Quality specification of ferroalloys and its impact on steel quality at Rourkela Steel Plant

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ABSTRACT

Ferroalloys are essential raw materials for steel making. The quality of steel and also economics of steel production are greatly influenced by the quality of ferroalloys. Therefore quality specification of ferroalloys and their judicious use are of paramount importance to the management of any steel plant which is a bulk consumer of the ferroalloys. Details of quality specifications of various ferroalloys in use at present at Rourkela Steel Plant and their technical justifications have been described in this paper. Impact of ferroalloy quality on the quality of steel and different control measures exercised for the most effective and beneficial use of the ferroalloys have also been discussed.

Introduction

Ferroalloys are the integral constituents of any steelmaking process, as these are indispensible materials for refining, deoxidation, desulphurisation and alloying to achieve the desired chemical and physical properties. As such they influence the steel quality and steelmaking economics to a great extent. Because of increasing demand of special quality steels with stringent quality requirement particularly with respect to restricted chemical composition and cleanliness the role of ferroalloys is becoming more significant day by day. Rourkela Steel Plant being a bulk producer of special purpose steels, consumes a variety of ferroalloys and other alloy additions. Table 1 shows the consumption pattern of some common ferroalloys for the last 15 years. In addition to these bulk ferroalloys, i.e. FeMn, FeSi, FeCr a large number of other ferroalloys, i.e. FeV, FeNb, FeTi, FeB, FeMo, FeP, FeAl are also used as minor raw materials for the production of different grades of steel. Consumption of ferroalloys will depend on the type of steels and its proportion on the total steel production. To cater to the needs of sophisticated and diversified product-mix, steel produced at RSP covers over fifty standard specifications both Indian and foreign starting from low carbon rimming steel to multi-alloyed special steels. These constitute about 15 % rimming steel, 20% killed steel and balance semi-killed steel. The cost of ferro-alloys used in the production of steel form a significant part of the total cost. This is around 5 to 8% of total cost and 10 to 15% of raw

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TABLE—1

Consumption pattern of some common ferro-alloys at Rourkela Steel Plant (1968-69 to 1982-83)

	Consumption in M/tons			
Year	Ferro manganese (High carbon)	Ferro-silicon	Ferro-chrome (Low carbon)	Ferro vanadium
1968-69	9064	2191	5	—
69-70	9452	2404	39	—
70-71	8175	2410	10	—
71-72	8569	1996	85	—
72-73	10914	3066	23	—
73-74	9719	2703	22	—
74-75	13122	2876	46	—
75-76	13721	3212	55	—
76-77	17920	2986	13	—
77-78	16715	3461	24	119
78-79	16778	3872	19	135
79-80	18095	2831	23	74
80-81	17895	2848	18	16
81-82	20423	3653	68	38
82-83	19992	2976	24	6

material cost under RSP condition. As the quality of ferroalloys affect the steel quality and yield at subsequent various stages of processing they have great impact on the profitability of the plant. Therefore due emphasis is laid by the steel plant management on quality specifications of ferroalloys, their effective and economic use by adopting suitable control of steel making parameters.

Ferroalloys and their use

The types of ferroalloys commonly used in steel making at Rourkela Steel Plant are shown in Table 2 alongwith their specified chemical composition and sizes.

Ferro silicon is used as ladle addition for deoxidation purposes in the production of killed and semikilled steels either singly or in combination with aluminium. Silicon in semikilled steel normally varies between 0.04 to 0.06% and in killed quality steel between 0.15 to 0.35%. It is also used for the production of hot/cold rolled electrical sheets in which silicon is maintained between 1.20 to 2.6% depending upon the grades. Low aluminium grade of high purity ferro silicon is required for the production of Cold Rolled Grain Oriented and Cold Rolled non-oriented steels. Silicon desired in CRGO steels is about 3.0 to 4.0% and for CRNO 1.2 to 2.6%. Dual phase steel is also produced using ferro silicon in which silicon is maintained 1.0 to 1.2%. The consumption of Fe-Si in open hearth is 1.5—2.5 kg/t steel and in LD 2.5—3.5kg/t steel.

Ferro manganese is added as a deoxidiser, for minimising the harmful effect of sulphur and alloying to increase the strength and toughness of steel. Ferro manganese addition is made in all the grades of steel to obtain manganese in the range of 0.25 to 1.8%. The consumption of FeMn in open hearth furnace is 30-32 kg/t steel and in LD 11-13 kg/t steel.

