrates are of ultrafines stage. These may have to be pelletised either heat indurated or cold bonded. Since the heat indurated pellets are energy intensive and will need oil as fuel, it will be better to find out pelletising by cold bonded methods. Serious R & D efforts have to be made in this field. First commercial cold bonded Mn. ore pellet plant has become operational recently in Japan. The possibilities of using furnace top gases of ferro manganese plants for making heat indurated pellets may also be studied.

M/s Paramount Sinters Private Limited through their own R & D activities have developed the technology of Mn. ores sintering and have established a 15000 tpy sintering plant which is in operation since February 1981 and has produced more than 26000 metric tonnes of high grade sinter till date for Maharashtra Elektrosmet Limited, their promoter. This has resulted in conservation of nearly Rs. 10 million worth of high grade Mn. ores.

The use of Mn. ore sinters is claimed to have been advantageous over lumps because of their higher permeability and reducibility, though from a first consideration it will appear that the exothermic heat which would have been otherwise available when higher oxides of Mn. reduced to lower oxides inside the furnace is lost in sintering. The pre-reduction of the higher oxides in the sintering process results in the loss to the furnace of exothermic reactions of reducing  $MnO_2$  to  $Mn_2O_3$  and  $Mn_2O_3$  to  $Mn_3O_4$ . This heat being quite appreciable, and, therefore an explanation of the additional power required for smelting sinter. But there seems to be no appreciable increase with small amounts of sinter upto 20% in the charge. The reason is, a small proportion of sinter blended with ore increases the porosity of the charge and results in improved gas distribution. In India this has at least been the experience of M/s. Maharashtra Elektrosmet Limited, by far the only ferro manganese people to have used sinters on a regular basis. However, studies to establish techno-economics of maximum sinter usage in Fe-Mn production should be undertaken.

#### Other Raw-materials

##### *Coke :*

Present production capacity of HC Fe-Mn in the country is of the order of 2,30,000 tonnes. For this the requirement of high grade Mn. ore with maximum 0.15% P is around 6.2 lac tonnes and the requirement of coke is 1.7 lac tonnes. The coke used at present has 0.16 to 0.18% phosphorous and, hence, can be treated on par

with high 'p' Mn. ores as regards its phosphorous content. A hundred pct. substitution of coke reductant by any other suitable Phos. free reductant would, therefore, result in the conservation of equivalent quantity of low phos. high grade manganese ores. Even if 100% substitution not possible, substantial quantity of low phosphorous high grade manganese ore could be conserved per year.

Large quantities of Silicious high grade Mn. ores are available in MP-M S which could be utilised for making silico-manganese if only low phosphorous or phosphorous free reductant were available. The large scale production and use of silico-manganese in place of HC Fe-Mn will also enable the use of high MnO slag and justify production of HC Fe-Mn by high MnO slag practice which uses less power.

Fe-Mn smelting furnaces can accept a variety of reductants. Isolated trials at plant scale have indicated that LTC and LECO could be used as substitutes. LECO has almost no phosphorous. Talchercoal has been shown to have excellent washing characteristics as found by C. F. R. I. In general non coking coals of India have very low Phosphorous and the Fe-Mn industry is not averse to using coals provided that they are washed first and then formed into acceptable sizes.

##### *Limestone/Dolomite*

India has huge resources of limestone totalling to 50 million tonnes of all grade and 4000 m.t. of B.F. grade. The Fe-Mn industry wants to use limestone with low  $SiO_2$  content. Like limestone, the problem arises for low silica dolomite. India has total 1000 m.t. of dolomite including 240 m.t. of Jayanti hills (W B.) and a part in U.P. which is not yet tapped. However, in view of huge deposits in totally and comparatively very small requirement of Fe-Mn industry, the limestone/dolomite scene can be considered quite satisfactory.

### **The role of MDB in the resources development of manganese ore for ferro manganese industry**

The MDB has taken certain essential studies in the interest of augmenting the resources of Mn. in general and high grade manganese ores in particular. As a first step the Board co-ordinated between steel plants and manganese ore producers for using low grade Mn. ore fines in the iron ore sinter strands. This was tried in one or two steel plants and the possibilities of using the fines in sinter strands was established and only the modalities of cost, price, quality etc. have to be decided between the buyers and the sellers. With regard to high grade Mn. ore fines, MEL has already established a captive sinter plant through Paramount Sinters for using the generated manganese fines in the plant by sintering it.

