Manganese-ore Beneficiation Plants for India

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Big producers with large ore-reserves should put up their own beneficiation plants. But, since majority of the manganese mines are small producers and have only medium or small ore-reserves, and since about 50% of the manganese ores of India are of a complex nature requiring elaborate treatment, erection of custom type mills is the best way to their up-grading and conservation. The mills are to be designed to suit the ore characteristics of each region and located in central places on a regional basis.

ACCORDING to the Industrial Policy Resolution (1956) of the Government of India, all industries of basic and strategic importance should be in the public sector and the State should assume responsibility for the future development of these industries. Other industries which are essential and which require investments on a scale which only the State in the present circumstances could provide, have also to be in the public sector. Accordingly the Government of India has classified industries into three categories, having regard to the part which the State should play in each of them.

In the first category where the future development of industries will be the exclusive responsibility of the State, are included among other items the following:—

1. Coal and lignite
2. Mineral oils
3. Mining of iron ore, manganese ore, chrome ore, gypsum, sulphur, gold and diamond
4. Mining and processing of copper, lead, zinc, tin, molybdenum and wolfram
5. Minerals specified in the schedule to the Atomic Energy (Control of production and use) Order 1953.

The second category comprises industries which will be progressively State-owned and in which the State will generally take the initiative in establishing new undertakings but in which private enterprise will also be expected to supplement the effort of the State. Under this category fall the following industries, among others:—

1. All other minerals except 'Minor minerals' as defined under the Mineral Concession Rules.
2. Ferro-alloys, etc.

The third category includes all the remaining industries, and their future development will be generally left to the initiative of the private sector.

Manganese ores with which this paper is mostly concerned, fall within the first category from the point of view of mining and under the second category for production of ferro-alloys. Development of new manganese ore mines in future will thus be the sole responsibility of the State whereas processing and production of ferro-alloys could be undertaken by the State and the private sector on its own or with State participation. As mining has been defined to include ore-dressing operations also, erection of mineral dressing plants in future manganese mines may also be the sole responsibility of the State.

The production of manganese ores in India for the past five years is given in Table I.

TABLE I—PRODUCTION OF MANGANESE ORE

1950	1951	1952	1953	1954
882,929	1,292,375	1,462,264	1,902,238	1,413,847

MANGANESE ORES

Mines have been classified in Table II on the basis of their production in 1954.

TABLE II

		Production %
No. of mines producing over 100,000 tons in 1954	Nil	—
,, ,, producing between 100,000 & 50,000 ,,	5	27.1
,, ,, producing between 50,000 & 25,000 ,,	6	13.9
,, ,, producing between 25,000 & 10,000 ,,	18	22.4
,, ,, producing between 10,000 & 5,000 ,,	24	12.8
,, ,, producing below 5,000 tons	396	23.8
	449	100.0

Table II indicates that except for a few big producers the rest of the output is from a large number of small mines, whose individual ore-reserves and capacity to finance modern beneficiation plants cannot

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be expected to be high. Out of the total production of 1,413,847 tons, 50.6% is contributed by Madhya Pradesh, 24.5% by Orissa, 11.5% by Bombay, 6.2% by Mysore, 4.1% by Andhra and 0.2% by Rajasthan.

MINING AND DRESSING

Except for two or three mines which are worked by the underground method, all the rest are surface workings operated by the open-cut method. Two of the open-cut quarries have been mechanized with power shovels etc., while all the rest employ manual labour. There are two types of deposits which are mined for manganese : (i) float ore, and (ii) bedded deposits.

Ore lumps dislodged from the parent mass by procession of disintegration are drifted down hill and, form subsidiary mass constituting float ore. Mining of float ore involves digging up of the deposit, hand screening for removal of fines and hand jigging of the gravel after suitable sizing. Jigging can eliminate the light gangue present in the ore, but not the ferruginous and garnetiferous minerals. The jig concentrates often contain interlocked gangue and as no crushing is done with this material, these concentrates are not always of the required purity, for production of standard grade ferro-manganese. Only such of the deposits of float ore which contain quartz and other light gangue and which yield high grade jig concentrates without any crushing, are being worked, though low grade concentrates obtained by this method, are also marketed at low prices.

