

FERRO ALLOY RAW MATERIALS OF INDIA
- MINERAL RESOURCES, CHARACTERIZATION AND BENEFICIATION

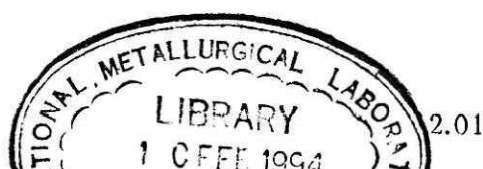
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1.0 INTRODUCTION

Ferro alloys are the essential ingredients for steel making. These are used for either deoxidation or alloying to impart desired properties (strength, toughness, hardness etc.) to steels for their various end uses. The extent of usage of ferro alloys depends on the type of the steel being produced, as also on the type of process route followed. Further the demand is inextricably linked with the growth of steel production and the change in steel making process. Presently 23 firms are operating in India, with a total installed capacity of 677,130 tonnes per year, for different ferro alloys. Besides, many small scale sector units produce special ferro alloys. But the present capacity utilization is hardly 50%. The main reason is lack of demand, (due to non-attainment of steel production targets, besides problem of availability of good quality raw materials and shortage of power). Though, the present capacity can meet the domestic demand of ferro alloys till 2000 AD, the changing ferro alloy preferences and stringent quality norms would call for a change in product wise modernisation. In this context, the raw materials, which are nonrenewable resources, needs special attention and review of their resources and utilization strategy. Identifying the problems of raw materials and finding solutions to solve them, is the need of the hour, for making available the right quality raw materials. In this paper ferro alloy raw materials, related to manganese, chromium, silicon and nickel, their problems, Indian scenario, characterization and beneficiation are briefly discussed.

2.0 CLASSIFICATION.

Based on the consumption pattern of ferro alloys, the raw materials can be divided into two categories viz. 1) tonnage ferro alloy raw materials, and 2) special ferro alloy raw materials.



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2.1 TONNAGE FERRO ALLOY RAW MATERIALS

These include manganese ore, chromium ore and silica raw materials. The main focus in this paper will be on tonnage ferro alloy raw materials.

2.2 SPECIAL FERRO ALLOY RAW MATERIALS

Modern integral steel plants are using not only tonnage ferro alloys but also wide variety of special ferro alloys. The important special ferro alloy raw materials are those related with vanadium, titanium, zirconium, nickel, tungsten, molybdenum, niobium, tantalum, phosphorus, boron etc. Current demand of special ferro alloys is low (i.e, approx. 1800 tonnes per year). By the end of 2000 AD, the requirement may be the order of 4000 tonnes/year [1]. At present, ferro nickel, ferro phosphorus etc., are being imported. Considering the future requirements and importance of the nickel raw materials, these are specially included in this paper.

3.0 QUALITY REQUIREMENTS

The quality requirement of ores used for the production of ferro alloys is evaluated in terms of iron content, metal (e.g., Mn, Cr) content, iron to metal ratio, impurities such as S, P etc, slag forming constituents and physical nature of the ore (hard lumpy form preferable).

The general acceptable specifications for production of standard grades of ferromanganese and ferrochromium are given in Table 1(a),(b). For the production of ferrochromium, the Mn/Fe ratio in the ore should be in the range of 5.5-7.0, and suitable to produce standard ferro manganese with 78% Mn. Similarly, the Cr/Fe ratio in the ore is to be such that it can be suitable to produce chrome alloys of 55-70% Cr.

For producing ferro-silicon the quartzite / quartz / silica sand should have minimum 97-99% SiO_2 , 0.05-1.2% Fe_2O_3 (max.), 0.2% CaO (max.), 0.2% TiO_2 (max) and 0.05-0.8% Al_2O_3 (max.). The important factor is that the quartz should have good thermal stability at 1200 degree or more. It should also be free from P and S. Dense quartzite seems to be better suited than coarse grained / loosely compacted varieties.

4.0 RESOURCES, PRODUCTION AND DEMAND

4.1 MANGANESE ORES [4]

Category wise distribution and reserves of Indian manganese ores are given in Table 2. The estimated manganese ore reserves are around 175 million tonnes (of all grades). Out of these reserves, only about 18 million tonnes, found in M.P., Maharashtra, are of high grade ores. Large quantity of ore reserves (about 126 million tonnes) belongs to medium to low grade variety.