TABLE—2

Chemical compositions and sizes of ferro-alloys used at Rourkela Steel Plant

Type of ferroalloy	Chief constituent	C% max	Si %	Mn%	S% max	P% max	Al% max	Other element	Size
Ferro manganese high carbon	72-74% Mn	7.5	1.5 max	72-74	.05	.35	—	—	40-80 mm for LD 80-150 for O H
Low/medium carbon	72-74% Mn	1.5	2.0 max	72-74	.01	.15	—	—	—
Ferro silicon normal	70-75% Si	.15	70-75	—	.05	.05	1.25	—	50-150 mm
For CRGO & CRNO	74-77% Si	.03	74-77	—	—	—	.10	Ti.04 max Zn.15 ,, Mo.35 ,, B .02 ,,	12-37 mm
Ferro chrome (low carbon)	60-67% Cr	.05	1.5 max	.75	.05	.05	.01	—	50-100 mm
Ferro vanadium	50% V	0.10	1.25	—	.05	.05	1.50	—	20-40 mm
Ferro Niobium	63.5% min Nb	.25	4.00 max	2.00 max	.05	.10	1.00	Ta.5 max	20-40 mm
Ferro Titanium	30-40% Ti	.10	2.00 max	—	.05	.10	4.6	—	20-40 mm
Ferro Phos	20-26% P	1.00	—	—	—	—	—	—	40-80 mm
Ferro Moly	60-67% Mo	.50	1.50	—	0.25	—	—	—	10-25 mm

Ferro chrome is generally used in high strength weldable grades of structural steels to increase resistance to wear, heat and corrosion and improve creep and impact properties. Chromium content in such steels ranges from 0.4 to 1.0%.

Ferro vanadium and ferro niobium are added for micro alloying steel with V and Nb in the production of low alloy high strength either singly or in combination for production of plates, sheets and pipes. Niobium in such a steel is maintained in the range of 0.03 to 0.05% and vanadium in the range of 0.4 to 0.10%.

Ferro titanium is also used as micro alloying element for production of high strength steel sheets of thinner sections. Titanium is normally kept between 0.08 to 0.12%.

In addition to the above ferro boron is used as ladle addition in the production of non-ageing drawing quality steels. Boron content generally ranges between 0.003 to 0.006%.

Ferro phosphorus is normaly used in manufacture of weather resistance steels like, SAIL-COR etc. Phosphorus in this steel is maintained between 0.07 to 0.15%. Ferromoly is used in production of Dual phase steel in which moly. is maintained .3 to .5% Moly helps in improving hardenability of these steels. Fe-Mo is also added to steel for improving the shock and creep resistance properties.

Ferro aluminium (Al—35% min., Si & Mn—0.5% max., S&P – 0.03% max., other impurities 0.6% max. and balance, Fe) has been tried for the production of Al. semikilled steels intended for some critical applications. However, due to severe disintegrating tendency of this ferro-alloy during storage, even for a short period, its use could not be established for regular production.

Ferroalloys and steel quality

Chemical Composition

Ths most important factor for assessing the value and quality of a ferroalloy is the content of its chief allov constituent. The chief alloy should be uniformly distributed throughout a consignment so that the composition of the ferroalloy is consistent[1]. If there is a wide variation in composition of a ferroalloy in use from one lot to another this may result in a steel going off in composition. The composition of a ferroalloy affects the composition of steel directly. A typical example of the effect of the composition of FeMn on the composition of steel is shown in Table 3. The quality of a ferroalloy affects cleanliness of steel also. The effect of two grades of ferrosilicon[2] with different silicon and aluminium content on the inclusion ratings of steel has been indicated in Fig. 1.

The impurities present in ferroalloys have marked effect on the quality of steel produced. The effect of the impurities depends on the extent of the impurities in the ferroalloys and the requirement of the steel specification. Common impurities present in most ferroalloys are carbon, silicon, sulphur and phosphorus. Generally these impurities have deleterious effects on quality of steel. Non-metallic contamination of ferroalloys such as, slag increase inclusions in steel and hence they are to be restricted to the minimum level possible. All these factors also lead to inconsistency in recovery of the alloy and in extreme cases off the specification heats.