The bedded deposits which are massive and well defined or sometimes lenticular in character, are blasted, reduced to a suitable size and the coarse fraction alone hand picked. It is obvious that only those deposits or portions thereof which yield a marketable grade of concentrate are exploited at present, leaving the low-grade deposits in situ untouched or in the dumps. Fines below the size suitable for hand-picking, produced during the working of bedded deposits, also invariably go to waste. As will be shown later, not all ore deposits lend themselves to hand-picking, in view of the intimate association of gangue with the manganese minerals.

CONSERVATION

Thus there is considerable wastage of ore in the present system of mining, handling and dressing. It is estimated that for every ton of concentrate produced, an equal amount goes to waste in the form of low-grade ore and fines, which could all be treated by modern ore dressing methods for production of high-grade concentrates. One of the primary causes contributing to the colossal wastage of mineral wealth is the non-employment of trained mining engineers and geologists in the manganese mines. Though the Mineral Conservation and Development Rules (1955) stipulate that all mining operations should be in charge of qualified personnel, mines are still worked by not wholly qualified men. It may be that qualified mining engineers are not available in sufficient numbers to cope with the heavy demand at present, but it is expected that in due course this will be remedied.

So, for proper conservation of manganese as well as all other ores in general, the following methods are suggested: —

1. Employment of qualified mining engineers or geologists in-charge of all mining operations.
2. Stopping selective mining which is employed at present in almost all the mines.
3. Fixing a ceiling on dividends that can be paid by mining companies to their shareholders, to enable their resources to be diverted towards better development of the mines.
4. Putting up beneficiation plants to treat the low-grade ores, or the rejects obtained after hand picking the high-grade concentrate from the run-of-mine ore.

Methods 1 and 2 are too well-known to need any further explanation.

Regarding method No. 3, namely fixing a ceiling on dividends, the author is aware that this will meet with strong opposition from capitalists and the investing public, but it is to be noted that minerals constitute the wasting assets of a nation and that once they are mined and removed, they canont be produced again like agricultural commodities. In this connection, it may not be out of place to stress the need of reviewing as often as market and other conditions warrant, the 'pay grade' of ore, which never remains at any particular level. The 'pay grade' of ore that can be mined depends on various factors such as (i) price of the commodity, (ii) mining conditions, (iii) availability of power, labour etc., (iv) availability of rail, road and steamer communications, (v) scale of operations, and (vi) ore-reserves.

These are some of the important points for consideration, before starting of mining and processing operations. Once the operations have commenced, the 'pay grade' is governed primarily by market conditions. If the price of the commodity remains at a higher level than was anticipated, the 'pay grade' of ore that can be mined will be lower enabling even lower-grade ores to be mined with profit. Under these conditions, poorer ores should be increasingly mined, instead of mining only the comparatively higher-grade ore. This will considerably assist in the proper conservation of mineral wealth. This aspect, which is not well appreciated, has to be brought home to the mineral industry. Profits accruing during prosperous days should be partly utilised for developing the mines and creating reserves to fall back upon during the lean years, instead of freely distributing the entire profits to the shareholders and becoming easily vulnerable to market fluctuations. This is applicable to the entire mining industry, and not confined to manganese alone, though the ups and downs have been rather too steep for manganese ore, forcing most of the mines to close down during the slump periods.

