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April 1985

UNIDO PROJECT, SI/IND/84/802

India.

TECHNOLOGICAL CHOICE AND APPRAISAL

of

METALLURGICAL PROCESS ROUTES

for

MAHARASHTRA ELEKTROSMELT LTD.

OF

STATE INDUSTRIAL AND DEVELOPMENT CORPORATION OF MAHARASHTRA (SICOM), INDIA

A report prepared for:

United Nations Industrial Development Organization
Vienna International Centre
Austria

by:

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Elkem a/s, Oslo, Norway

EXECUTIVE SUMMARY AND CONCLUSIONS

Maharashtra Electrosmelt Ltd., MEL, a wholly owned subsidiary of State Industrial and Development Corporation of Maharashtra (SICOM) established in 1977 a ministeel plant in Chandrapur. The plant location was based on large coal resources in Chandrapur which gave basis for a large thermoelectric power plant, and on the nearby deposits of iron ores.

The plant was equipped with one 33 MVA electric pig iron furnace, two LD converters and facilities for small sections ingot casting. (Later on a 2-strand continuous caster was added).

However, a profitable steel operation was for a number of reasons never established.

In the present situation the only activity at the MEL works is the production of standard ferro manganese in a no. II electric smelting furnace, while the no. I pig iron furnace and the steelmaking facilities have been idle since May 1982.

The ferromanganese furnace is running on reduced load, due to market limitations, and the economic contribution from the present activity is far from covering the works fixed costs burden.

The United Nations Industrial Development Orgainization (UNIDO) invited, among others, Elkem a/s, Engineering Division to look into possible ways of making the future activity at the MEL works viable by doing a study of: "Technological Choise and Appraisal of Appropirate Metallugical Process Routes for Maharashtra Elektrosmelt Company of State Industrial and Development corporation of Maharashtra".

A contract was awarded Elkem a/s, and the report presented is the result of the expert team's work in cooperation with MEL officers and the technical staff in Elkem a/s.

UNIDO has in "Substantive Terms of Reference" given guidelines for the consultants work. (Enclosed next to this summary, referred to as "ToR").

To reach a recommendation for optimal product mix and process routes (ToR, page 1) following areas are analysed to give some background:

- existing plant and production facilities
- historical events
- plant organisation and manning.

The existing plant and production facilities are considered in Chapter 2.

The MEL plant with one electric smelting furnace for ferromanganese, one electric pig iron furnace, two LD converters, one continuous caster and auxilliary equipment is well planned and have a good layout.

The pig iron/steelmaking facilities represent a small scale steel plant of good design with adequate production units adjusted mainly to mild steel production.

The pig iron furnace have a partly damaged lining and a major lining repair is necessary before restart.

The general impression is that the equipment has been taken good care of during idleness.

Remarks on the events since incorporation of the company are given in Chaper 3.

The ferromanganese production has been continuous since 1977 when delayed steelmaking equipment led MEL to start the furnace no. I on ferromanganese instead of pig iron.

The steel production started December 1979 based on hot metal from cupola furnaces. Pig iron production started in November 1981 after the furnace no II was started on ferro manganese, and only in a short period until May 1982 the pig iron based steel production was running, before it was shut down because the production costs exceeded the ex-works realization value.

Main reason for the loss experienced was the dramatically increase in power price, small scale operation not adequately metallurgical controlled, and the general recession.

MEL have themselves considered a large number of projects to improve on the company's economic situation, the most important of this is the converting to stainless steel by the CLU process.

Organization and manning at the MEL works are studied (Chapter 4) and it is noted that we would prefer a more flat orgainization with fewer levels between superintendants and foremen.

The manning is very numerous, compared to our practice, but this does not affect the produciton costs seriously.

The question is raised if optimal relationships exsist, regarding responsibility and decision making, between the works management and the Bombay and Nagpur offices.

The selection of product areas and processes are treated in Chapter 5.

The ferro manganese product area (ToR, pages 2.3) is considered in sub-chapter 5.1.

The exsisting ferro managanese production can be substancially improved by increased metallugical control of the process.

Recommendations are given for selection of ores, blending and sampling, slag composition and carbon balance. An optimal range, for manganese oxide in the slag is given.

Establishing a production of medium or low carbon ferromanganese is not considered possible at present, because of lack of commercially available technology and substantial development work to be performed - even if the CLU process in principle should work.

Our general view on the future MEL activity in ferro manganese is influenced by the following factors:

- The exisisting surplus production capacity for ferromanganese in India will most likely last for several years.
- The high power price excludes any exporting possibilities.
- Limited supply of high quality manganese ores in India.

We do not think that ferro manganese production should be a part of the long term strategy for MEL.

As soon as the MEL steel operation has developed so far that more pig iron than the production from furnace no I is needed, the furnace no II should be converted to pig iron.

Ferrochrome or chargechrome production could be taken up instead of ferromanganese at a cost of approximately 10 mill. Rs for the converting, but we do not consider this as viable.

There are no suitable chrome ores nearby Chandrapur and a substantial part of the production had to be exported. With the present high power price this export would give a loss.

In Chapter 5.2 the smelting of the Khursipur vanadium containing ore is considered. (ToR, page 4, point Ia)

The ore deposit is not sufficiently explored to give a reliable estimate for mining costs and ore benefication costs.

A smelting process with prereduction of the ore is considered to be the only reliable process way because of the high content of titaniumdioxyde in the ore.

Investments for agglomeration and prereduction would cost approximately 250 mill. Rs.

Based on a guestimated ore concentrate price the production costs for pig iron are calculated to 2.600 Rs per tonne, on the same level as for the MEL pig iron from Lohara ore.

The value of vanadium obtained as slag from oxygenblowing of the vanadium containing pig iron amounts to approximately 50 mill. Rs per year. This would give a pay-back periode of approximately 5 years, and the project seems to be viable.

There are, however, richer sources of vanadium containing ores in India, and we will raise the question if the Khursipur deposit is the first to be attacked, and if Chandrapur is the right place for this first operation of this kind in India.

This project is certainly not of short term interest for MEL, and more informations, especially about the ores, are neccessary to consider it as a long term project.

The pig iron smelting is given a detailed consideration in Chapter 5.3.

Recommendations are given for achieving a more succesful operation than experienced during the short period in operation in 1981/82.

Better raw materials control by blending - screening - sampling is necessary.

Control of slag basicity, silicion content and metal temperature can be improved by better sampling and analysing practice.

The operational period for the pig iron furnace was too short to establish good control and good working routines, and we suggest that a restarting of the furnace should be done with the assistance from experienced engineers and foremen to establish a consistent operation in shortest possible time.

Calculations of production costs for electric smelted pig iron and hot metal from the cupola furnaces are showing that the cupola hot metal will have no cost advantages that can outweigh the pig irons supremacy in quality, even if the cupola furnaces are rebuilt to hot blast. (ToR, page 7, point IIIiii)

Installment of a low shaft blast furnace (ToR, page 7, point IIIii) has been discharged by MEL because of experiences from Kalinga Iron Works.

We support this decision.

Regarding the future supply for iron ores we point to the fact that the Lohara Mines will last only for 5-7 years of operation. Prospecting, evaluating and starting of a new mine will need that long time, and decision about future ore supply should be taken in the near future.

Preheating/prereduction of the ore prior to smelting (ToR, page 6, point II) will need investments of approximately 180 mill. Rs. With the existing high power price the production costs would be substantially reduced - with 800 Rs per tonne of pig iron. The production capacity would be increased from 65.000 to 100.000 tonnes per year.

The project is most interesting and should be worked out more in detail when more pig iron is needed and capital availability is more likely.

The viability of restarting the MEL steel operation is considered in Chapter 5.4. (ToR, page 3)

Experiences from previous operations and recent calculations make clear that steel operation at MEL based on mild steel or other ordinary steel grades is not viable.

Market informations points toward stainless steel as the most interesting product for MEL. Limitations in the market possibilities for stainless steel makes a production of special carbon and low alloyed steel actual.

Market demand is good in these areas, but actual market penetration is very much dependent on steel technology level and product quality. During the development period, mild steel and special foundry iron are outlets for pig iron production and surplus steelmaking capacity.

Pig iron from the electric smelting furnace will be the main raw material, and this represents a good basis for high quality steel production.

Special low phosphorous foundry iron (ToR, page 6, Iii) will be a natural part of the product mix, but a pig casting machine for the special foundry iron is necessary to market the actual tonnages of this product.

The existing steel melt shop represents a good basis for an effective small scale steel operation, which can be modified to a high quality steel production with moderate investments.

MEL's plans for rebuilding one of the LD converters to CLU reactor for stainless steel are based on sound techno-economicål considerations.