The effect of various elements of the ferroalloys on the quality of different grades of steel produced is mentioned below in brief.

Rimming steel

Rourkela Steel Plant produces significant quantity of rimming steel by LD converter for manufacture of tin plates, galvanised sheets and drawing quality sheets. The finished product surface is to a great extent dependent on the control of rimming action in the mould. It is well known that even a small amount of silicon in liquid steel hinders rimming action. Ferro manganese is added in ladle in this grade to make up manganese content of steel. Therefore silicon content in ferromanganese is kept to 1.5% max. Poor rimming action leads to low acceptance of rimming heats and affects yield and surface quality at subsequent stages of processing.

Trials have also been conducted by adding a small quantity of ferro vanadium in low carbon rimming steels for making of non-ageing deep drawing steels.

Semikilled steels

Majority of steel produced at Rourkela Steel Plant is of semi-killed quality for end products like, low carbon hot rolled coils, pipes,

TABLE—3

Increase in carbon silicon & phosphorus content of steel per 0.40% manganese addition

ALLOY	INCREASE IN % C	% Si	% P
Standard Fe-Mn (7%C, 0.25%, Si, 0.35% P)	0.035	0.0012	0.002
Standard Fe-Mn (7%C, 0.80% Si, 0.35% P)	0.035	0.0040	0,002
Low/Med CF-Mn (1.25%C, 1.25% Si, 0.15% P)	0.007	0.0060	0.001
Silico Manganese (1.25% C, 20% Si, 0.15% P)	0.007	0.1300	0.001
Electrolytic Manganese	Nil	Nil	Nil

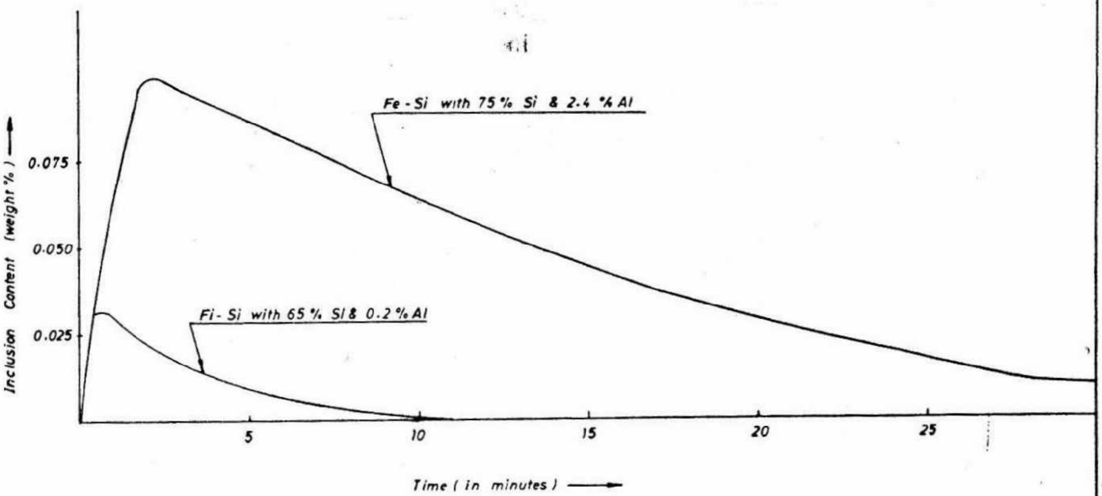

Fig 1. EVOLUTION OF THE INCLUSION CONTENT IN A STEEL MELT DEOXIDIZED WITH TWO DIFFERENT QUALITIES OF FERRO SILICON.

plates of ship building and structural quality. Except adjusting the oxygen level by addition of small quantity of aluminium bars and shots in the mould deoxidation of semi-killed heats is generally done by ferrosilicon. Silicon content is normally kept within 0.04 to 0.06%. This gives maximum yield and also good surface. Quality and quantity of ferrosilicon has great influence on deoxidation control of this grade of steel. Improper quality of FeSi may lead to under/over deoxidation of steel resulting in poor ingot to slab yield and inferior surface quality. This grade of steel is produced both by LD and OH furnaces.