PUTTING UP BENEFICIATION PLANTS

Next comes the most important method for conservation of manganese ores, namely putting up of beneficiation plants to treat the low-grade ores as well as rejects obtained after hand-picking. This aspect has received considerable attention at the National Metallurgical Laboratory for the past six years. Manganese ores from the important occurrences in India have been tested at the Metallurgical Laboratory to work out the best method of concentrating them ; and particulars of the 19 samples investigated so far are given below:—

Madhya Pradesh.—(i) Tirodi mines, Balaghat ; (ii) Netra mines, Balaghat ; (iii) Miragpur mines, Balaghat ; (iv) Mansar mines, Nagpur ; (v) Kachidhana mines, Chhindwara.

Orissa.—(i) Keonjhar ; (ii) Siljora, Keonjhar ; (iii) Sagur, Keonjhar ; (iv) Barajamda, Keonjhar.

Bombay.—(i) Shivrajpur, Panchmahal ; (ii) Nagri Joida, Supa Petha, N. Kanara ; (iii) D'grade ore from Nagri Joida, Supa Petha, North Kanara.

Andhra.—(i) Salur, Srikakulam ; (ii) Kodur mines, (Bed Ore) ; (iii) Kodur mines, (Elluvial) ; (iv) Chipurupalli.

Mysore.—(i) Sandur, Bellary ;

Rajasthan.—(i) Kamji mines, Banswara ; (ii) Kalakunta etc., Banswara.

The results of our investigations have revealed that no two manganese ores are alike in their characteristics. But from the point of view of mineral dressing depending upon the types of gangue associated with the manganese minerals and their degree of association, the ores in general could be classified into four groups: Simple Ores ; Ferruginous Ores ; Garnetiferous Ores ; and Complex Ores.

Simple ores contain quartz, felspar, clay and micaceous minerals, amphiboles, pyroxenes, baryte, etc. as the common gangue. The manganese minerals are free from gangue at a coarse size. Such ores are easily amenable to beneficiation by simple processes like washing, heavy media separation, jigging, tabling and magnetic separation.

Ferruginous ores contain generally hematite and hydrated iron oxides as the major gangue. When conditions are favourable, the former can be eliminated by a patented process involving washing and direct high intensity magnetic separation. In the case of ferruginous ores in general, the ferruginous gangue can be separated by a method based on reduction roast which converts it to magnetite or γ-hematite, and followed by magnetic separation. An interesting feature of this method is that the manganese concentrate is an ideal raw material and in some respects superior to ordinary high grade run-of-mine ores for the production of standard grade ferro-manganese. The strongly magnetic iron-rich product carrying some manganese can be valuable as manganiferous iron ore.

Garnetiferous ores are those containing garnets as the major gangue, the elimination of which is not found possible by gravity or magnetic methods of separation. However electro-static separation brings about a good separation of garnets from the manganese minerals. Quartz, if present can also be eliminated along with garnet as a non-conducting fraction. It is found possible in some cases to float selectively the garnets from the manganese minerals by employing cationic reagents.

Complex ores are those in which either the gangue consists of different types of minerals or is in intimate association with the ore minerals necessitating thereby a complicated beneficiation procedure. They contain sometimes several of the undesirable constituents like silica, alumina, iron and phosphorus —the elimination of all of which requires elaborate treatment. The concentrates obtained fall short of the standard requirements in one constituent or other, which however can be made up by blending with appropriate ores or concentrates.

The classification done above is not claimed to be complete. And it is not as rigid as it appears to show. The first three however, broadly indicates the main gangue present in the ore and the treatment necessary for each of the groups. Evidently complex ores are meant to include ores falling under more than one of the first three groups or when the ores require extremely fine grinding before they can be concentrated.

Phosphatic ores have not been classified as such into a separate group, because high phosphorus (over about 0.2% P) has been found to be present in simple, garnetiferous as well as complex ores. If phosphorus is present as a mineral which is liberated at a size coarser than about 100 mesh, magnetic separation or flotation could be employed for their separation. One remarkable thing about ferruginous ores is that they have been invariably found to be quite low in phosphorus.