High quality ferromanganese grade ore is depleted year after year. The available ore reserves are high phosphorus and high grade ores of Madhya Pradesh (M.P.)-Maharashtra region, low Mn/Fe ratio, medium to low grade ores of Orissa, Karnataka and Goa, and high phosphorus, medium grade ores of Andhra Pradesh and Gujarat. Geographically more than 80 million tonnes of ore reserves (of Karnataka, Goa and Gujarat) are far away from the existing steel and ferro manganese plants.

The manganese ore production of India during the year 1990 was around 1.5 million tonnes. Ferro alloy industry consumed 0.5 million tonnes of the ore mined. It is expected that the demand of high grade manganese ore will be about 0.7 million tonnes/year by the end of this century.

4.2 CHROMIUM ORES [4]

The estimated reserves of chromite ores of India are at about 186 million tonnes, of which about two third are available in the Sukinda valley of Orissa. The other areas of occurrence in the country are in Karnataka, Bihar, Maharashtra, Tamilnadu, Manipur and Andhra Pradesh. The detailed distribution of chromite ores are given in Table 3. Bulk of the reserves, essentially fines and high grade, occurs below a capping of low grade ores.

The production of chromite ore is mainly from Orissa and Karnataka. In the year 1990, India produced about 900,000 tonnes. The proportion of high, medium and low grade ores was in the ratio 8:5:4 and 80% of the production consisted of powdery and friable ores. The consumption by ferro alloy industry is more than any other industry. The projected annual demand of chromite ore by the year 2000 is 960,000 tonnes.

4.3 SILICA RAW MATERIALS [4]

Total country's reserve position is not fully available. The available estimates of reserves for quartzite and quartz/silica sand are of the order of 365.5 and 983.5 million tonnes, respectively. On the whole, the country's resource position of these raw materials is comfortable, which can meet the requirements of all industries. The production of quartzite is mainly from Orissa, Bihar and Madhya Pradesh. Silica sand production is from U.P, Maharastra, Rajasthan, Haryana, A.P and Karnataka.

The production of quartz, silica sand and quartzite, in the year 1990, was 1.1, 0.23 and 0.09 million tonnes, respectively. In the same year, out of total produced silica raw materials 14% of quartz/silica sand and 17% of quartzite were consumed by 7 ferro silicon 3 silico chrome Indian plants. The demand for quartzite and quartz/silica sand will be in the order of 300,000 tonnes per year by the end of 2000 A.D.

4.4 NICKEL ORES

Indian total estimated reserves of nickeliferous ores are 231.4 million tonnes, with an average grade of 0.2 to +0.9% Ni. The detailed distribution and reserves are given in Table 4. The only workable deposit with potential reserves of nickel ore, in the form of laterites, is found in the Sukinda Valley, Orissa. The laterites associated with chromite bands are removed during mining, as overburden/rejects (at a rate of 10 tonnes per every tonne of chromite ore recovery). The rejects are estimated to contain, on an average, 5% chromite, 0.5% nickel and 0.05% cobalt, besides substantial iron values. Nickel occurs as an intimate association (as adsorbed and crystal lattice / structural association) with limonite/goethite. As per the estimate, nearly 20 millions tonnes of overburden has already been generated and around 3 million tonnes of raisings/year are envisaged. The reserves with slightly less than 1% nickel are estimated at about 100 million tonnes.

Presently Ni is recovered as a by-product in the form of nickel sulfate during refining of copper at Ghatshila smelter of HCL, Bihar. The production of nickel sulfate in the year 1990 was

around 250 tonnes. The demand of nickel will be around 20,000 tonnes/annum by the end of this century. It is aimed to produce at least 10,000 tonnes of nickel by 1994-95, either in the form of nickel metal or ferro nickel. The present day domestic demand of nickel and its alloys was met by imports. Out of the total money spent for importing ferroalloys in every year, about 50% is being spent only for ferro nickel imports.

5.0 PROBLEMS RELATED TO FERRO ALLOY RAW MATERIALS

5.1 MANGANESE ORES

- * High phosphorus content

Majority of the recoverable reserves of manganese ores are having more than 0.15% phosphorus and thereby they are not suitable for ferro alloy industry. Ores of Madhya Pradesh-Maharashtra region ores, though rich in Mn content but contains around 0.6% P and Southern Orissa (Koraput) and A.P (Srikakulam) ores contains 0.2 to 1.0% P.

- * Low Mn/Fe ratio

The low Mn/Fe ratio is due to the high percentage of iron minerals association. These ores are generally termed as ferruginous ores and distributed in Karnataka, Goa and Orissa. The principal associated iron minerals, in impurities and these are contributed by quartz and other silicate minerals. Ores of Gujarat, Rajasthan and some areas of Karnataka are having these high slag forming impurities (silica/alumina). Silica is also present in the crystal structure of braunite and rhodonite.