The remaining LD converter must be rebuilt to bottom stirring to allow a good dephosphorization in the stainless steel production and to give a metallurgic. well balanced steel basis for the special steels production.

Gas stirring and injection in the teeming ladles are necessary to cope with the special steel production.

Total investment costs for the modifications in equipment are calculated to approximately 17. mill. Rs with 4-5 mill. Rs in addition for the pig casting machine.

The process routes are discussed and calculations are made of production capacity and production costs.

The production costs for stainless steel are calculated to 18.000 Rs per tonne of billets, and for special carbon steel to 3.900 Rs per tonne of billets. (Direct costs).

Alternative development schemes for MEL steel operation are discussed, and alternative 3 of these have our greatest confidence.

A successfull, but realistic development in the stainless steel operation is foreseen with tonnages increasing from 10.000 tonnes per year to 36.000 tonnes per year (21% market share) during the first 5 years of operation.

A conservative estimation is made of the development of increasing tonnages in the premium price range of special steels and decreasing mild steel/foundry iron tonnages to match with the frame set by the pig iron production of 65.000 tonnnes per year.

The resulting contributions from this operation are calculated to be approximately - for the 5 first years of operation-respectively:

30 - 56 - 73 - 86 - 96 mill. Rs.

With total fixed costs per year of 53.5 mill. Rs, the breakeven point will be reached during the second year of operation , and substantial profit will be possible thereafter.

Reopening of the MEL steel operation will be viable - provided that a level of steel technology and product quality can be developed, and provided strong marketing efforts.

The importance of collecting know how from outside expertise is highly stressed upon. Assistance from SAIL is supposed to be available, and some Scandinavian potential advisers are recommended.

Well planned, extensive progams for recruiting, education and training must be worked out and performed.

MEL has basically no special premises for a steel operation, and only if the steel technology and organization of the operation are on a high level, a succesful operation can be achieved.

A summary of recommendations is given in Chapter 6, where a long-term development of the MEL plant into a pure iron and steel works with capacity in the 200,000 tonnes per year range is indicated.

The diagram on the next page illustrates a tentative development scheme.

The consultants have additionally been asked to give their opinion on the desirability of SAIL, Research and Development Center, taking over the MEL plant.

We have too little knowledge about the financial situation and the SAIL plans for the MEL plant inside their organisation to give a well-based opinion in this matter.

Some point of view can however be given in this connection.

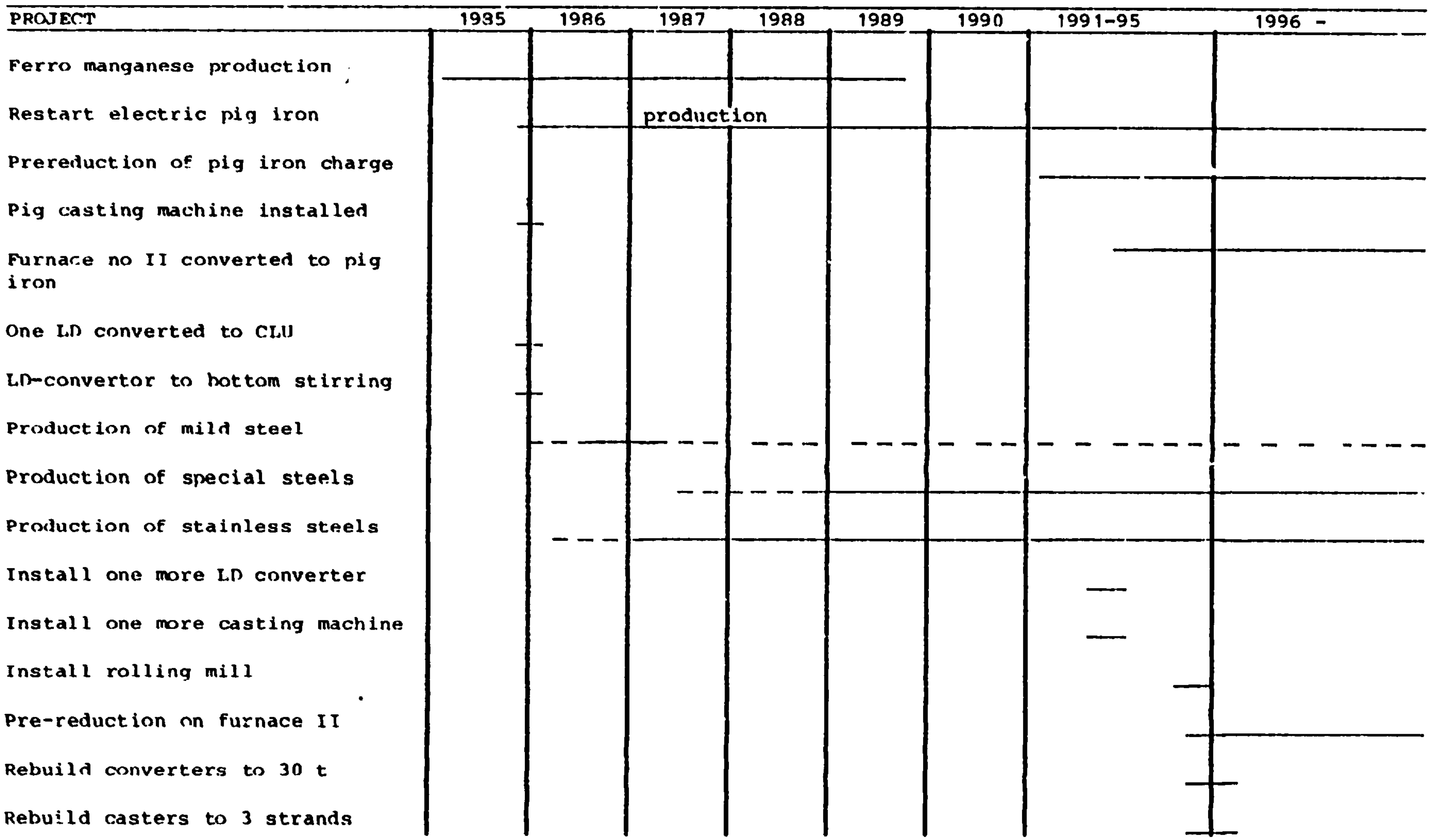
We think that the MEL plant can be developed into a profitable steel producing plant. For this development the technical resources from SAIL, Research and Develoment Center are of great value.

Flexibility and aggressive marketing efforts are also important factors, that are more often found in small independant companies than in big organisations.

Perhaps a cooperation model for the relationship between MEL and the SAIL, Research and Development Center would be more effective than a full taking over.

If the MEL plant should be used partly as a Research/Development station, a profitable production should not be expected, and the question if the Research/Development value will outweigh the profit loss cannot be answered by us.

TENTATIVE STRATEGIC DEVELOPMENT PLAN FOR MAHARASHTRA ELEKTROSMELT COMPANY



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ANNEX E

18 April 1984

Substantive Terms of Reference

Project Title: Technological Choice and Appraisal of Appropriate Metallurgical Process Routes for Maharashtra Electro-Smelt Company of State Industrial and Development Corporation of Maharashtra (SICOM).

Project No.: SI/IND/84/802

Country: India

1. Objectives

A) Development Objectives

Development objectives of the project are to ensure maximum productivity of optimum product-mix, based on judicious choice and applications of appropriate metallurgical technology at the Maharashtra Electro-Smelt Plant of SICOM at Chandrapur and thereby to up-grade its operational results conforming to sound techno-economic parameters.

B) Immediate Objectives

a) To study, analyse and select appropria e technological process route(s) for plant operations of Maharashtra Electro-Smelt at Chandrapur and based thereon to:

i) formulate the most appropriate product-mix (pig iron, steel and ferro-alloys) which can lead to:

ii) - maximum productivity

iii) - at lowest production costs possible

iv) - of high quality product-mix

b) To up-grade the operational results of Plant operations adjudged on sound techno-economic parameters to acceptable levels, of Maharashtra Electro-Smelt project at Chandrapur.

c) To define technological measures required to achieve (a) and (b) above and arrange to systematically apply requisite measures at the Corporate management levels of SICOM.

d) To provide the services of internationally renowned Technical Consultants for implementing (a), (b) and (c) above, and whereby,

e) To prepare a detailed Technical/Substantive Report compiling and analysing the results of (a) to (d) above for the State Industrial and Development Corporation of Maharashtra (SICOM) and make appropriate recommendations.

f) To define requisite follow-up action required to be undertaken by SICOM and UNIDO on the completion of this SIS project, to ensure techno-economically acceptable and metallurgically stable operations of Maharashtra Electro-Smelt plant at Chandrapur of the State Industrial and Development Corporation of Maharashtra (SICOM).