Out of the 19 samples investigated in detail at the National Metallurgical Laboratory, two fall under Simple ores, three under Garnetiferous, five under Ferruginous, and nine which represents nearly half fall under Complex. If these could be taken to fairly represent all the important occurrences in India, very few ores are of a simple type requiring a single inexpensive treatment. Plants to treat such ores can be installed with a capital outlay less than that required for other types of ores, for the same capacity. Garnetiferous ores requiring flotation or electrostatic separation need a more costly plant. A plant for reducing roast and magnetic separation needed for ferruginous types of ores, is also expected to be as costly as for garnetiferous ores. The costliest of all the plants are the ones to treat complex ores, which fall under two or more of the above mentioned groups.

Custom mills are ore-beneficiation plants generally designed to treat ores of a particular region. As no two ores are alike even in the same region, a plant to treat ores on a regional basis, has to be equipped on an elaborate scale and this increases the capital cost. Custom mills are therefore to be preferred only when conditions are not favourable for installation of individual mills to treat particular ores.

Mines have therefore been classified below into four categories on the basis of their low-grade ore reserves, the financial resources of the mine owners and the complexity of the ores. The author's suggestions are also given as to who should put up beneficiation plants in each of the cases, and to what extent the State might offer assistance.

Category 1. Mill for big producers with large ore-reserves.—If a particular deposit has sufficient ore reserves to justify the putting up of a mill, the owners of such property should themselves take the initiative to put their own plants. Sending the ores from such mines for treatment to a custom mill though there may be one in the region, will be very costly in the long run.

Category 2. Mill for medium or small producers with large ore-reserves.—The question that arises is whether medium or small-scale producers with large ore reserves have financial resources to install their own beneficiation plants. It has been shown earlier that the number of small mines producing less than 10,000 tons per year and contributing 36.6% to India's production, is quite considerable (about 426) of which some must be having ore reserves to justify installation of a mill. These mines cannot all be expected to have the financial resources to put up their own mills, inspite of their having sufficient ore reserves. Though, under the Minerals Conservation and Development Rules, it is the responsibility of the mine owners to beneficiate their low grade ores, practical considerations point to the desirability of Government assistance in putting up ore dressing plants and if necessary, control over such of the mines which receive Government help.

Category 3. Mill for small producers with medium size reserves.—Next comes another category of mines which includes a large majority of the producers, who do not have sufficient ore resources of their own to justify individual mills, but could join hands and start one or more custom mills among themselves with State assistance to treat their ores. Such an arrangement will be all the more attractive in places which have already the same type of ore, for example, Orisa and North Kanara where the ores are mostly ferruginous in character requiring reduction roast and magnetic separation. Even if such ores are high in silica, high intensity magnetic separation can eliminate this gangue. Ores of these regions with their particularly low phosphorus lend themselves to the production of concentrates suitable for very high grades of ferromanganese. The proposal for custom mills will also be most helpful for treating complex ores which can be economically beneficiated, but which need elaborate equipment. As indicated earlier about 50% of the Indian manganese ores come under this category and consequently, there is considerable scope for putting up mills of the custom type.

Mines falling under this category will necessarily need the financial and technical assistance of the State in the installation of ore-dressing plants. In the interest of the manganese ore industry and with a view to translate the conservation policy into practice, the State should take the initiative in bringing these small producers together and rendering necessary assistance to start custom type mills which is the best solution to the small producers, with limited reserves of ore even of a complex nature.

Category 4.—Complex ores which need a complicated treatment or involve very fine grinding and consequently low recoveries, might preferably be beneficiated by pyrometallurgical or chemical methods.