- * Marketing of low grade ores

Mining of high grade lumpy, marketable ores, simultaneously compels the production of off grade (medium to low grade) ores. The production ratio between high grade and off grade ores is 1:6.

5.2 CHROMIUM ORES

* Low Cr/Fe ratio

The resources of low Cr/Fe ratio are plenty. The low Cr/Fe ratio is due to either high proportions of individual iron minerals or iron presence in the chromite mineral itself. Therefore, incessant efforts are to be made to develop a technology, to improve the Cr/Fe ratio.

* Fine Nature of Ore

Majority of the available country reserves are in the form of fines. The existing plants use these fines to the limited extent than lumps. This problem has to be solved using either agglomeration or developing a metallurgical process which use fines directly.

* High slag forming impurities

Silica/alumina minerals are present in more than acceptable amounts and needs their separation for making the mined ore suitable for the industry.

* Mining problems

Presently chromite is mined by open cast method except at the Byrapur mines of Karnataka. Operations are semi mechanized at most of the mines. At Boula, Kaliapani in Orissa underground mining is taken up. Many of the open quarries in Sukinda valley are abandoned at 40-50 meters, despite the fact that the ore body continues to extend below. During mining of metallurgical grade ore, considerable quantities of low grade ores are also produced.

5.3 NICKEL ORE

* Inconsistent nickel values in the raw material

The economics of extraction of nickel from these laterites, based on the contemporary technological practices elsewhere, known to heavily depend on the nickel content of the ore. It has been noticed that the nickel content should be above 0.9% for profitable extraction of nickel from lateritic material. Further, pyrometallurgical process demands that the ore should have minimum 1.8% Ni and for hydrometallurgical processes 1.5% Ni. So, without

any preconcentration, the Indian lateritic deposits are not useful, for the extraction of Ni. Hence a preconcentration technique, to improve Ni values above 1% even in the alumina rich overburden material, is need of the hour.

* High Fe/Ni ratio of the ores

The iron to nickel ratio in Sukinda laterites is high (+45), while the Fe/Ni ratio in the end product is 5:1 i.e, low. This calls for preferential elimination of large part of the iron contained in the ore.

6.0 MINERAL CHARACTERIZATION AND BENEFICIATION

The best solution to solve majority of the above mentioned problems, is characterization, beneficiation and agglomeration of offgrade/high impurity ores. Beneficiation is an imperative step to be taken for improving the future prospects of country's ferro alloy raw materials.

6.1 MANGANESE ORES

The manganese minerals present in Indian ores are pyrolusite, cryptomelane / psilomelane, braunite (Maharashtra, M.P), manganite, hausmanite, rhodocrocite etc. The iron minerals are hematite, goethite and other secondary iron oxides. Sometimes iron present in the manganese mineral as substitution to manganese (jacobsite etc.). The silica/alumina gangue is contributed by quartz, altered feldspar, garnet, limonitic clay etc. The phosphorus impurity is present in the form of discrete mineral (apatite/ collophane) and also as lattice/ structurally adsorbed with manganese minerals.

Beneficiation point of view manganese ores can be classified into four groups (siliceous, ferruginous, garnetiferous and High phosphorus complex groups)[5]. The classification is not rigid as each ore has its own peculiarities.

Siliceous ores are beneficiated by heavy media separation (if the gangue is liberated at very coarse (>50 mm) size), jigging (if the gangue is liberated at 19mm to 2mm size), spiraling/ tabling (liberation is in between 2mm and 65 mesh), and flotation (gangue liberation still at finer than 65 mesh size). Bulk of the Indian siliceous ores are beneficiated by gravity methods only.

In the case of ferruginous ores, as the difference in specific gravity between iron and manganese minerals is marginal, the only way to separate goethite/limonite from hematite is to roast the ore in a reducing atmosphere (to convert all iron oxide minerals to magnetite). The phases can be magnetically separated after grinding to proper liberation size. If the iron mineral is magnetite/jacobsite, they can be separated by magnetic separation directly.

Garnetiferous ores are processed by electrostatic separation and sometimes by flotation.

In the case of high phosphorus ores, if the phosphorus is in the form of apatite/collophane it can be generally separated by flotation technique. Whereas the phosphorus in the lattice structure of manganese minerals can be separated either by alkali roast leaching (A.P ores) or leaching with HCl (M.P-Maharashtra ores).

