Beneficiation of raw materials and utilisation of fines and slags

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Status of ferro-alloy industry in India

Production of ferro-alloy on tonnage scale started in India with manganese and silicon alloys in mid-fifties This was followed by ferro-chrome in late sixties. In course of time, the production capacities for these alloys have increased appreciably. A large unit for the manufacture of charge-chrome has been commi-ssioned recently in 1983 and another unit under construction at present is scheduled to be commissioned in early 1985.

The bulk production of ferro alloys in the country comprises mainly of ferro-silicon of different grades, ferro-manganese of high, medium and low carbon varieties, high and low carbon ferro-chrome, silicon metal, silico-manganese and silico-chrome. These ferro-alloys are manufactured by the carbothermic process. Some small quantities of ferro-vanadium, ferro-silico-magnesium, low aluminium ferro-silicon etc. are also being produced by the carbothermic process route. The high value ferro alloys viz. terra tungsten, ferro-titanium ferro-molobdenum ferro-vanadium etc. are mostly being produced by the aluminothermic and other batch pro-cesses (thermit process).

Generally, the conventional technology has been adopted in the ferro-alloy plants in the country employing smaller capacity furnaces and utilising mostly high grade lumpy raw materials.

The products made by the ferro-alloy manu-facturers not only meet the requirements of the consumers within the country but also a consi-derable amount is being exported.

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Advantageous position of ferro-alloy industry in the country

The single major factor which has led to the steady growth of ferro-allov industry in India is the availability of the basic raw materials at reasonable prices. Most of the plants use indigenous raw materials except for some of the high value ferro-alloys for which the concen-trates are imported. Most of the plants are loca-ted near the source of basic raw materials and in the states where electricity and labour costs are comparatively favourable.

The raw material resource potential of the country can be said to be quite comfortable. However, it is high time the same is exploited judiciously. Many ferro-alloy producers possess their own captive sources of raw materials. Mining and utilisation of raw materials, in general, have mostly been selective to a certain extent, due to process limitations. Such a situa-tion, if continued further without any check, will naturally lead to quick depletion of all the high grade reserves of the basic raw materials in the country. Ferroalloy producers owning raw material mines are in an advantageous position to give a lead in implementing effective measu-res in optimising the utilisation of lower grade raw materials. This may be achieved by modi-fying the technologies of manufacturing ferro-alloys and employing larger modern furnaces. Many of the ferro-alloy units working in the country are over two decades old and need to

be modernised to keep them running competiti-vely with the newer plants. Under such moder-nisation programme, utilisation of lower grade materials and recovery of waste heat energy should be aimed at.

Modernisation of the older plants and addi-tion of new capacities should be considered keeping in view the prime objective of conser-vation of high grade raw materials. It is heart-ening to note that the new charge-chrome units of the country, are based on utilisation of lower grade raw materials.

Modern steelmaking practice is advanta-geous to ferro-alloy producers

Bulk of the ferro-alloys are consumed by the iron and steel industry in the country.. The new techniques of making steel and metals offer

ture of the ferro-alloys, the fact remains that the efficiency of a process adopted and the ferro-alloy production facilities will always be judged by the capability of their acceptance of lower grade raw materials without sacrificing the quality of the products.

The lower grade raw materials, may be used directly or after beneficiation and/or agglome-ration in different proportions depending on the technology adopted and the efficiency of oper-ation of the facilities. It has often been **found** that the characteristics of beneficiated and / or agglomerated raw materials excel those of the conventional run-of-mine raw materials. The main features of the raw material which influ-ence the techno-economics are :

- chemical composition and basic structure flexibility in the chemical compositions and forms of the ferro-alloys. The requirements of metal contents and impurity levels in the ferro-alloys are no more so stringent as it used to be in earlier days. This has a significant benefit to the ferro- alloy producers in allowing them to use more and more lower grade raw materials, considered so far as unsuitable for the manufacture of conventional grade ferro-alloys. Though the changing requirements of ferro alloys may pose some problem to the conventional ferro-alloy manufacturers but this offers scope in updating the existing ferro-alloy production process and furnace technology as well as the possibility of utilising more and more lower grade raw materials and thereby achieve economics of production.