PROPOSED FERRO-MANGANESE PLANTS

The second Five Year Plan target for ferromanganese production is 1,60,000 tons to be attained by 1960-1961 and licenses have been issued to nine firms for his purpose. The amount of high-grade concentrate required for producing the above tonnage of ferro-manganese will be about 320,000 tons. The information available at present indicates that only the plant to be set up at Garividi in Andhra will beneficiate their ore from the start. It is reported that the plants to be located at Joda (Orissa) and Dandeli (Bombay) will utilize their high-grade hand-picked ores to start with, till their beneficiation plants are installed. Nothing is known about the plans of the other licensee. As production of standard ferro-manganese is difficult to maintain from hand-picked ore alone from a mine, it is advisable to use beneficiated product of the required specification. Such practice not only enables utilization of the off-grade ores produced during mining operations, but ensure production of high-grade ferro-manganese suitable even for export. The sooner this aspect is realised by the prospective ferro-manganese producers, the better.

SINTERING

Manganese concentrates produced after beneficiation will invariably be in the form of fine powder, except in the case of concentrates from heavy-media separation plant, and hence they will have to be sintered before export. It will be very inconvenient even to rail these fines as such, without bagging which is costly. Sintering plants require heavy capital outlay and it is quite unnecessary for beneficiation plants to have their own individual sintering units. A sintering plant can serve two or more milling plants in the same region and it should be designed for a capacity to deal with the concentrates from the whole region. Fortunately for the manganese ore industry in India, the mines are concentrated more or less in certain districts, namely Keonjhar (Orissa), Balaghat, Chindwara and Nagpur (Madhya Pradesh), Srikakulam (Andhra) and North Kanara (Bombay); and this suggestion to have regional sintering plants should be most welcome to the industry. They could be financed by the regional producers with or without State aid and located at the nearest railhead or some such suitable place.

During the second Five Year Plan period, all the fine concentrates that will be produced from beneficiation plants will be utilized as such, by the ferro-manganese producers in India in their electric furnaces which can take in such fines. But with the enforcement of the Government policy of conservation of minerals, more concentrate fines will be produced than are likely to be consumed in India and the surplus will need sintering before it can be exported. It is expected that the third Five Year Plan will see the export from India of sintered manganese concentrates.

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as by-products. The pig iron assayed about 4% C, 0.8 to 1.5% S, 0.03 to 0.04% P, 0.60 to 2.35% Si and 1.20 to 0.60% Mn and the pyrite assayed 46.4% Fe, 44.4% S and 7.3% SiO_2. Iron recovery of the process was more than 95% and that of S, 60%. Loss of S was mainly due to leakage in the equipment which is possible to minimise resulting in higher recovery. Power consumption was of the order of 2700 to 2800 kWh/ton of iron produced.

We are also inclined towards experimenting into autogenous smelting of copper ores to get copper matte of high copper content which may directly be charged in the converters to get blister copper. Sulphur, which is converted to sulphur dioxide can be directly purified, compressed and marketed as liquid sulphur dioxide without the necessity of the usual processing for enrichment and upgrading of the dilute products. The process consists in the introduction through a burner of dry concentrates (20-30% Cu) and flux (silica) to a tall shaft or smelting furnace, where preheated air or oxygen required for combustion is also blown in. The reaction is exothermic due to the burning of sulphur to SO_2; the impurities enter the slag and copper concentrate is obtained as matte having about 70% copper. This matte can be directly charged in the converter for production of blister copper. The gas generated is sufficiently hot and can be used for preheating air and steam raising.

In conclusion let me emphasize that during the short period of six years, though no epoch making discoveries can be claimed by it, the National Metallurgical Laboratory has established its place among laboratories of its kind in the world. By long-range researches, by shorter sponsored investigations, and by offering technical guidance to and undertaking field investigations for numerous small and medium scale industries throughout India, the Laboratory has proved its ability to assist in the country's mineral and metallurgical developments in a significant manner. The good work done so far by the Laboratory has been duly appreciated not merely in this country but outside as well; commendable comments and reviews on its research activities and publications have appeared in the foreign technical Press from time to time. This young Laboratory has, doubtless, gone some way in achieving the objectives for which it was established !