2. Special Considerations - Not applicable.

3. Background and Justification

The plant of Maharashtra Electro-Smelt Limited is located at Chandrapur, about 160 Kms south of Nagpur. It has the following major production facilitie

1. 1 no. of 33,000 KVA electric smelting furnace to produce high carbon ferro manganese (carbon around 8%) from manganese ore.
2. 1 no. of 33,000 KVA electric smelting furnace to produce pig iron from iron ore.
3. 2 nos. of L-D converters to produce steel from liquid pig iron
4. 1 no. of 1100 cum metres per hour oxygen plant to produce oxygen required in steel making
5. 1 no. of 35 tonnes per day kiln to produce calcined lime required in steel making
6. 6 metre Radius Continuous Casting machine to cast billets upto 180 mm square section
7. 2 nos. of 15 tonnes per hour capacity cupolas to melt solid pig iron for further use in steel making.

High Carbon Ferro Manganese

The Company is currently producing high carbon ferro manganese since 1977. The technical problem faced is the higher slag volume (about 900 to 1000 kgs. per tonne of FeMn as compared to normal 600 kgs. per tonne of FeMn leading to high power consumption. In the area of ferro manganese, the

Company is facing the problem of low demand within the country and non-remunerative prices in the export market. As a result, ferro manganese unit is being operated to 40% of its capacity. These low capacity level operations have detrimental effects on consumption norms and power costs.

Low Carbon Ferro Manganese

The Company tried to produce medium/low carbon ferro manganese (carbon less than 2% by transferring the liquid high carbon ferro manganese to L-D converters and blowing oxygen from the top through a lance to reduce the carbon content. However, in this process the manganese loss was also very high and hence low carbon FeMn, with manganese much less than the desired limit and phosphorous much higher than the desired limit, was produced. This technical problem may be solved by creating partial pressure conditions in the converter either by use of vacuum or by blowing of argon/oxygen from bottom of the converter.

Steel

Production of steel by first producing pig iron in electric smelting furnace and then converting the same into steel is a very power intensive process like the production of high carbon Fe-Mn. About 3200 to 3500 Kwh of power is required to produce one tonne of steel billets. A plant based on this process is therefore, economical in a situation where power cost is low and stable.

The consumption of raw materials and power to produce pig iron in electric smelting furnace largely depends on control of slag composition. The basicity of the slag needs to be closely controlled. However, this is possible only if the quality of raw materials used is consistent. MEL had a problem of not being able to control the slag basicity very closely.

Another problem being faced is lower temperature of the liquid pig iron coming out of the smelting furnace. The temperatues were around 1200 to 1250°C, whereas the required temperatures should be 1350 to 1400°C. This lower temperature of pig iron led to quality and operational problems in steel making.

Due to lower temperature and variations in the silicon content of pig iron the oxygen blowing parameters have to be continuously changed. This leads to lar amount of gas content in the steel as well as higher refractory consumption. The larger quantity of gas cannot be removed completely by addition of deoxidizers like ferro manganese and ferro silicon, as large quantities of these will bring down the temperature of steel and also effect the composition. This leads to the problem of cleanliness of steel and a[illegible]cts internal soundness of steel billets/ingots.

Due to high power consumption and costs, it is necessary to produce special alloy and stainless steels fetching high sales realisation. However, production of high grade steel is not possible as the cleanliness of steel cannot be ensured in the absence of facilities to remove the gases from the steel and ensure proper temperatures for continuous casting of billets. Here again an intermediate secondary refining arrangement using vacuum is required if high grade alloy and stainless steels are to be produced.

The major problem in steel making is the high power consumption intensiveness of the process, which at today's power costs of nearly 50 paise per unit, equal to about US 5 cents/KWH, makes production of mild steel and other ordinary steels uneconomical. The production of good quality high grade allo steels including stainless steels is dependent on availability of optimum secondary refining facilities.

With the above background and current plant operations/status, the services of internationally renowned technical consultants are required to undertake the study of the following technological alternatives/ process routes.

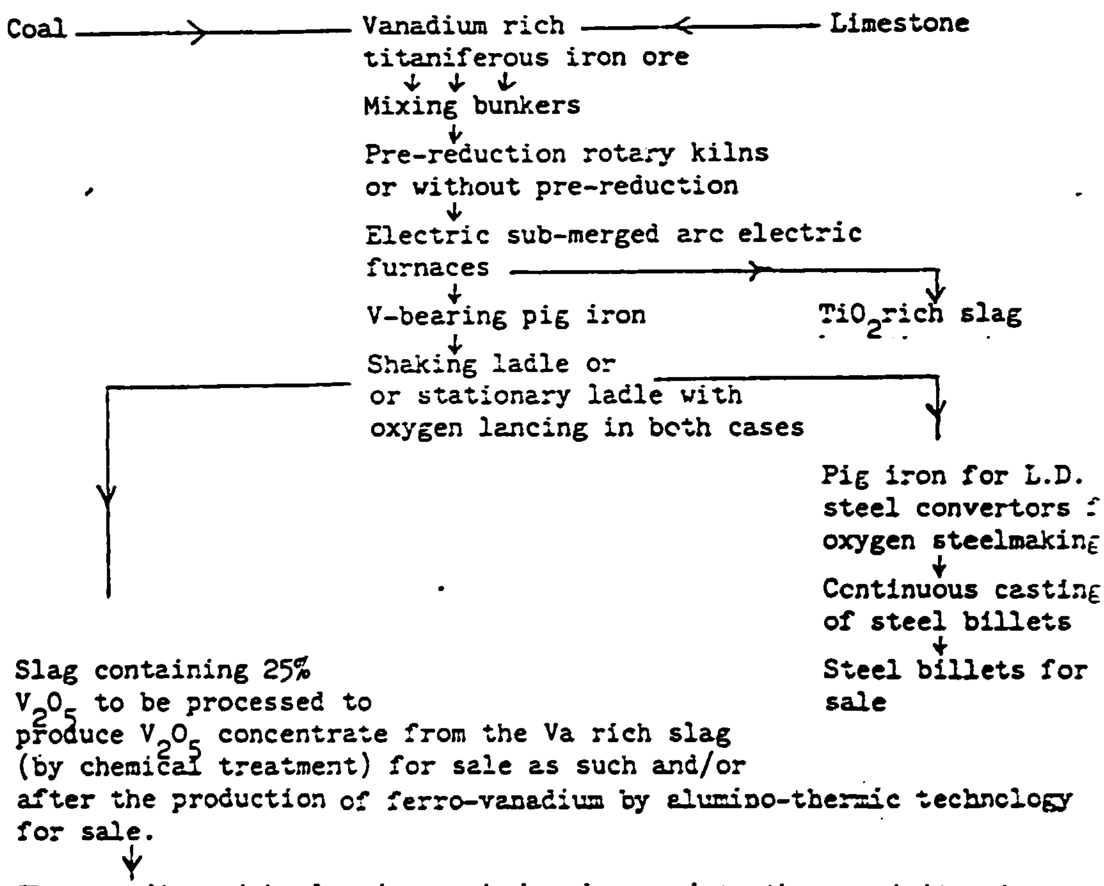
I. Study, analyse and techno-economically adjudge the following technological and metallurgical process routes in relation to multiple product-mix obtainable in each case and in terms of the capital costs/investments further required over and above the plant equipment and infra-structure facilities already installed and available at Chandrapur of Maharashtra Electro-Smelt Company of SICOM.

a) Smelting in electric submerged arc furnace installed at Chandrapur of Khursipur iron ore deposits in Maharashtra conforming to the following average chemical analysis:

Total Fe	-	55.68 (percentages)
TiO_2	-	13.6
Va	-	0.4
SiO_2	-	2.71
Al_2O_3	-	3.54
S	-	0.008
P	-	0.01
CaO	-	Traces

to produce the following:

i) Vanadium rich pig iron for further processing by the 'High Veld' route based on the following Flow Sheet with or without prior pre-reduction in rotary kiln operations of the Khursipur iron ore.



The vanadium rich slag is crushed and ground to the requisite size. The ground slag and soda ash in the required proportion are thoroughly mixed in a mixer and roasted in the roasting furnace. The roasted product is then passed through a cooler and the cold product is next thoroughly leached with hot water and washed in mixer settlers in five counter current stages. Sulphuric acid is added to the leach liquor and it is allowed to settle in precipitation vessels. The red cake precipitate is filtered in a filter press and dried; and melted in a melting furnace. The fused V_2O_5 (vanadium pentoxide) is solidified in a rotating disc in the form of flakes and is available for sale as such.

Additionally, the vanadium pentoxide is reduced with aluminium powder in magnesite lined thermit vessels to produce ferro-vanadium for sale.