Raw materials for modern ferro-alloy making

On the face of a very competitive steel market as at present, the cost and quality of the ferro-alloys will determine the prosperity of the ferro-alloy industry. Cost of raw materials contribute substantially to the cost of the ferro-alloys and therefore, plays a key role. Although the good physical and chemical properties of the charge materials are desirable for the manufac-

— basic metal content and impurity levels
- consistency and reducibility characteristics
- metal recovery efficiency in the smelting process

— delivered cost of raw materials at plant site

Efforts may also be directed towards the manufacture of those ferro-alloys which are **not** presently being manufactured in the country by utilising the available resources like FeV, FeW, FeNi, etc.

Visvesvaraya Iron Et Steel Ltd is presently utilising the vanadiferous iron ore reserves of Kemmangundi for production of ferro-vanadium from the slag produced at the iron making stage. Feasibility of utilisation of the vanadiferous — titaniferous iron ore reserves of the Mayurbhanj district in Orissa may also be explored. Utilisation of the nickel bearing laterite reserves of the Sukinda valley in Orissa for production of ferro-nickel is under active consideration.

Adoption of effective measures towards conservation of high grade material

The research projects initiated by the Working Group on co-operation on Research and Development between the Council of Scien-

tific ft Industrial Research fCSIR) and the Steel Authority of India Ltd (SAIL) in the ferro-alloys area is an appropriate step. The problems of the ferro-alloys industry in the country may be tackled by these institutes effectively. The projects initiated by Mineral Development Board (MDB) aimed at the effective utilisation of all available mineral ores and extraction of metal therefrom also need special mention.

With the changing requirements of the quality and forms of ferro-alloys it will be worth• while that certain R ft D work may also be undertaken by the ferro-alloy producers with a view to develop and adopt new production technologies as well as to establish effectively the utilisation of lower grade cheaper raw materials for making quality products.

This national seminar provides an opportunity for a detailed interaction amongst all concerned organisations for evolving the most appropriate measures for a brighter future of the ferro-alloy industry in the country.

I would like to deal briefly the various aspects of raw materials required for the tonnage ferro-alloys. This is also to reflect a general picture of the raw materials situation in the country. I am sure that both the producers and users of the raw materials **will** discuss in detail the problems being faced by them and arrive at suitable conclusions on the feasible measures to be adopted to overcome the same.

Basic raw materials for the **production of tonnage ferro-alloys**

Ferro-alloys are essentially master-alloy compounds of one or more specific metals alongwith iron. Carbothermic process normally employed for smelting of the basic raw-materials i. e. mineral ores containing the desired metal of the specific alloy and iron (except in case of quartzite which contains negligible amount of iron) in varying proportions, use a reducing agent in the form of hard coke, coal, charcoal, etc. In addition, fluxes in the form of lime stone, dolomite, quartzite, etc. are used. Fluxes are generally not required to be used in the manufacture of higher grade silicon alloys and silicon metal. No flux is also required in the manufacture of ferro-nickel due to the self-slagging character of the gangue materials present in the lateritic nickel ores. The gangue materials in the mineral ores of manganese and chromium essentially needs the use of some flux to obviate the slagging problems associated with the production of most of the manganese and chromium alloys.

Advantages of fines agglomerates

The efficiency and stability of furnace operation is largely dependent on the control of raw materials especially for the modern large furnaces. Use of agglomerates in such furnaces has a number of advantages over the run-of-mine ores. In the process of preparation of the agglomerates, an uniformity in the chemical compositions of the ores is achieved and also the grain sizes can be closely controlled. Due to uniform sizing of the agglomerates, better porosity in the furnace charge is achieved and the reducibility characteristics improve substantially.

Significant improvement in preparation of raw material for the production of silicon alloys is not called for as the quartzite available is of high purity.

There is, however, enough scope in the areas of sintering, pelletising and briquetting for the manufacture of the manganese alloys.