It has been seen that high grade Mn. ore is occurring in fines in different deposits in the country but no clear cut assessment of same has been made as yet. The fines are mostly lost either by dumping much or by not working the pockets. Some amount of these fines are used for sweetening low grade within the toleration limits. Apart from this there is also the generation of fines while handling the ore which is to the tune of 15-20 pct.

The RRL (B) had developed a pan sintering method at bench scale. MDB took up this project and made bulk sinters using the pan sinter facilities available at Kalinga Iron Work, Barbil. The high grade Mn. fines from the mines of OMC were used for the sinter and the sinter of about 250 tonnes made was tested in the ferro manganese plant at Joda belonging to TATAs by mixing the sinter in different proportions in the burden. The tests have revealed that mixing sinter upto 25 pct. has no adverse effects in the metallurgy of the Fe-Mn and so the Fe-Mn plant can mix sinter in the burden, as long as the sinter can meet the specifications of the plant. This is a healthy trend. The Board is also making arrangements for assessment of the high

grade Mn. fines in different deposits of the country.

Also the Board took up a modelling study of use of different grade of manganese ores in Fe-Mn. production in order to find out the effects of same in the process. Some of the conclusions are :—

- a) Preheating of charge appears to have a significant impact on productivity and power consumption. Mn. content of the ore and Co/Co<sub>2</sub> ratio in the top gas also have a considerable effect on process performance.
- b) Computations show that the Mn. burden should not contain more than 0.15—0.18 pct. Phosphorous to meet the Phos. specification in high carbon ferro manganese.
- c) Relatively low grade Mn. ore (40-42 pct. Mn) can be used to produce medium grade Fe-Mn. However, the use of such ores adversely affects the production rate and specific power consumption.
- d) While using relatively lower grade Mn. ores, it becomes necessary to blend the charge with suitable ores to get the desired Mn., iron and phosphorous levels to meet the specifications for Fe-Mn.
- e) Partial replacement of coke (upto 20%) by coal or formed coke does not appear to have any deleterious effect on the process. This possibility has to be investigated in greater detail for industrial scale application.
- f) A review of the Phos. problem in Fe-Mn production shows that dephosphorisation of ferro alloys holds much promise from the point of view of Mn. ore consideration. It is recommended that studies be initiated to assess this possibility as well as other methods of beneficiating Mn. ore.
- g) Power accounts for over 40 pct. of the total production cost of Fe-Mn. Technological options favouring the use of fossil fuels (non-coking coal) as a primary source of energy are becoming increasingly relevant. In this context, it would be worthwhile taking a look at emerging processes like INRED. Studies in this area deserve support.



## **Other methods of conservation**

### *Relaxing grade requirement of Mn. ore for Fe-Mn making :*

TISCO is producing Fe-Mn with 68% Mn. If public sector steel plants can accept this grade, then all Fe-Mn plants in the country can use lower grades (42%Mn) of ores.

### *Use of Fe-Mn fines :*

TISCO's size specifications for Fe-Mn are also less stringent than those of SAIL. As a result there is greater generation of fines in respect of supplies to SAIL.

MEL, Chandrapur has successfully used Fe-Mn fines as part of sinter mix upto 10%. Bellbay, Tasmania (BHP) Fe-Mn plant has a sintering capacity of 600 TPD and uses all generated alloy fines as a part of sinter mix, thus, recycling the same. This can be tried by other Fe-Mn producers.

Japan uses Fe-Mn fines upto a size range of 4-5 mm as a result upto 96% of their production is saleable. SAIL plants can study this possibility.

### **Alternate processes/process routes/ future processes**

#### *Yonemochi process :*

MDB has obtained some details of the Japanese process of Fe-Mn making by which considerable energy saving is claimed. As against the normal 2800-3000 units for per tonne of ferro alloy, the Japanese process is said to consume only 1800 units of power. This we have brought to the notice of MEL, Chandrapur. The Japanese technique of dipping electrodes in a slag bath improves productivity because the furnace acts as a resistance furnace.

It has been reported that this technique has been tried at SMIORE on a 15 MVA Pig iron furnace. During a short campaign in 1971 for about 20 days there were good indications regarding increase in productivity of the furnace. It

was claimed that Japanese process would improve productivity by 50-70%. Unfortunately the campaign had to be abandoned because the 16%  $Al_2O_3$  ramming mass used at the side wall lining proved inadequate. High FeO slag was the main cause for lining failure. The Japanese however say that existing Elkem furnaces can be modified to suit the process.