The charge mix contains V_2O_5 flakes, aluminium powder and iron shots or mill scale in requisite proportions along with the primary ignition mixture. After the reaction is completed in the vessel and the product is cold, the ferro-vanadium is seperated from the slag, cleaned, sized and packed for sale.

The current sale price FOB (USA) of the ferro-vanadium is of the order of US $ 8-19 per pound or US $ 18-20 per Kg. of contained vanadium. Its sale price in India should be correspondingly increased after adding to it the freight charges, customs duty, port handling and inland transport costs, etc.

ii) Incidentally, it is mentioned that the phosphorous content of the pig iron so far smelted at Chandrapur or that which would result from the use of Khursipur iron ore, would be around 0.06 to 0.08% or 0.09% and with suitable adjustment of its silicon contents to correspond to high grades of foundry pig iron, its direct domestic sales and/or export should fetch a premium/high price; the current prices in the U.K. of the low phosphorous foundry grades of pig iron are Pounds Sterling 130 £S per ton; 1/ this subject needs to be equally studied further. Brazil is producing in charcoal blast furnaces 4-5 million tons of low phosphorous pig iron of foundry grades and is exporting the latter reportedly at the FOB price of 200-225 US$ per ton.

It is also to be pointed out that if the iron ore is first pre-reduced in rotary kiln operations and the pre-reduced product is charged hot in the electric sub-merged arc furnace for smelting (as in the case currently of High-veld process at Dunswart (S.A.) and as is projected in New Zealand plant), the power consumption per ton of pig iron produced should come down to about 1500 KwH/ton of hot metal from over 3,200 KwH/ton of hot metal when the iron ore is not first pre-reduced. This brings into focus the second possible technological process route/alternative namely;

II. Pre-reduction of iron ore in rotary kiln operations prior to smelting in sub-merged arc electric furnaces and which will include the charging into the latter of the hot pre-reduced charge and not cold pre-reduced charge; hot charge is being done at Highveld plant at Dunswart in S.A. and currently also being successfully done at the Skpoje iron and steel works in Yugoslavia 2/ and now projected in the New Zealand steel corporation in New Zealand. The power consumption per ton of hot metal (pig iron) in the electric sub-merged arc furnace has dropped to 1530 to 1550 KwH/ton of pig iron from 3200-3300 KwH/ton of pig iron based on continuous operations as reported by the Skpoje iron and steel works in Yugoslavia.

A complete rotary kiln DR/sponge plant with a capacity of 65,000 tons/year of DR sponge is for sale in Tennesse (USA). SICOM could investigate its sale/procurement for the above purpose with or without UNIDO involvement. It would, of course, be understood that the installation of a rotary kiln for pre-reduction and charging of hot pre-reduced charge to the electric sub-merged arc electric furnace would entail additional capital expenditures

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1/ Foundry Trade Journal, March 24, 1983 Issue, P. 422 (UK)

2/ Skpoje iron and steel works - Document no STEEL/SEM.9/R.15 - UN/ECE D.R. Seminar - dated 15 February 1983.

by SICOM which has to be worked out by the international technical consultants under this UNIDO/SIS project under the current plant conditions and layout of Maharashtra Electro-Smelt Co. at Chandrapur.

III. Another technological alternative/process route to be considered and evaluated would be based on:

i) Operations of both the sub-merged arc electric furnaces for the production of ferro-manganese only for domestic sales, and

ii) Installation of a small blast furnace (150 to 250 tons per day capacity) for pig iron production as currently practised at Kalinga Iron Works in Orissa using Maharashtra iron ore deposits and Low Temperature Carbonized Coke (LTC) from Hyderabad based on Singrenni coal. The availability and costs of the LTC would need to be determined by the international technical consultants as also the additional capital costs/investment needed for the installation of the small blast furnace (Kalinga type) etc. The estimated capital and production costs for each of the above listed alternatives will needed to be worked out/elaborated by the international consultants under this UNIDO sponsored SIS project along with appropriate recommendations as referred to earlier on in the foregoing. The molten basic grade of pig iron will be converted into steel in the existing LD steel converters installed at Chandrapur and no additional steel making capacity is envisaged.

iii) The conversion of existing cold blast cupola(s) into hot blast cupola through the application of a simple recuperation system would also need to be examined so that the use of C.I scrap and steel scrap in appropriate blends, will yield requisite quality hot metal for the LD oxygen steel converters already installed at Chandrapur.

IV. International technical consultants will further integrate their studies/ investigations to cover additionally the following:

a) In line with different technological process routes, formulate the more appropriate product - mix viz pig iron - foundry grades and basic iron, steel and ferro-alloys which can lead to:

i) maximum plant utilization and productivity;

ii) at least production costs;

iii) of high quality outputs.

b) Capital costs estimates for each of the technological alternatives will be worked out along with the production costs of the industrial product - mix as appropriate.

c) Prepare a detailed project report to cover cases I and II above. and make appropriate recommendations in each case in order to prepare the grounds for appropriate corporate/management actions required by UNIDO as appropriate. The foregoing thus provide the background and justifications for this UNIDO/SIS project for urgent/expeditious implementation by the latter.

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" "	3	K.K. Banerjee: Market Survey on Stainless Steel and Other Alloy Steels, August/September 1984
" "	4	Feasibility Study on CLU Process from Uddeholm
" "	5	Agenda Note, MEL considering of Uddeholm proposal

1. INTRODUCTION

Maharashtra Elektrosmelt Ltd. (MEL) is a wholly owned subsidiary of State Industrial and Development Corporation of Maharashtra (SICOM).

The MEL company, as its first and only enterprise, established a mini-steel plant in Chandrapur (Maharashtra) in 1977. Because of very late equipment deliveries to the oxygen plant, which is an essential part of the plant to supply oxygen to the steel production, the plant was not started as an iron and steel plant in 1977. The electric furnace was started on standard ferromanganese instead.

Only in 1979 did the oxygen plant become operative, and steel production could commence. This was done on the basis of hot metal produced in two cupola furnaces installed for that purpose, as it was found desirable to continue the ferromanganese production in the electric pig iron furnace. A new electric ferromanganese unit was started in 198 , and late autumn the original electric pig iron furnace was transferred to pig iron production.

Because of heavy recession in the steel market, and also because of, in our opinion, excessive increases in the price for electric power from the nearby state-owned thermal power station, the plant operated with heavy losses, and it had to discontinue the steel production in May 1982. The iron and steel units have been standing idle since then. The ferromanganese furnace, however, has been in operation, partly on low load, and is now the only unit in production at the plant.

The MEL iron and steel plant in Chandrapur is a well equipped modern plant, well laid out and well connected to the rail road transport system, both the narrow and the broad gauge tracks. The nearby hematite iron ores are of a pure and good quality and provide a useful basis for the production of high quality steels. With the prevailing prices for electric power the mini plant in Chandrapur has no chance to meet the market competition in ordinary mild steel qualities. Our task, as we see it, will in this connection be to investigate if MEL can adjust their steel operations to niches in the markets for steel grades with premium prices. Electric pig iron can provide a pure raw material for high quality steel production.

The United Nations Industrial Development Organization (UNIDO) invited, among other companies, Elkem a/s Engineering Division in a letter dated 19 April 1984 to do a "Technological Choice and Appraisal of Appropriate Metallurgical Process Routes for Maharashtra Elektrosmelt Company of State Industrial and Development Corporation of Maharashtra (SICOM)". A contract was awarded Elkem for such services dated 13 September 1984.

According to the terms of the contract the selected project team, consisting of Birger Ydstie (team leader) and Magne Mohagen, both of them process metallurgists, visited the project area and had discussions with leading officers and managers of Maharashtra Elektrosmelt Ltd. in two periods:

12 to 30 September 1984, equal 16 working days
23 November to 8 December 1984, equal 14 working days.

In addition one working day was spent in discussions on modern processes for stainless steels with the Metallurgical Research Station of the Swedish Iron and Steel Association (Mefos) in Luleå, Sweden.

The present report is produced with the support of the technical staff in Elkem a/s Engineering Division as well as the Elkem Ferro Alloy Division, Steel Division and R&D Center.

TERMS OF REFERENCE

a) To study, analyse and select appropriate technological process route(s) for plant operations of Maharashtra Electrosmelt at Chandrapur and based thereon to:

- formulate the most appropriate product mix (pig iron, steel and ferro alloys) which can lead to:
- maximum productivity
- at lowest possible production costs
- of high quality product mix.

b) To upgrade operational results of present operation (which is only high carbon FeMn).

c) To define technological measures required to achieve (a) and (b) above. Apply requisite measures at the corporate management levels of SICOM.

d) To provide the services of internationally renowned technical consulants for implementing (a), (b) and (c) above, and whereby:

e) To prepare a detailed technical/substantive report compiling and analysing the results of (a) to (d) above for the State Industrial and Development Corporation of Maharashtra (SICOM) and make appropriate recommendations.

f) To define requisite follow-up action required to be undertaken by SICOM and UNIDO on the completion of this SIS project, to ensure techno-economically acceptable and metallurgically stable operations of MEL.