Processing of complex ores calls for more than one Route stated above, and is dependent on the mineralogy, locking pattern of the constituting minerals.

6.2 CHROMIUM ORE

Chromite is the chief ore mineral of chromium. Chromite, the double oxide of chromium and iron, theoretically should contain 68% Cr_2O_3 (maximum) with a Cr: Fe ratio of about 1.8:1. But in practice, the composition varies widely due to replacement of iron by magnesium and Cr by Fe+3 or Al[6]. Indian chromite generally may be characterized by their high iron content which is present in chemical combination with the mineral chromite. Some Orissa chromite ores have high Cr:Fe ratio (>3) and such ores should be carefully conserved for the metallurgical industry for production of ferro chrome. The general gangue minerals are quartz, clay, talc, serpentine, pyroxene, olivine, dolomite, magnesite, anthophyllite, antigorite, chlorite, tremolite, limonite, goethite, hematite, magnetite, gibbsite etc.

Indian chromite ores can be classified broadly into two groups.

- 1) Siliceous ores
- 2) Ferruginous ores

Majority of the siliceous type ores are successfully beneficiated by gravity methods. Depending upon the liberation size of gangue, different gravity equipments are selected. The further observation is that the ores containing serpentine, talc, chlorite, etc. as the chief gangue minerals can be easily concentrated by simple gravity methods or flotation and in some cases by magnetic separation.

Magnetic methods of beneficiation do not have much use in improving Cr_2O_3 values of Indian chromites except in the cases where magnetite is the predominant gangue mineral. The loosely adhered slimy form of limonite/goethite is removed by simple washing along with clay materials. In the ferruginous type of ores, most of the iron is present in the form of secondary iron oxide minerals. These can be separated by reduction roast followed by magnetic separation. Chemically associated iron in the chromite mineral can be reduced by production through sintering technique followed by acid leaching [7].

Chrome spinels can not be beneficiated by physical beneficiation methods to any appreciable extent beyond removal of free gangue minerals, as the chromite mineral itself is of a low grade. Treatment by pyrometallurgical methods could perhaps make such ores marketable. It is certainly possible to obtain a chromite concentrate suitable for charge chrome preparation.

6.3 SILICA RAW MATERIALS

Quartz is the principle mineral. Silica sand and Quartzite raw materials are plenty and mostly as such suitable for the ferro alloy industry. Further there is no need to do any type of processing, but simple crushing is necessary to meet the size requirements. All the mines of the silica raw materials are worked by open cast. Mined material is broken into small pieces and hand sorted before it is despatched to the industries.

6.4 NICKEL ORES

Lot of work has been done by RRL, Bhubaneswar, and other research organizations to beneficiate lateritic ores from Sukinda valley. The studies showed that Ni and Fe are concentrated in the finer fractions, whereas chromite and cobalt are concentrated in the

coarser fractions. Serpentine bearing lateritic material, with relatively high magnesia and silica (mostly quartz), is found more amenable to preconcentration relative to those containing alumina rich (kaolinite, clay and gibbsite) laterites.

The process adopted in essence contains a complex flow sheet involving classification, grinding, magnetic and gravity separation techniques applicable to fines. RRL, Bhubaneswar could produce 1.6% Ni from 0.6% Ni ore with a recovery of 60%. The reduction of Fe/Ni ratio is marginal (from 48.7 in the feed to 44.4 in the nickel rich concentrate)[7].

6.5 AGGLOMERATION PRACTICE

The concentrates produced by beneficiation and fines generated during mining/handling are generally agglomerated by sintering (10 mm and below), brequetting (0.6-0.15mm) and pelletisation (below 0.05mm) to meet the size requirements of ferro alloy industry.

7.0 FUTURE PROSPECTS

7.1 MANGANESE AND CHROMIUM ORES

The problems related to mining can be solved by planning for deep open cast mechanized mines, by way of putting considerable R & D inputs in determining the optimum side slopes, overburden dumping and keeping the quarries dry. One of the consequences of mechanization is dilution of grade. This can also be solved by way of beneficiation. The advantages of beneficiation is production of multi grade, slime free end products.

Fines can be successfully utilized after agglomeration. Further R & D inputs are necessary to develop a metallurgical process to use fines directly.

In India, though enough beneficiation technology is available to treat the off grade ores, still some RandD inputs are required to find a economic process to improve Mn/Fe ratio, and for identifying and exploiting the new deposits. Mining strategies are also to be properly planned, keeping in view the production and consumption patterns.