#### *Kawasaki process :*

A new iron making process which can be used for production of ferro alloys also such as Fe-Mn, Fe-Cr, etc. has been developed by Kawasaki Steel Corporation of Japan. The process uses fine ore. It involves the same basic metallurgical changes as those that go on inside a B. F. The difference is that it splits them into two Stages. First Stage operation consists of a pre-reduction furnace in which hydrocarbon such as methane are injected with CO gas for reaction at 1000°C. The ore leaving the first furnace is 20-50% reduced. In the main furnace where temp. reaches 1550-1650°C in ferro alloy production, the dual tuyler system makes it possible to regulate hot blast flow and high temp. zone separately from the injection rate of ore.

#### *New Swedish INRED process*

It can be foreseen that Fe-Mn industry in future will have to rely chiefly on beneficiated fine raw materials and non coking coal as starting raw materials. Within the next 20 years or so, a new source of manganese may become accessible viz the mining of nodules on the ocean floor. The nodules will primarily be mined for Cu, Ni and Co and Mn will come as a by product. However, in most likelihood the Mn will be available as a fine concentrate only.

The future will therefore see development and adoption of processes which can use fine raw material directly without agglomeration. INRED of Sweden is one such process which holds promise for the production of ferro alloys also as the metallurgical principle underlying the production of pig iron and ferro alloys are mostly the same.

## Conclusions

Thus it can be seen that raw materials preparation specially of Mn ore is one of the important necessities for getting quality ferro manganese production. However, the different deposits have different deficiencies and the wide geographical distribution of these different deposits in the country precludes any possible economic blending of some for supply to ferro manganese plants which are far away. There is also a necessity to beneficiate the low grade manganese ores and utilise the fines by agglomeration. Continued R&D efforts both in the above aspects and for better utilisation of available resources by finding a suitable process of production of Fe-Mn in the country is to be accelerated.

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## Discussion :

*Subir Kumar Pal, Alloy Steel Plant, SAIL*

1. You have mentioned that if small size of FeMn can be marketed then the saleable production and the Fe-Mn could be increased. In this context I have the question as follows :
  - a) What is the minimum size of the Fe-Mn being produced ?

Ans : All conceivable sizes get generated during the breaking of metal cakes and also obtained on jiggling the slag mix, pool cake etc.
  - b) In case of L. C. Fe-Mn we do require some small size i.e. 50-75 mm for final additions in the electric arc furnace. What is the size being produced ?

Ans : I do not know.
2. Presently we are getting L. C. Fe-Mn containing lot of fines which is posing a problem in the recovery. Could not the industry solve this problem during packing ? If not why ?

Ans : I should think that industry normally keeps fines within tolerable limits. In case the user feels that the fines are excessive, he is always free to take up the matter with the suppliers.

*R. B. Tiwari, Universal Ferro & Allied Chemicals Ltd., Tumsar.*

Q. Regarding pre-reduction of manganese ore, in which plant the process and pre-reduction was tried and with what results vis-a-vis consumption of power and manganese recovery ?

A. I was just giving the effects of pre-reduction as revealed by a mathematical model study sponsored by M.D.B. I am not aware whether any Fe-Mn plant in India practices pre-reduction of Mn. ores prior to the charging into the furnace.

*G. Rangarajan, Maharashtra Electromelt Ltd, Chandrapur.*

Q. INRED process, it is understood to have been developed for production of Pig Iron. Is it also applicable for the production of Fe-Mn ? If so, what are the parameters and results of tests if any ?

A. You are right. It is thought that newer iron making, process can also be extended/adopted to production of Ferro-alloys. Because of low volatility point of Mn some problems are expected in INRED process. However, it has been considered suitable

for Fe-Cr production and can also be extended for other ferro-alloys. Similarly a two stage process developed by Kawasaki Steel Corporation has been successfully used for production of ferro alloys.

*Patulu, MECON*

B. You mentioned that MDB has already launched studies in the field of dephosphorization of high manganese ores. Kindly give certain details regarding process, scale of operation etc. ?

A. I only mentioned that MDB proposes to look into this matter thoroughly. We have already sponsored a project with M/s. P. S. P. L. for developing a sintering process for a dephosphorized concentrate that was obtained from I.B.M. Nagpur.

*S. Ghosh, Mukand Iron & Steel Works Ltd., Bombay.*

Q. How Dephosphorization is practised in the Fe-Mn production and what is the maximum dephosphorisation achievable ?

A. As far as our information goes dephosphorisation is not practised in the Fe-Mn production in the sense you mean.