2

2. DESCRIPTION OF THE PRESENT PLANT AND ITS PRODUCTION FACILITIES

The lay-out of the present plant is shown in Enclosure No. 2.a.

The main production units are:

2.1 The electric pig iron plant

One modern and well equipped electric pig iron plant with one 33 MVA electric smelting furnace, supplied by Elkem a/s, Norway - complete with weighing and charging equipment, Venturi gas cleaning plant and equipment for electrode operations and automatic furnace operating control.

The furnace was started in February 1977 to produce 50,000 tpa of high carbon ferro manganese, and reconverted to pig iron production in November 81. It was, however, stopped again in May 82 because of too high operational costs and has been idle since.

During our last visit to Chandrapur in Nov/Dec. we were presented with the problem of restart of the pig iron furnace to produce foundry pig for a marked that suddenly opened for a while (6 months was said) because of a power shortage at another producer.

This gave us a chance to a thorough inspection of the furnace hearth and tapping region - both of which proved to be severely damaged, partly through the period the furnace was operated on FeMn, partly through the time the furnace has been standing idle from May 82. What happens is that the tar dolomite hearth, exposed to moisture in the air, will hydrolize and gradually disintegrate. Besides there are signs (by inspection done in the tapping region) that the magnesite brick layer underneath the tar dolomite hearth may be partly destroyed by water having leaked in to the furnace through cracks in the 3/4" steel plate furnace shell.

Conclusion: the furnace lining and hearth must be subject to a major repair/replacement before this furnace can be restarted.

The cost of complete relining would be in the order of: 3.5 mill.Rs.

2.2 <u>The cupola plant</u>

One cupola plant supplied by Fafeco Engineers Pvt. Ltd. of Bombay, consisting of two 15 t/h cold blast cupola furnaces, one 30 t hot metal receiver and one 5t charging crane.

The plant has a capacity for supplying 45,000 tpa of hot metal. It was started in December 1979, but stopped when the steel production was discontinued in May 82.

The plant seems to be fairly well in-tact.

2.3 <u>LD steel plant</u>

One steel plant supplied by Utkal Machinery Ltd., Kausbahal, in collaboration with Gute-Hoffnungs-Hütte, Sterkrade (W.Germany). The plant is equipped with one 300 t hot metal mixer, two 15 t concentric mouth LD converters, oxygen lancing and flux charging equipment, gas cooling stacks, transfer cars, cranes and all auxiliary equipment to make it fully operational for mild steel production.

Major auxiliary equipment is:

- Conventional ingot teeming in duplex moulds up to 5" x 6" with bottom pouring practice
- Philips emission spectrometer
- Philips electronic hot metal weighbridge
- Stand for surface inspection of billets with manual grinding machines.

Capacity: 100,000 tpa of ingot steel.

2.4 <u>Continuous Casting Plant</u>

Main equipment supplied by Industrial & Structurals Pvt. Ltd., Bombay, in collaboration with Demag of W.Germany.

- 2 strand, 6 metre radius billet caster for billets from 100 x 100 upto 180 x 220 section.

Capacity - 60,000 tpa (on basis of 100/120 sqare billets).

Commissioned in June 1981.

2.5 Oxygen plant

Supplied by Indian Oxygen Limited in collaboration with Cryoplants Limited, U.K.

Main equipment -

- one 740 kW 3-stage turbo compressor supplied by Joy (USA)
- one air separation unit with reversing heat exchanger
- one 40 kW expansion turbine of Linde type
- three 600 N.m^3/h 3-stage dry type reciprocating oxygen compressor supplied by VEB (E.Germany)
- two 17,000 litre vacuum insulated liquid oxygen storage vessels
- one 1000 N. m^3. /h centrifugal liquid oxygen pump supplied by Cryostar

Capacity -

- 1100 N.m^3/h of gaseous oxygen of 99.5% purity
- 36 N.m^3/h of liquid oxygen
- 1980 N.m^3/h gaseous nitrogen with less than 10 Vpm oxygen content

Commissioned in November, 1979. The plant seems to be well taken care of during its idleness from May 1982.

2.6 Lime Calcination Plant

Main equipment supplied by Westerwork Engineers Ltd., Bombay, in collaboration with West's Pyro Ltd., U.K.

- one 35 tpd vertical shaft lime calcinating kiln with EPIF gas/oil firing
- skip charging system for limestone

Auxiliary equipment -

- lime storage bunker with skip charging system

- one double roll chrusher
- one double deck vibrating screen

2.7 Ferro manganese Plant

Main equipment

- one 33 MVA submerged arc electric smelting furnace supplied by Elkem a/s, Norway

Capacity - 50,000 tpa of high carbon ferro manganese

Commissioned in August, 1981.
This is the only unit operating at present.

2.8 Sintering Plant (Paramount Sinters Pvt. Ltd.)

Main equipment supplied by m/s Paramount Furnace Co., Nagpur.

- one 4 tph down draught type sinter strand
- one 5 tph disc type sinter breaker
- one 5 t/h sinter cooler

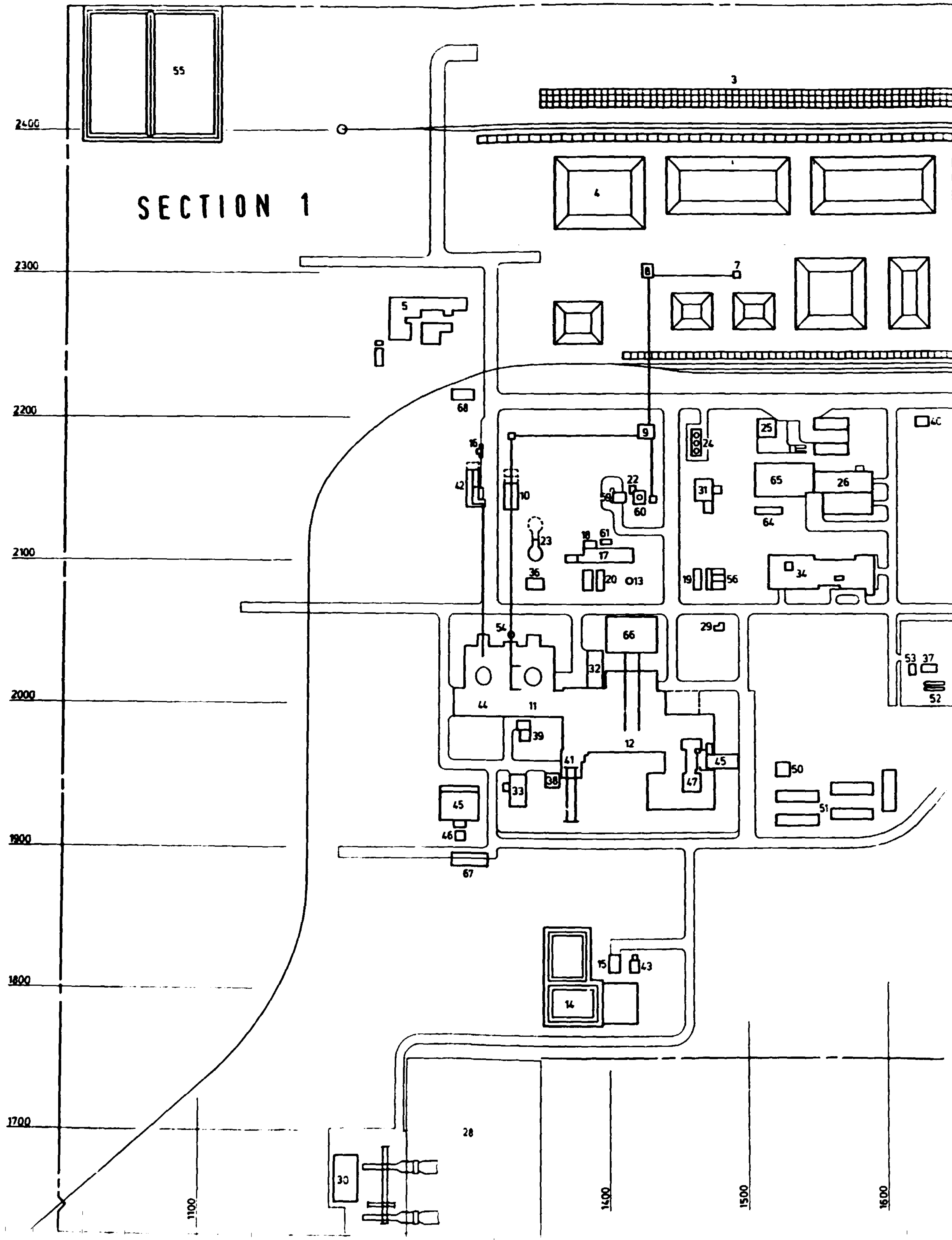
Capacity - 15,000 tpa of manganese ore sinter

Commissioned in May, 1981.
This plant is owned and operated by Paramount Sinters and produces sinter for MEL of the fines that are screened from the manganese ores and cokes.