Ferro chrome grade ore has to be conserved properly as a sweetener

or exporting directly or in the form of ferrochrome to other countries for higher prices. Therefore, India has to formulate a conservation strategy and explore all possibilities of finding marketing points for ferro chrome grade ores, in the light of present day international chrome preferences.

On the whole, the studies of beneficiation indicated that the Cr_2O_3 content of even very low grade ores can be improved to acceptable levels by physical beneficiation. But Cr/Fe ratio improvement needs thorough look into it.

7.2 SILICA RAW MATERIALS

The prospects of silica raw materials for future requirements are very bright, but detailed systematic complete inventory of these deposits are to be made available [8].

7.3 NICKEL ORES

Since beneficiation does not result in upgradation of nickel content (substantial) or reduction of iron content much, reduction of Fe/Ni ratio can perhaps be realized by : a) selectively mining, sections with high incidence of nickel; b) Locating Ni deposits with low Fe content, in MgO rich saprolite zones; and c) blending Sukinda ores to improve the quality, with imported oxide ores of high nickel and low Fe/Ni ratio. These suggestions call for R & D work and critical examination.

The Ni ore potentials are large. Govt. of India has already started a National project, to develop technology for producing Ni. Thus, future requirements to some extent can be met from indigenous resources, if not all.

8.0 CONCLUSION

The tonnage ferro alloy raw materials are abundantly available. But good quality manganese ore and chromite can be available only after beneficiation and agglomeration of the off grade/low grade ores and fines.

The chromite ore position is comfortable in the country. But would call for increased use of fines/friable ore after agglomeration as well as beneficiation of medium and low grade ores. There is a

greater need for adopting advanced processes developed, elsewhere in the world, to improve Cr/Fe ratio especially from ores, where iron is in the atomic structure of chromite mineral or utilizing directly the low Cr/Fe ratio fines in the metallurgical industry by adopting suitable advanced metallurgical process.

Agglomeration of high grade in situ as well as beneficiated fines to meet the indigenous requirement for making ferro chrome (high and low carbon) by the existing plants is to be worked out in detail and needs implementation.

Mining strategies are also to be properly planned by keeping in view of the production and consumption patterns.

The special ferro alloy raw materials like molybdenum, niobium, cobalt, nickel, tungsten are not abundant enough. But India is having more resources of titanium, vanadium, zirconium etc. sufficient enough to meet the industrial requirements.

Sustained efforts have to be made to solve the following problems, to tackle some of the constraints related to raw materials.

- 1) Demonstrating the processing technology in large scale to reduce phosphorus content to the acceptable limit in manganese ore.
- 2) Effective maximum utilization of friable chromite ores and their fines by appropriate beneficiation and agglomeration technique.
- 3) Developing a suitable technology to recover vanadium from vanadium bearing titanomagnetites, and nickel, cobalt from the nickel bearing laterites, to substitute at least a part of the imports.
- 4) In the case of Molybdenum, tungsten it is necessary to quickly evaluate the prospective deposits and draw up suitable mining plans as a component of exploration-cum-exploitation strategy. Efforts are also to be made to beneficiate the low and marginal grade ores and should be translated at the earliest to the pilot plant level.
- 5) Substantial exploration has to be done on the multi-metal nodules of the Indian ocean bed and demonstration of large scale trials of the processing route.
- 6) Alternatively, a technology has to be developed to utilize low

grade ores and fines directly and also find out alternative raw materials for molybdenum, tungsten etc.

Invariably, all the raw materials, except quartzite, needs beneficiation and agglomeration. Thereby the cost of the raw materials will definitely increase. In some cases (technology related to phosphorus removal from manganese ores), the present status of technology does not make it economical at the moment. Talking of economics, which is time, situation and location dependent, what is uneconomical now, may be economical tomorrow.

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TABLE-1(a) : SPECIFICATIONS FOR MANGANESE ORES FOR THE PRODUCTION OF STANDARD FERRO-MANGANESE [2]

GRADE	Mn%	Fe% (Max)	SiO ₂ % (Max)	P% (Max)	Al ₂ O ₃ % (Max)
1	48 & above	7.0	8.0	0.12	4.0
2	46-48	7.5	9.0	0.15	-
3	44-46	9.0	10.0	0.15	-
4	40-44	12.0	12.0	0.15	-
General	48	6-7	6.0	0.12	4.0

TABLE-1(b): GENERAL SPECIFICATIONS OF CHROMITE AND OTHER INDIAN FERRO ALLOY PLANT ORE SPECIFICATION REQUIREMENTS [4].