Killed steel

Substantial quantity of steel is produced in killed quality by OH and LD process for plates of structural and boiler quality, electrical sheets and other products of special quality. The composition of the ferroalloys has to be uniform and within the desired limit and the impurities to the minimum level when used in the production of these grades of steel because, even a small amount of impurity in ferroalloy will affect the quality of these steels adversely.

Size of ferroalloys

Size of ferroalloys required depends on time, size of operation, method of addition and sequence of addition and also the stage at which they are added during the process of steel making. Ferroalloys added to the bath of the steel must be large enough to penetrate the slag but small enough to go into solution during the time available before teeming. Sizes of the ferroalloys which are added in the furnace or converter are usually higher than the sizes of ferroalloys which are added in the ladle. In case of open hearth process of steel making most of the ferromanganese is added in the furnace, whereas in LD process total quantity of ferromanganese is added in the ladle. Moreover the heat weight of open hearth furnace is 90 tonnes against the heat weight of 50 tonnes/66 tonnes of the LD converters. Because of these reasons size of ferromanganese specified for open hearth steel making is 80-150 mm and for LD steel making it is only 40-80mm. Ferrosilicon is always added in the ladle and the size of ferrosilicon used in both LD and OH processes is 50-100mm. Ferrochrome is normally used in open hearth furnaces and the specification of size for ferro-chrome is 50-100mm.

The costly ferroalloys like ferrovanadium, ferroniobium and ferrotitanium are generally added to the ladle in the last and the size of these is kept on lower side, i e. 20-40mm, for the sake of better recoveries.

Most of the fines added in the furnace/converter or ladle go as waste and hence fines (—10mm fraction) in case of most of the ferro-alloys are not allowed to exceed 1%. However, the generation of too much fines in ferrosilicon is a common problem faced at Rourkela Steel Plant. The tendency of ferrosilicon towards dusting depends on a number of factors like, silicon, phosphorus, aluminium, calcium and moisture content[3]. Ferrosilicon having about 50% silicon is most likely to disintegrate because of the phase change taking place accompanied by a change in density leading to cracking. Therefore this range of composition is generally avoided in the specification. Moisture also affects disintegration of ferrosilicon particularly in the presence of phosphorus. Because of this reason in some plants[4] pre-weighed ferrosilicon is used in moisture proof bags. In addition advantages of preweighed bags are consistent deoxidation with better silicon control, lower handling loss, improved shop cleanliness, inventory control, etc.

Sampling and analysis of ferroalloys

Sampling of ferroalloys at Rourkela Steel Plant is done as per the Indian standards specification IS : 1472. When the materials like, FeMn, FeSi and FeCr are supplied in wagon-loads, samples are taken at regular intervals during unloading to give a primary sample of 2% of the total consignment. The quantity of a consignment does not exceed 100 tonnes. When the ferroalloys like, ferroniobium, ferro-titanium and ferrovanadium are supplied in drums, 25% of the drums are emptied and samples at the rate of 1 kg/t of ferroalloys are taken. The size of consignment does not exceed 5 tonnes. The sample is crushed, quartered and reduced to constitute a laboratory sample of 0.30 kg for materials supplied in bulk quantity in wagons and of 0.15 kg for materials supplied in small quantity in drums.

The laboratory samples are analysed for the various constituents of the ferroalloys by the standard methods of analysis. Many methods have been developed in the laboratory by means of which the important constituents can be analysed and reported quickly for control purposes. Latest techniques like, application of direct reading spectrograph and X-Ray fluorescence are being adopted for more accurate analysis of ferroalloys.

Recovery of ferroalloys and steel making parameters

In addition to quality of ferroalloys such as its solubility, composition, size, density and vapour pressure, etc., there are a large number of steel making parameters which need to be controlled for the optimum use of ferroalloys[5]. Some of the major operating factors which are important from the recovery point of view are, tapping temperatures, tapping carbon, deoxidation practice and sequence of ferroalloys additions, timing and mode of addition, converter slag carryover to ladle etc. While most of the factors are operator controlled from heat to heat basis, RSP has undertaken projects alongwith RDCIS for deoxidation control and deoxidation practice of special steels using costly micro-alloying elements such as, Nb, V, etc. For deoxidation control of semikilled and killed steels, oxygen measurements by means of oxygen sensors based on solid electrolyte are being carried out before tapping, after deoxidation and complete homogenisation in the ladle. The objective of this study is to establish relationship between C Mn-O-Temp. in the bath and to develop a nomogram to determine the amount of deoxidants to be added using the above correlations. Initial trials have given encouraging results and it is hoped that when implemented fully, will not only improve the quality of steel but also save costly ferroalloys and deoxidizers.