Use of agglomerates together with preheating, and pre-reduction for efficient heat utilisetionrid proper adjustment of the burden resistance lead to the most efficient operation of large capacity furnaces being employed today. Of the three forms of agglomerates viz. sinter, pellets and briquette, the pellets are found to be economic at an optimum production level. The maintenance cost is reported, in general, to be the highest in briquetting while the energy costs are reported to be comparatively higher in sintering, if the waste heat is, not utilised.

However, the selection of a particular type of agglomerate will be influenced also by the characteristics of the raw material, ferro-alloy production process, furnace operation technique and specific local conditions if any, and the cost of conversion.

Characteristics of raw material for the manufacture of manganese alloys

The recoverable reserve of manganese ore in the country is estimated at about 80 million tonnes comprising about 17 million tonnes of high grade ore having **a** manganese content of plus 46 %, about 23 -million tonnes having 35 to 46% Mn and the balance 40 million tonnes containing 25 - 35% manganese.

Depending on the chemical composition and the process technology adopted, about 2,000 Kg to 2,600 Kg of manganese ore having a grain size varying between 6 to 50 mm is required to produce a tonne of HCFeMn (75 — 80% Mn) by the conventional method.

Manganese ore with a minimum manganese content of 45% and a manganese to iron ratio of 8.0 and a maximum phosphorus content of 0.15% is desirable. Silica (Si02) and Alumina (A1203) contents are also desired to be limited to 6% and 4% respectively. Higher silica content in the ore leads to increased slag rate, reduction in productivity and higher loss of manganese in slag.

Reserves of ore of the above specification (chemical composition and granulometry) are very limited in the country. The high grade manganese ore reserves in the country are estimated to be about 20% of the total reserves. About 50% of the total reserves are of high phosphorus content. Substantial amount of high grade manganese ore reserves are located in Orissa. The reserves of Madhya Pradesh and Maharashtra are characterised by high silica content. Some of the reserves are also reported to be highly ferruginous.

Phosphorus content being one of the critical characteristic of manganese ore, the normal practice being followed in the mines is to blend the low-phosphorus ore with the medium and high phosphorus ores, a practice, which may not be allowed to continue indefinitely. The feasibility of optimum utilisation of high-phosphorus ores after dephosphorisation may be explored.

The use of lower grade ores having low manganese and high silica contents as well as the highly ferruginous ores should also be considered after beneficiation. Flexibility of the smelting process for direct utilisation of higher percentages of ores having lower Mn/Fe ratio, lower manganese and higher silica contents and higher phosphorus contents should also be aimed at by improving the process technology employed.

The beneficiation/upgrading of the manganese ores, therefore, need to be aimed primarily to achieve the following objectives.

— dephosphorisation of high-phosphorus ores,

- increasing the manganese content in the low grade ores,
- reducing the iron content in the highly ferruginous ores,
- improving the manganese to iron ratio in the low grade ores,
- removal of silica in the highly siliceous ores.

It has been found possible to reduce the phosphorus content of ores by floatation technique where phosphorus is mostly in 'apatite' form. When phosphorus is in colloidal form, the floatation technique normally does not give the desired result. In such case, dilute acid leaching and/or alkali roast leaching are adopted. It is also necessary for some types of ores to be subjected to magnetic separation and thermal beneficiation after acid grinding.

It needs to be borne in mind that such beneficiation techniques should be based on simple flow-sheet and be suitable for ready adoption in industrial scale. **It** will be desirable to plan centralised beneficiation plants to achieve optimum economical operation.

Beneficiation of manganese ores

The most commonly adopted technique for beneficiation of manganese ores comprise floatation and gravity separation by heavy media followed by jigging and tabling. For highly ferruginous ores, reduction roasting followed by magnetic separation is generally followed for upgrading. The beneficiation targets should be fixed in consultation with the user industry to evolve economically viable flow-sheets and optimum capacity.