2.9 General consideration

Maharashtra Elektrosmelt Ltd. plant is adequately equipped with railway yards, both for the broad gauge and narrow gauge tracks servicing the site, and with unloading facilities for raw materials, maintenance shop, offices etc. Day silos with charging and weighing systems are very well equipped with remote control load cell weighing systems for accurate charge control The plant gives the impression of being well planned and is essentally a well equipped ministeel mill which can be geared for specialized production programs.

Total investement for the whole plant was stated to be Rs. 300 million.



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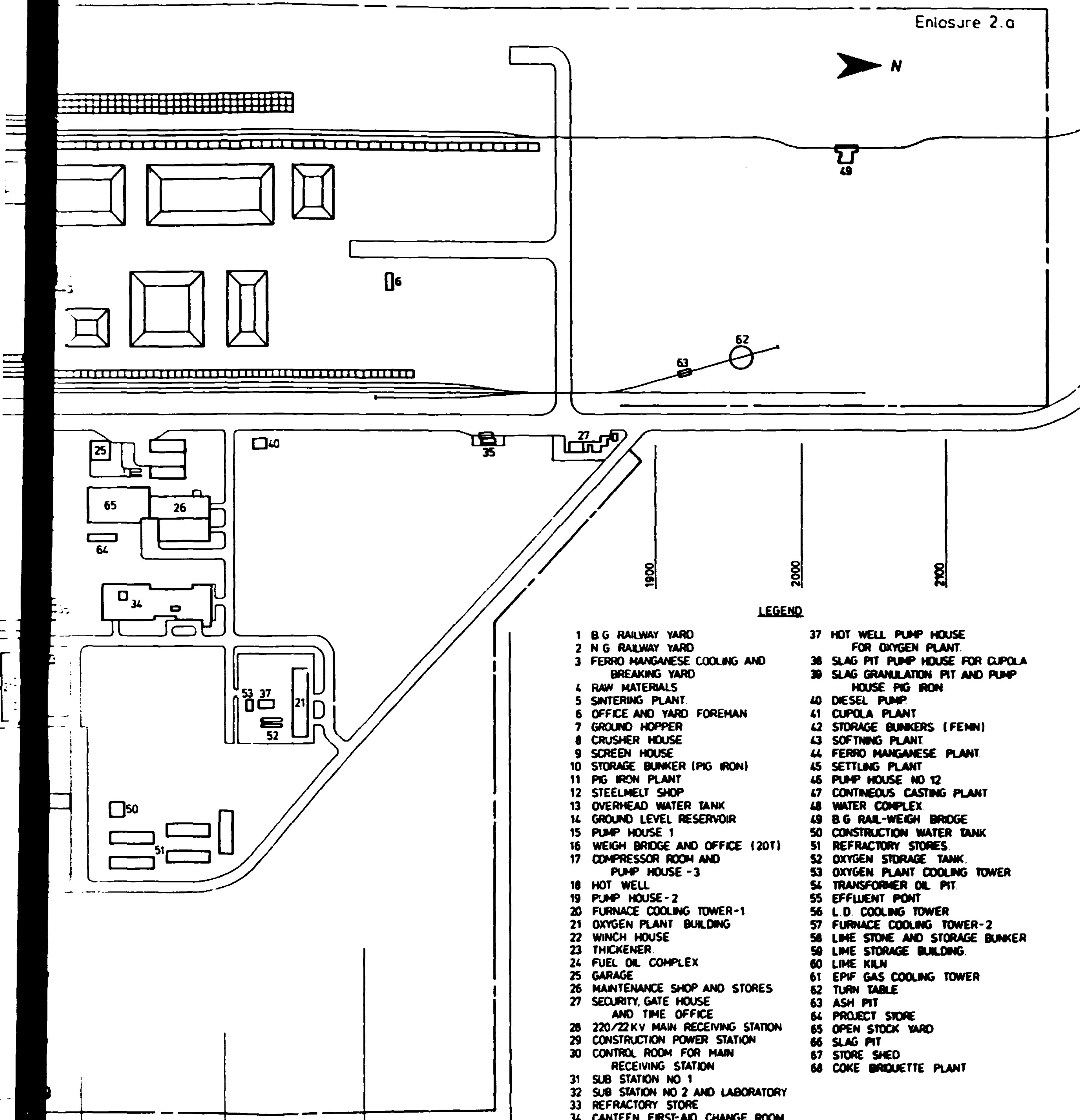
Enlosure 2.a



LEGEND

1 B G RAILWAY YARD
2 N G RAILWAY YARD
3 FERRO MANGANESE COOLING AND BREAKING YARD
4 RAW MATERIALS
5 SINTERING PLANT
6 OFFICE AND YARD FOREMAN
7 GROUND HOPPER
8 CRUSHER HOUSE
9 SCREEN HOUSE
10 STORAGE BUNKER (PIG IRON)
11 PIG IRON PLANT
12 STEELMELT SHOP
13 OVERHEAD WATER TANK
14 GROUND LEVEL RESERVOIR
15 PUMP HOUSE 1
16 WEIGH BRIDGE AND OFFICE (20T)
17 COMPRESSOR ROOM AND PUMP HOUSE - 3
18 HOT WELL
19 PUMP HOUSE - 2
20 FURNACE COOLING TOWER - 1
21 OXYGEN PLANT BUILDING
22 WINCH HOUSE
23 THICKENER
24 FUEL OIL COMPLEX
25 GARAGE
26 MAINTENANCE SHOP AND STORES
27 SECURITY, GATE HOUSE AND TIME OFFICE
28 220/22KV MAIN RECEIVING STATION
29 CONSTRUCTION POWER STATION
30 CONTROL ROOM FOR MAIN RECEIVING STATION
31 SUB STATION NO 1
32 SUB STATION NO 2 AND LABORATORY
33 REFRACTORY STORE
34 CANTEEN, FIRST-AID CHANGE ROOM AND CYCLE STAND
35 WEIGH BRIDGE AND OFFICE (30T)
36 BOOSTER HOUSE
37 HOT WELL PUMP HOUSE FOR OXYGEN PLANT
38 SLAG PIT PUMP HOUSE FOR CUPOLA
39 SLAG GRANULATION PIT AND PUMP HOUSE PIG IRON
40 DIESEL PUMP
41 CUPOLA PLANT
42 STORAGE BUNKERS (FEMN)
43 SOFTNING PLANT
44 FERRO MANGANESE PLANT
45 SETTLING PLANT
46 PUMP HOUSE NO 12
47 CONTINEOUS CASTING PLANT
48 WATER COMPLEX
49 B G RAIL-WEIGH BRIDGE
50 CONSTRUCTION WATER TANK
51 REFRACTORY STORES
52 OXYGEN STORAGE TANK
53 OXYGEN PLANT COOLING TOWER
54 TRANSFORMER OIL PIT
55 EFFLUENT PONT
56 L.D. COOLING TOWER
57 FURNACE COOLING TOWER - 2
58 LIME STONE AND STORAGE BUNKER
59 LIME STORAGE BUILDING
60 LIME KILN
61 EPIF GAS COOLING TOWER
62 TURN TABLE
63 ASH PIT
64 PROJECT STORE
65 OPEN STOCK YARD
66 SLAG PIT
67 STORE SHED
68 COKE BRIQUETTE PLANT

SECTION 2

MAHARASHTRA ELEKTROSMELT LTD., CHANDRAPUR
PLANT GENERAL LAYOUT

0 500 1000

1-69485

3

3. HISTORY

The Maharashtra Elektrosmelt Limited was incorporated in 1974, essentialy promoted by the Government of Maharashtra through its "State Industrial & Investment Corporation" (SICOM) which holds 49% of the company's equity share capital of RS 50 million. 49% of the share capital is held mainly by Indian financial institutions, banks and insurance companies, and the remaining 2% is held by the Development Corporation of Viderbha Limited, another Maharashtra Government development agency.

The company's production facilities are located at Chandrapur, abt. 160 km south of Nagpur in Maharashtra State. The head office is in Bombay, and a district sales office is located in Nagpur. The Nagpur office takes care of raw materials and other supplies for the plant.