NAME OF THE PLANT	Cr ₂ O ₃ (min%)	Cr:Fe	P and S (max%)	Al ₂ O ₃ & SiO ₂ (max%)	SIZE (mm)
General					
a) ferro chrome	48	2.8:1	0.04, 0.08	8-10 & 2-6	lump 25-50 fines 2-10
b) charge chrome	40- 44	1.6:1	-		both lumpy & friable
FACOR, Garividi	48	2:1	-		lump 13-38
IDCOL, Jaipur	50	3:1	-	6*	lumpy ore
VISL, Bhadravati	52	-	0.01 each		lump 10-50

* SiO₂

TABLE-2 : GRADE WISE RECOVERABLE RESERVES OF MANGANESE ORES OF INDIA [4]

State/Type	Proved				Probable				Possible				Total
	H*	M	L	Mi	H	M	L	Mi	H	M	L	Mi	
ORISSA (ferrugeneous)	0.7	1.6	1.6	0.6	0.7	1.8	3.4	1.5	2.9	5.5	10.7	2.6	33.6
MAHARASHTRA (P Rich)	3.4	2.0	0.3	.02	2.8	1.7	.35	.07	2.0	1.8	0.4	0.3	15.2
M.P (P Rich)	5.5	0.7	-	.08	3.3	0.6	-	1.9	3.6	1.3	-	2.7	19.7
KARNATAKA (Ferrugeneous, Siliceous)	-	0.7	0.9	.02	.02	3.6	6.2	4.6	.05	21.0	28.4	7.8	73.3
GOA (ferrugeneous)	-	-	.02	-	.02	0.2	0.9	1.6	-	.01	1.2	0.8	4.8
GUJRAT (high P, Siliceous)	-	-	-	-	-	-	-	-	0.4	-	-	1.1	1.5
BIHAR (Ferrugeneous)	-	-	-	-	-	-	-	-	-	0.7	1.6	.03	2.3
A.P. (high P, Garnetiferous)	-	-	-	-	0.3	0.1	1.3	0.8	0.1	0.2	0.8	0.1	3.7
RAJASTHAN (Siliceous)	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2
W.B.	-	-	-	-	-	-	-	-	-	-	0.1	-	0.1
ALL INDIA	9.6	5.0	2.8	0.7	7.1	8.0	12.1	10.5	9.1	30.5	43.2	15.6	
TOTAL		18.1				37.8				98.45			156.9

In addition newly, unclassified deposits are about 22 million tonnes.

* (H: high grade) (M: medium grade) (L: low grade) (Mi mixed grade)

TABLE-3: GRADE WISE RESERVES AND DISTRIBUTION

OF CHROME ORES OF INDIA [4]

(QUANTITY: IN 000 TONNES)

Grade/ Category	Orissa	Mahara- shtra	Karna- taka	Bi-har	Manipur	Tamil- nadu	Andhra- pradesh	Total
Ferro- chrome	28,375	-	-	-	-	-	-	28,315
Charge- Chrome	32,318	-	-	-	-	-	-	32,318
Chemical	3,691	-	-	-	-	-	-	3,691
Refrac- tory	3,829	469	318	-	124	-	1.9	4,749.9
Low	25,220	262	825	86.5	334	261	-	26,988.5
Unclass- sified & others	11,880	-	-	-	8	-	-	11,888
Proved	32,513	294	420	-	15	7	0.2	33,249.2
Probable	36,901	-	577	0.2	98	22	-	37,598.2
Possible	35,839	437	146	86.3	353	232	1.7	37,095
Total	105,253	731	1143	86.5	466	261	1.9	107,942.4

In addition, unconditional resources are about 78 million tonnes.

TABLE-4 : ESTIMATED RESERVES OF NICKEL AND THEIR DISTRIBUTION [4]

(QUANTITY: IN MILLION TONNES)

STATE/DISTRICT	RESOURCES OF NICKEL				GRADE (Ni%)
	PROVED	PROBABLE	POSSIBLE	TOTAL	
BIHAR/SINGHBHUM	-	-	7.31	7.31	0.35-0.8
NAGALAND/TUENSANG	-	4.45	-	4.45	0.63
ORISSA/CUTTACK, KENDUJHAR, MAYURBHANJ	23.15	97.81	98.69	219.65	0.2-0.9+
ALL INDIA	23.15	102.26	106.00	231.41	0.2-0.9+