Utilisation of manganese ore fines

It has been found that apart from the reserves which are fines or friable in nature, substantial amounts of fines are also generated while mining the specified grade lumps and crushing of the same to bring to the required size range, which are always left over at the mines head. This is because of the reason that the undersized

Use **of manganese ore sinters**

Manganese ore sinters are regarded as an excellent charge material for production of ferromanganese due to its improved burden porosity and high reactivity. This helps in achieving reduction of reductant rate and increased power input. It is, therefore, profitable both technically and economically to use as much of ore sinters in the furnace feed as possible. This is applicable not only for the manufacture of high carbon ferro manganese (HCFeMn) but also for the medium carbon ferro manganese (MCFeMn) and silico manganese (SiMn). As manganese ores are quite amenable to sintering the sinter is cheaper, and technically it is possible to replace the lumpy ore to a large extent by sinter, use of other agglomerates of manganese ore viz. briquette and pellet is not so common.

Manganese ore sinters are being **used** by some of the ferro-alloy producers in the country to a limited extent It is understood that R Et D work are being carried out in the TISCO ferromanganese plant at Joda using pan sinters. A commercial plant in Maharashtra is producing manganese ore sinters in a small scale.

In keeping pace with the modern high capacity ferro-manganese furnaces, the sintering ores are generally not accepted by **the** buyers. Utilisation of all fines generated during mining as well as the fines reserves should be planned systematically. The first step in this regard would be to utilise the ore fines directly as furnace feed as much as possible by improving/ modifying the furnace operation technique.

For beneficiating the low grade ores, it is necessary to crush and grind the ores to the desired fineness for liberating the gangue materials and further beneficiation processing. **It is** the normal practice to utilise such fines in the form of a suitable agglomerated. e. either sinter or briquette or pellet. Such agglomeration techniques may be adopted for the fines reserves as well as the fines generated at the mine heads during mining.

plant of higher capacity may be planned. **These** plants may be of continuous in-line type. Such facilities should preferably be located within **the Fe-Mn** plant boundary or at locations within a reasonable distance from the ferro-manganese plants.

Use of high manganese. slag

It is well-knon **that the ultimate metal recovery truly reflects the economy in the use of raw materials. This is directly influenced by the smelting technology adopted and the efficiency of furnace operation. This has particular importance to the production of high-carbon ferromanganese. Depending upon the chemical composition of the ore and the chosen productmix, either the fluxing or the flux-free method is**

adopted. In the fluxing method, reduction of ore in the furnace charge in one step is aimed at. This leads to the production of a slag containing not enough manganese (as Mn0) for further use and is discarded, resulting in substantial loss of manganese and also reduced furnace capacity. On the other hand, in the flux-free method, manganese ore reduction is effected partially to produce a high manganese slag (Mn0 content is about 48 - 50 %) for use as raw material for subsequent silico-manganese (Si-Mn) production alongwith quartzite and fresh amount of manganese ore. Ultimate loss of manganese in the SiMn slag can thus be reduced. This, however, calls for either a periodic operation of a single reduction furnace or employment of a separate furnace for production of SiMn.

Silicon Alloys

Quartzites having about 96 to 97 % Si02, 1% A1203, about **1 %** Ca0 Mg0 and a maximum of 0.02 % P205 comprises the basic raw material for the manufacture of silicon alloys e. g. all grades of FeSi, FeSiMn, FeSiCr, etc. However, manufacture of silicon metal demands still higher purity quartzites. Reserves of suitable grades quartzite in India is widespread. The chemical composition of the quartzite reserves averages to 95 to 97 % Si02. 0.5 % to 1.5 % A1203, 0.5 to 1.5% Fe203, 0 to 0.5% Ca0 and 0.03 % max. phosphorus. Aluminium and phosphorus oxides are the two most detrimental impurities in quartzite. On an average, about 65% of the Al P contents pass on to the melt in the reduction process. The crushed undersized quartzite which normally contain high A1203, therefore, necessitates washing and screening off Control of phosphorus in the product is effected by controlling the phosphorus content of quartzite and the reductant used.

The natural slag composed of the gangue materials in quartzite and the ash of the reductant used generally has melting temperature low enough for slagging of the hearth and as such use of any fluxing agent is not called for in the manufacture of silicon alloys. However, due to the small difference in the specific gravities of such slag and the metal produced, higher amount of slag is undesirable to avoid the problem of separation of slag from the metal.