The original plant was built with one electric pig iron furnace 33,000 kVA with capacity for 75,000 tpa of pig iron, a steel melt shop with two top-blown LD-convertors 15 tons capacity each, and a billet casting stand to produce conventional ingot teeming in duplex moulds up to 5" x 6" size - capacity 100,000 tpa ingot steel.

Because of serious delays in the delivery of equipment for the oxygen plant it was decided to produce high carbon ferro manganese in the electric pig iron furnace for a period of time. The furnace was therefore commissioned on ferromanganese in February 1977, and not until Sept. 1979 was the oxygen plant started. At that time it was decided to continue ferromanganese production and install two cupola furnaces to supply the melt shop with liquid hot metal, based on iron and steel scrap. The two cupolas were commissioned in December 79 and steel production could commence. Simultaneously it was decided to add No. II electric furnace 33,000 kVA for ferro manganese with a capacity of 50,000 tpa FeMn. This furnace was started in August 1981 and the original pig iron furnace could be made available to produce electric pig iron for the steel production, as originally planned. The cupola furnaces have not been operated since.

A 2-strand continuous casting machine for 100 x 100 up to 180 x 220 mm billets with a capacity of 60,000 tpa was also installed in June 1981.

However, already in May 1982 the pig iron and steel production was stopped again , and the equipment has been idle since. They were reportedly loosing money for each ton of steel they produced.

The ferro manganese furnace, which was commissioned in August 1981, has been in continuous operation but it was running only half capacity during our team's visit in September 1984, due to the general marked situation for steel (and ferro alloys) in India.

We think it is essential to note these developments to understand that the plant has never had the chance to develop a working team of operators, supervisors, production routines and controls to achieve normal operating standards.

At the same time the economic basis for electric smelting of pig iron changed drastically already during the planning stage of this small iron and steel works. The original price for electricity from the coalbased powerplant in Chandrapur (Maharashtra State Electricity Board) rose from 15 paisa to 30 paisa already during the construction of the plant. Since then the price has risen to 60 paisa (Sept. 84) with an expected further rise already at the end of 1984. (see encl. 3.a, the development of power price for MEL).

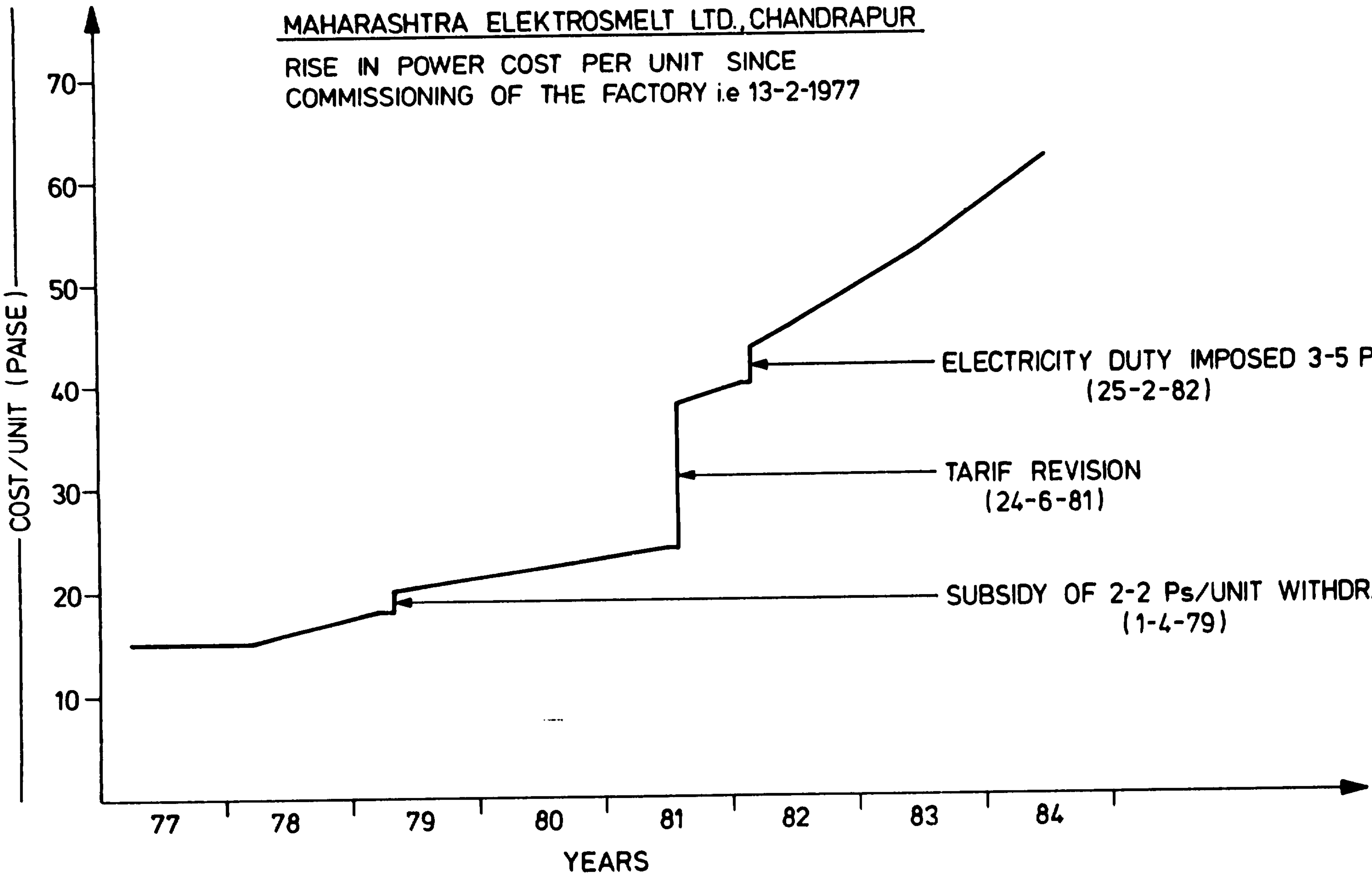
It is evident that under these circumstances the planning of future use and development of the plant would be very difficult. The world wide recession in the iron and steel industry in the beginning of the 80's did not make the situation any easier. It seems, however, that it is essentially the burdens put upon the company by way of extreme increases in the power price that has torn the carpet from under the economics of the plant.

A lot of suggestions have been made to introduce new processes, improvements and production schemes by MEL's own staff. (list of "New Projects" in enclosure 3.b).

Of these only the sintering plant for manganese ore fines has been successfully established. The tests to produce medium/low carbon ferro manganese in the LD converters were not successful, because of too high dust losses.

A project for stainless steels based on the CLU process is now under consideration by MEL. They are in the final stages of negociations with Uddeholm in Sweden.

Ref.: Notes on MEL, (ref. list 1).



Enclosure 3.a.

21811
February 1985

Encl. 3.b
Page 1

NEW PROJECTS

A) FERRO MANGANESE

1. Sinters
2. Coke Briquettes
3. Manganese Ore Briquettes
4. Drying/Preheating/Prereduction of Raw Materials (Outokumpu)
5. Ferro Manganese Casting in moulds
6. Expert Assistance from MMC Japan
7. Silico Manganese
8. Medium/Low Carbon Ferro Manganese
9. Ferro Chrome/Charge Chrome
10. Ilmenite Smelting
11. Ferro Nickel

B) PIG IRON/STEEL

1. Oxygen Bottling
2. Oxygen injection in Cupolas
3. Hot Blast Cupolas
4. I N R E D
5. 'KR' Process
6. Ladle injection/Desulphurization (Ovako)
7. Micro Alloying of Steels
8. Low Shaft Blast Furnace
9. Klockner
10. Ugine

11. Uddeholm

12. Ductile Iron Spun Pipes

13. Forgings

14. Rolling Mills

15. Vanadiferrous Slag/Ferrovanadium

4

4. PLANT MANAGEMENT AND LABOUR FORCE

The organization chart as of 1984 will be seen in encl. No. 4.a. It appears that for the maintenance and operating supervision there may be too many line levels between foremen and superintendant of the specific activity. This tends to present hinderances in decision making and to lessen line responsibility. We would prefer a more "flat" organization with more direct contact to first line leaders.