There has been considerable increase in the production of special quality steels at RSP since last 8 to 10 years. This calls for the use of costly ferroalloys like, FeNb, FeV. At the initial stages the recovery from these ferroalloys was low. In order to improve the recovery of these elements many development trials had been conducted. These include Canister practice, delayed Al. addition, early Al. addition, sandwiching these alloys between two deoxidizers, etc. These trials have helped in developing a suitable practice under RSP condition. With modified ladle addition sequence and sized FeNb-FeV, recoveries of these elements have improved.

There is a wide difference in the recovery of Si, Mn, Nb, V Ti, P, B depending upon the grade of steels viz. rimming, semikilled, killed for different composition made in LD and OH. The addition of ferroalloys in furnace or ladle has its own merits and demerits. The furnace addition practice has the advantage of better control of the alloy and homogeniety in composition, but it suffers from poor recovery of element. The main advantage of ladle addition is better recovery of the element, but it is associated with disadvantages like more chances of heats going off in chemistry, more segregation and in temp. drop particularly in case of heavier additions. In case of heavier additions required for the production of dynamo steels, multialloyed steels, like, SAILCOR, COST 8520, etc. the practice of preheating ferroalloys in ladle is adopted.

Proper weighment of ferroalloys for judicious addition is also very important. For this mechanised system of ferroalloy addition in ladle is being adopted. Use of preweighed and bagged ferroalloy is also being considered to obtain closer control over steel analysis and deoxidation.

Ferroalloys and steel cost

Cost of the ferroalloy is one of the most important factors which is taken into consideration while deciding the suitability of a ferroalloy for the production of a particular grade of steel. Price trend of some of the ferroalloys are shown in Fig. 2a and 2b.

While calculating the economics of using different grades of a ferroalloy, the steel making practice and the specification of steel are also to be taken into account. For instance, a particular grade of steel, which specifies very low level of P can be made in two ways, viz. either by following normal steel making processes and use of costlier ferroalloys having very low P or steel making practice with extra precautions like increased basicity of slag, more refining time in furnace/converter incurring additional cost to bring down P to a very low level in the steel bath and thus permitting the use of a high P content ferroalloy. One of the two alternatives can be selected depending on which works out to be more economical

Similarly in the production of dynamo grade of steel where carbon has been specified as 0.04% max. use of low carbon ferroalloy is necessary. While for this purpose the use of high C-Fe-Mn is ruled out, low C content may be achieved by the use of low carbon ferromanganese or silico manganese. Silico-manganese being cheaper is selected in preference to low C-Fe-Mn. Si-Mn also provide silicon which is desirable in dynamo grade of steel.

With increasing cost of ferroalloys, cost consideration in the steel making is becoming very important. When RSP commenced the bulk production of low alloy high strength steels irregular availability, inconsistency in quality and rising cost of FeNb, FeV, etc. became a subject of great concern. At that stage RSP management decided to develop the process of manufacturing these ferroalloys in the plant itself.