The amout of slag produced is therefore, restricted to about 2 to 6 percent by the use of rich quartzite having low A1203 content and a suitable reductant, low in ash content. Due to the above reasons, processing of slag is not called for in the manufacture of silicon alloys and the use of high grade quartzite is made rather obligatory. However, low grade quartzites having higher impurity levels can be used by adopting fluxing method in the manufacture of lower grade ferro•silicon.

As mentioned earlier, due to availability of large quantity of high grade quartzite, beneficiation of raw materials (to improve Si02 content) for production of silicon-alloys is not required.

Chromium Alloys

The bulk of the master alloys of Chromium comprises the high and low carbon ferro-chrome (HC Er LC FeCr), ferro-chrome silicon (Fe-Cr-Si)/ silico-chrome (SiCr) and charge-chrome (ChCr). Metallurgical grades of chrome ore used conventionally for the production of the above mentioned chromium alloys call for a minimum Cr203 content of 48% and a minimum chromium to iron ratio of 2.8 : **1. A** favourable magnesia to alumina (MgO/A1203) ratio of unity or more and a maximum silica (Si02) content of 4 to 6% is also generally demanded.

Chromite deposits in India are distributed in the states of Orissa, Karnataka, Maharashtra, Bihar, Andhra Pradesh and Tamilnadu. Orissa is bestowed with the major high grade deposits and about 85% of the total chromite reserves of the country is in this state. It also has low grade deposits having lower Cr203 and higher silica and iron contents. About 50% of the chromite deposits of Orissa are of medium and low grades and the remaining are of high grade. However, 70% of the total deposits of

Orissa are of friable/fines nature. Deposits in Andhra Pradesh and Tamilnadu are reported to be highly aluminous and the deposits in Bihar, Karnataka and Maharashtra to be highly ferru-

minated silica and serpentine are not amenable to simple beneficiation procedures to achieve the desired results. Highly siliceous/aluminous ores needs crushing and rough grinding upto the gange liberation size of about 0.5 to 0.2 mm ginous.

With the advent of new steelmaking process, specifications of chromium-alloys with respect to chromium content and impurity levels have been liberalised thereby allowing direct use of medium grade ore lumps and agglomerates in the smelting of chromium alloys. This has opened wide scope for utilisation of lower grade ores after beneficiation. With this, the practice of blending of only the high and medium grade ores leaving low grade ores to dump can be eliminated.

Although the requirement of LCFeCr and SiCr is gradually tapering off resulting from wide scale adoption of modern stainless steel making technology but some of the existing stainless steel and alloy steel makers particularly the small scale producers are likely to continue to use LCFeCr/SiCr even at a higher price for some time to come. High grade ores — both lumps and fines which are necessary for SiCr Ft LCFeCr production and for the chemical and refractory industries, may therefore, be used for such purposes only and its use for other purposes be reduced to the minimum.

Beneficiation of chrome ore

The chemical composition and minerology of chromite determine the extent to which any particular ore could be beneficiated. The main gangue mineral in chromite are the serpentine, limonite, talc, chlorite, magnesite and calcite. Use of run-of-mine ores in the smelting of chromium alloys is often associated with slag prob• lems. This could be solved appreciably by undertaking beneficiation together with achieving the objective of using the low grade ores.

The simplest form of Cr-Ore beneficiation practised at different mine-heads comprises hand picking, size reduction, screening, panning and tabling. Chrome ores having finely disse- followed by gravity separation by cyclones, tabling, spirals, etc.

A couple of industrial scale beneficiation plants are already in operation in the country and one more plant is at the planning stage.

Since ferruginous ores having chromium to iron (Cr/Fe) ratio varying between 1.8 to 2.0 can now be used directly without any beneficiation for the production of charge-chrome, beneficiation methods, employing high intensity magnetic separation and reduction roasting followed by magnetic separation may be restricted to the highly ferruginous low grade ores. As the chrome ore mines are clustered in particular regions, it may be economical to plan centralised beneficiation plant of large capacity. Concentrates obtained from such centralised beneficia• tion plant could be classified into different grades to meet varied requirements of the ferro-alloy industry, chemical industry and its use as foundry sands.