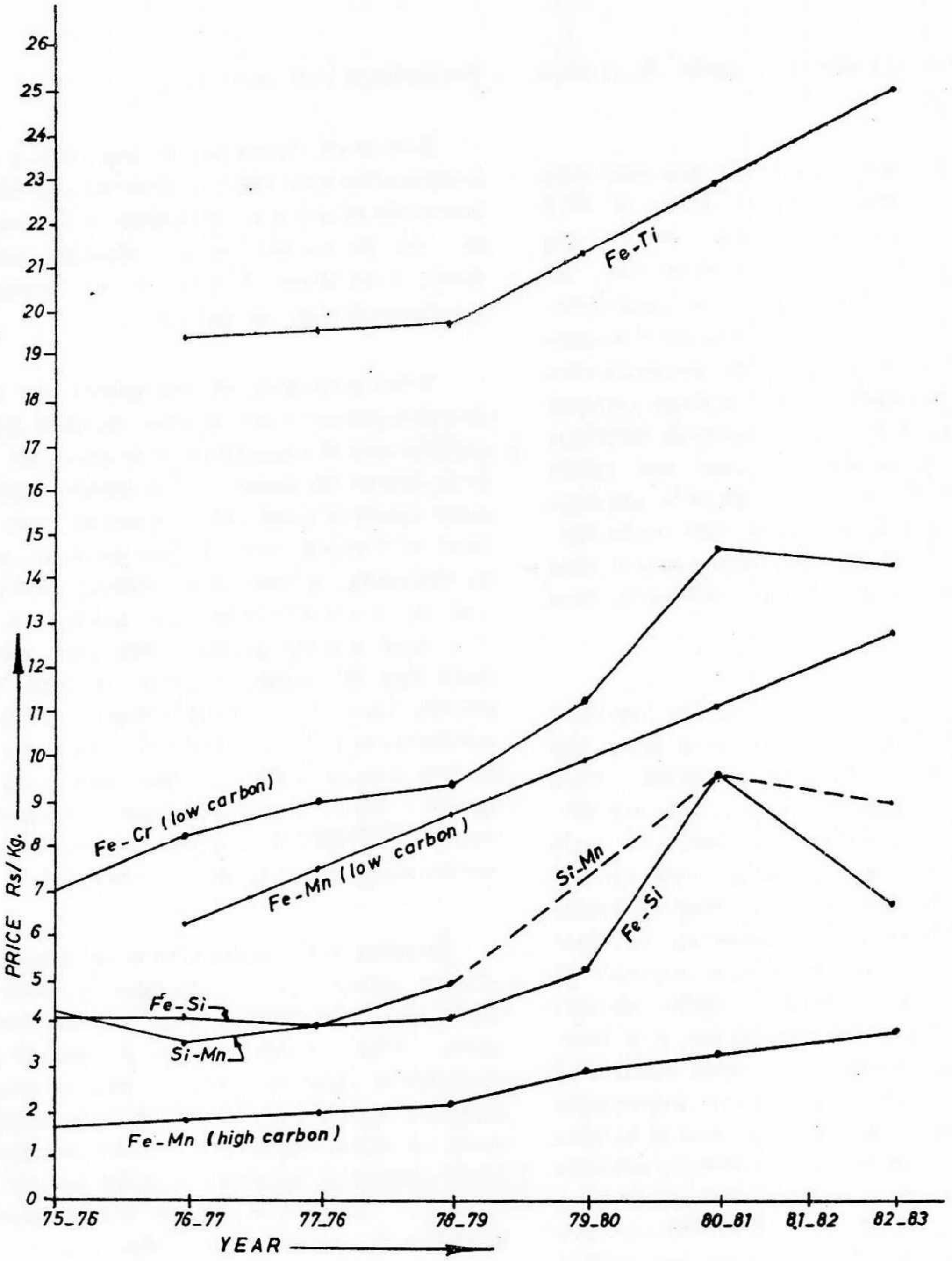

FIG. 2a COST TREND OF FERRO-ALLOYS

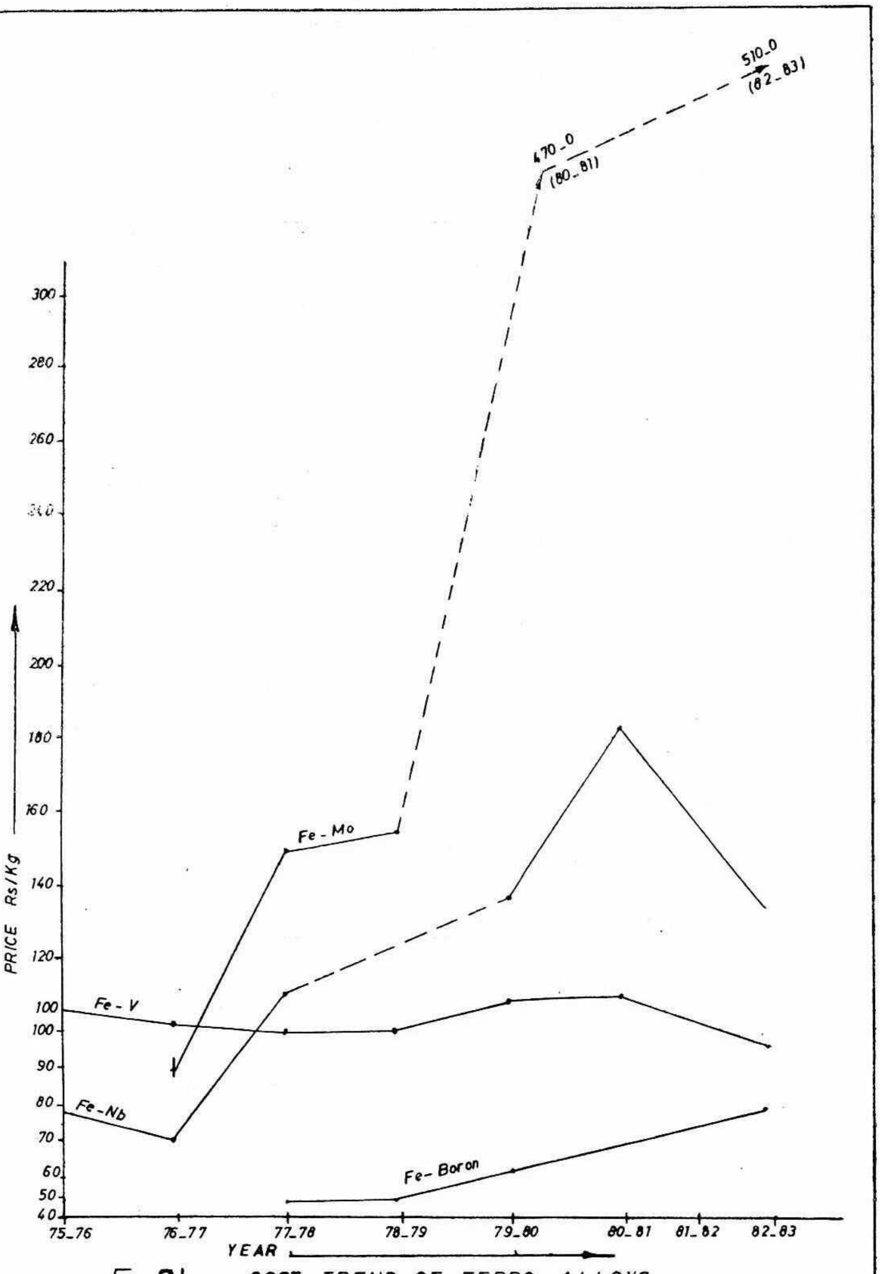

FIG. 2b COST TREND OF FERRO-ALLOYS

Conclusion

Considering the importance of the ferroalloys in the economy of the steel plant it is essential to exercise adequate control to optimise the use of costly ferroalloys by improved steel making practices. Growth of ferroalloy industry is directly linked up with steel. Increasing demand for special quality steels with stringent quality requirements calls for easy availability of suitable ferroalloys. Any improvement in the quality of ferroalloys, adoption of cost effective methods by the ferroalloy industry, development of new low cost ferroalloys would be of great help to steel industry in development of new steels, improvement in the quality, yield and cost of the steel. Hence clear understanding of each others requirements and close co-ordination between the two industries will go a long way in achieving the desired objective.

Acknowledgement

The authors are grateful to the management of Rourkela Steel Plant for giving permission to present this paper. The authors also wish to thank the colleagues for giving assistance in preparing the paper.

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Discussion

M. Subramanian, FACOR, Shreeramnagar

Q. In your report you have just mentioned that the addition of 0.4% manganese in steel you have given some figures about the silicon increment and the phosphorus increment. May I know the recovery figures and at what stage ?

A. These recovery figures will depend upon the type of steel produced. We are producing rimming steel, semikilled and killed steel. The recovery figures will vary accordingly. For instance in rimming steel, the recovery of ferro silicon/ferro manganese we get 55-60%.

Q. It is surprising to note the recovery is low. It may be the reason for the additional increment of phosphorus and silicon in the metal.

A. No, because the rimming steel is supposed to have higher oxygen level itself.

P. Chakra, Indian Metals & Ferro Alloys Ltd. Bhubaneswar

Q. In your table 2 while giving the specifications of ferro alloys, you have mentioned for ferro silicon, aluminium content is 1.25. How is that RSP refuses any ferro silicon containing more than 1.25 aluminium ?

A. The reference was given in the year 1980, subsequently it was changed to 1.5 max.

Q. While comparing the cost, you said that the cost of ferro alloys are tending downwards ?

A. Not all, in most of the cases.