Use of chrome ore agglomerates

Use of more and more chrome ore agglomerates in the form of sinters, briquettes and pellets is the trend of the day in the production of various chromium alloys. One of the charge-chrome plants has been started envisaging use of briquettes and another under construction is based on use of 100% pellet feed.

Chrome ore calls for high temperature for sintering. Acceptable quality of chrome **ore** sinters has been produced and used with advantages for production of HCFeCr Use of even 50% chrome ore sinters in the furnace charge has been reported resulting in higher metal recovery and reduction in specific power consumption. For a medium sized smelting furnace, Cr-Ore sinters may have a preference over the other agglomerates viz. the briquettes and pellets

as the agglomeration plants are found economically viable only at optimum production levels.

Production of Cr ore briquettes do not require fine grinding of chromite which are of friable/fines nature Even, while beneficiating the low grade ores, the rough grinding made for the liberation of siliceous/aluminous gangue is considered sufficient for briquetting purpose. Elimination of fine grinding, therefore, makes raw materials preparation comparatively easy apart from economic advantage compared to the run-of-mine ores. Since briquettes are liable to breakage in handling, it is desirable to locate the briquetting unit within the Cr-alloy plant premises. Pre-heated briquette charge also brings down the specific power consumption in closed furnace. Selection of suitable binding agent and composition of briquettes (i.e. content of ore fines, reductants, fluxes) and grain size of the ore fines are of prime importance for achieving the required strength of the briequettes and its stability in the smelting zone inside the furnace. It is often required to add lumpy chromite in the furnace charge to obtain stable furnace operation.

Pellet is found to be the most popular and acceptable form of chromite agglomerate to the majority of the chromium alloys producers. This is due to its classic reducibility, hardenability to withstand long storage and handling, amenability to preheating and prereduction outside the smelting furnace and the highest metal recovery. While use of hot pellet charge brings down the specific power consumption to a large extent (about 30% reduction), the same is brought down to the minimum with the use of pre-reduced pellet charge. The added advantage of using prereduced and preheated charge in closed furnace is the availability of furnace gas rich in carbon monoxide (CO) which could be used suitably in the plant. The amount of CO rich furnace gas generated with a prereduced charge will evidently be less than with a preheated charge. The preheated charge, system, therefore, has an advantage over the prereduced charge system in balancing the fuel requirements in the plant needed for the hardening and preheating of the pellets and other miscellaneous purposes thus making the plant operation almost oil-free.

It has been possible to directly reduce SiCr by using prereduced i.e. metallised pellets thus dispensing with the conventional requirement of hard and lumpy ore in the Perrin process for production of LCFeCr. Another interesting feature of the metallised Chromite pellet is the possibility of its direct addition as charge material in stainless steel production in Argon Oxygen Decarburisation (AOD) vessel. It can, therefore, be said that chromite agglomeration in the form of pellet offers very wide flexibility and adaptability together with the considerable economic advantage.

Use of ferro-chrome slag

In the manufacture of LCFeCr, extra amounts of lime (CaO) is added to fix up the silica (SiO_2) in the slag resulting from the silico-thermic reduction of hige grade chrome ore fines by the ferro•chrome silicon (FeCrSi). **An optimum** basicity (i.e. CaO/SiO_2) of slag is aimed at say 1.8 to 1.9 to restrict the silicon content in the metal and loss of excess chromium in the slag. This results in a calcareous slag which disintegrates into powdery form on solidification. The slag bulk is generally 2.5 to 2.8 times **the** amount of LCFeCr produced.

The hot slag is utilised within the plant to provide protective linings for ladles and moulds. Powdered slag can also be used in the preparation of moulds for casting purposes. Due to the basic character and powdery form of the slag, it may be used in treating the acid soils. As some of the characteristics of this slag are akin to those required for cement, the same may also be used in the production of cement clinkers. While producing charge-chrome, the slag arising is about 1.2 times that of metal produced compared to 0.9 to 1.0 time in case of HCFeCr. This is due to the utilisation of lower grade chrome ores. The proportions of the refractory oxides of the charge-chrome slag together with its limited iron content offers scope for its use in the manufacture of heat resistant materials. Such slags are being used abroad as a raw material for the production of high grade refractory castables. The slag produced in the manufacture of HCFeCr and ChCr can be used as such for building and road making purposes also.

Ferro-Nickel

Conventionally the primary nickel products viz. briquettes, pellets and cathodes which contain approximately 98 — 100% nickel are used for nickel additions in the alloy steels and other industries. Production of secondary nickel products on tonnage scale like ferro-nickel and nickel oxide sinter containing lower percentages of nickel, started during the late fifties and early sixties. During the same period, technological improvement in stainless and alloy steel making technology resulted in the acceptance of the secondary nickel products. By the late sixties and early seventies, about 50% of the nickel inputs were in the form of secondary nickel products. With the steady growth in the consumption pattern in favour of secondary nickel products and depletion of high grade sulphidic ores, production of nickel from oxide ores such as serpentines (garnierite) and limonites (laterites) has been gaining major attention by the nickel producers.

Characteristically, the nickel ore reserves in India are limonitic laterities. About 95% of country's total reserves are located in the ultramafic belt of Sukinda valley in Orissa. The total reserves of nickeliferous laterite in the country have been estimated by the Indian Bureau of Mines (IBM) at about 160 million tonnes. Calculated at a cut off level of 0.5% nickel, a reserve of about 121 million tonne has been estimated by the Geological Survey of India (GSI) in the four major sectors in Sukinda valley viz. Kansa, Kaliapani, TISCO and Kumardah — Saruabil — Sukrangi. Limontic ores in these sectors are characterised by low nickel content, low magnesia (Mg0) and Silica (Si02) contents and high iron content.

Lateritic nickel ores are generally reported to be not amenable to conventional beneficiation/concentrating methods. This require further detailed investigations for determining the most suitable process for extraction of nickel. A project was initiated during early seventies for setting up of a plant for extraction of nickel and cobalt based on Kansa deposits but the same has not been materialised. Representative samples of Kansa nickel ores have been tested in the pilot plant in Europe. Based on these deposits, establishment of a ferro-nickel plant is under consideration which may require about 0.5 million tonnes of nickel ore mixture/blend having an average nickel content of about 1.12% and iron content of 51 %.

It may be mentioned here that cobalt content in ferro-nickel being restricted to th to ?th 30
of the nickel content, nickel ores having high cobalt content will not be suitable for ferro-nickel production by the conventional rotary kiln — electric furnace (RK-EF) process. Similarly, since most of the copper present in the ore will pass on to the ferro-nickel, a low copper content ore will be desirable to restrict the copper content in the alloy. All these factors need careful examination especially during the mining operation due to the heterogenous character of the lateritic nickel ore deposits.

The above conditions, therefore, leads to a situation that the nickel ore reserves having nickel content of lower than the average level of 1.12% and also not meeting other specification will not find any use in the manufacture of ferro-nickel.

It is noted that the over-burden, which is being removed during the mining of chromite in the Sukinda valley, contains not only a varying percentage of nickel (say 0.5 to 1.3) but also vanadium. This overburden and the lower grade nickel ores which can not be used in the manufacture of ferro-nickel maybe subjected to metallisation — separation technique for subsequent use in the manufacture of either ferro-nickel or extraction of the metals by the hydro-metallurgical (solvent extraction) routes. This needs to

he explored in detail.

Due to the ferruginous character of the limonitic nickel ore of Kansa and selective reduction of iron effected in the RK•EF while producing ferro-nickel, the slag produced will contain high amount of iron in the form of FeO (75 — 78%). Such slags together with low sulphur content rich iron ore may be smelted in electric furnace followed by oxygen blowing in converter to produce steel as practised in M-LAR process. It is evident that due to high investment required, adoption of this technology calls for operation at much larger scale to achieve economic viability. However, the feasibility of utilising such high iron slag directly or after some refinement/upgrading as charge/addition material in steel making need to be investigated.