The labour force was given as follows:

	Present FeMn operation	Complete plant working
Top management		6
Line superintendants		15
Engineers and general foremen		31
Foremen and officers		63
		115
Transport and yard, storage		181
Ferromanganese plant (furnace)	135	135
Pig iron furnace		71
Sinter plant	48-80	
Steel plant		
Cupolas		56
LD's		141
Refractory		44
Casting (continuous & billets)		51
Quality control		9
Workshop and maintenance		
Mechanical		183
Electrical		75
Instruments		11
Civil engineers		13
Oxygen plant		18
Calcining furnace		15
Laboratory		60

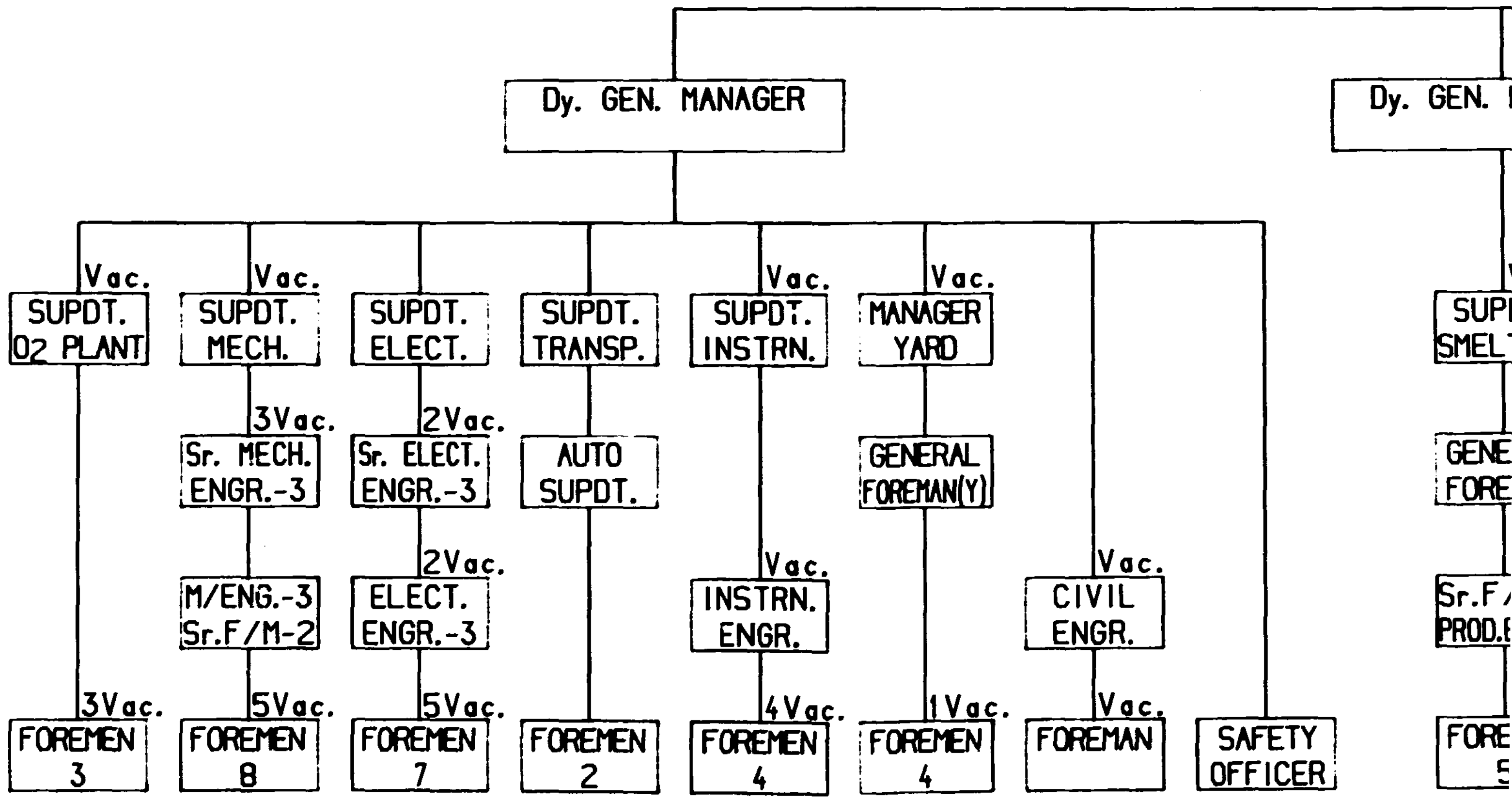
Operations	1063
Office workers, stores watch etc.	204
Contract labour	400
Grand total	1782

Compared to our practices the plant is rather overstaffed also on the labour force side, but we realize that the significance of a somewhat overstaffed labour force is not of the same importance in India as it is in our country.

On the contrary, a well organized, ample labour force, guided by experienced and well developed leaders may be an advantage in an area where wages are comparatively low compared to international standards.

We raise the question to what measure the offices in Nagpur and Bombay take part in the decision process and to which extent the plant management may be tied by strategic plans, purchase and sales policy etc. outside of their influence. In our experience it is extremely important that the plant top management takes part in all kinds of strategic decisions having an influence on plant operation and economy, and that the plant management is given full authority and responsibility, for the production according to a marketing plan and a budget, determined in cooperation and accordance with the plant management.

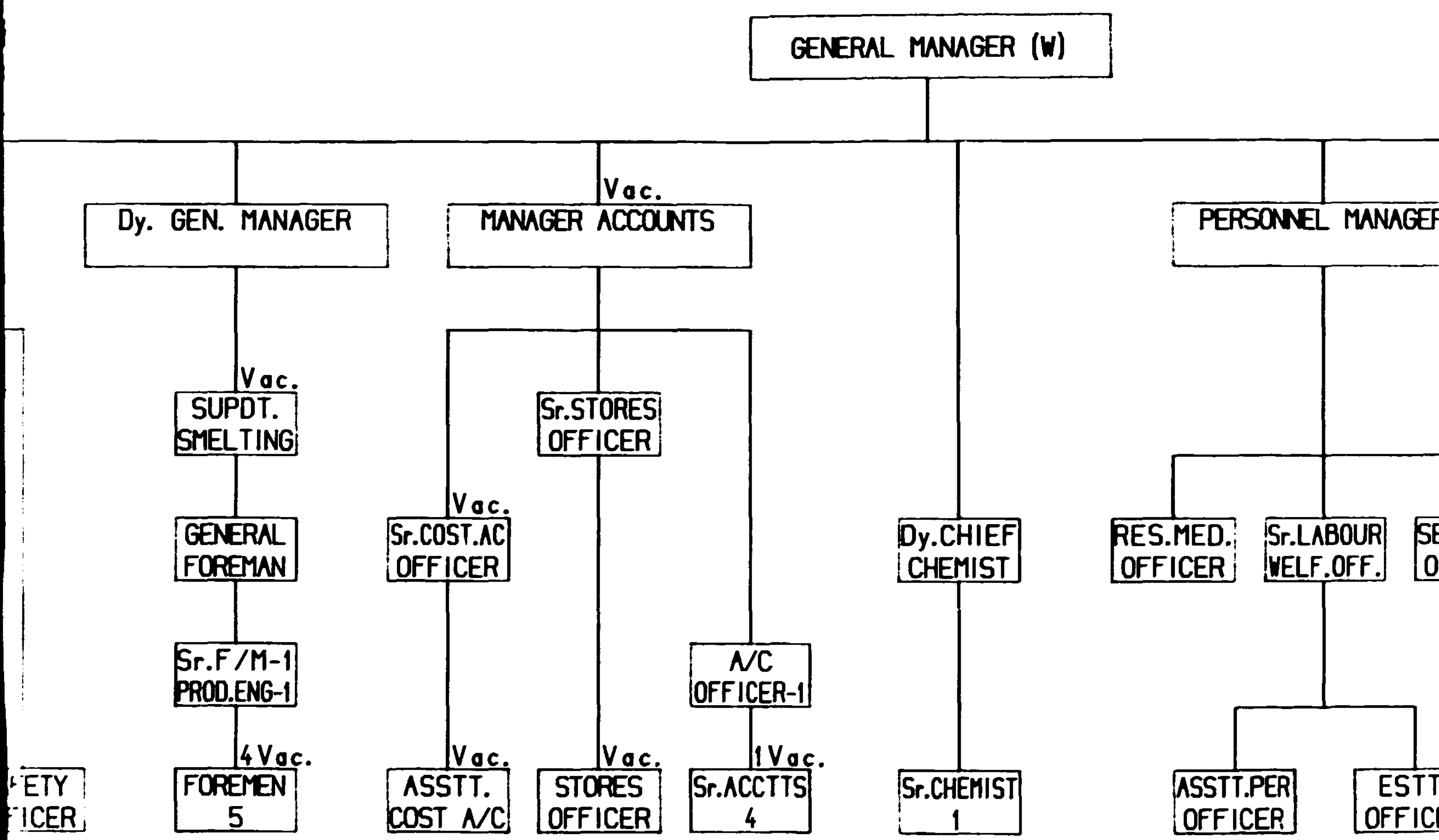
M



VAC - VACANT POSITION

SECTION 1

MAHARASHTRA ELEKTROSMELT LIMITED. CHAN
ORGANISATION CHART AS ON DT.-10-8-
at Works



SECTION 2

LIMITED. CHANDRAPUR
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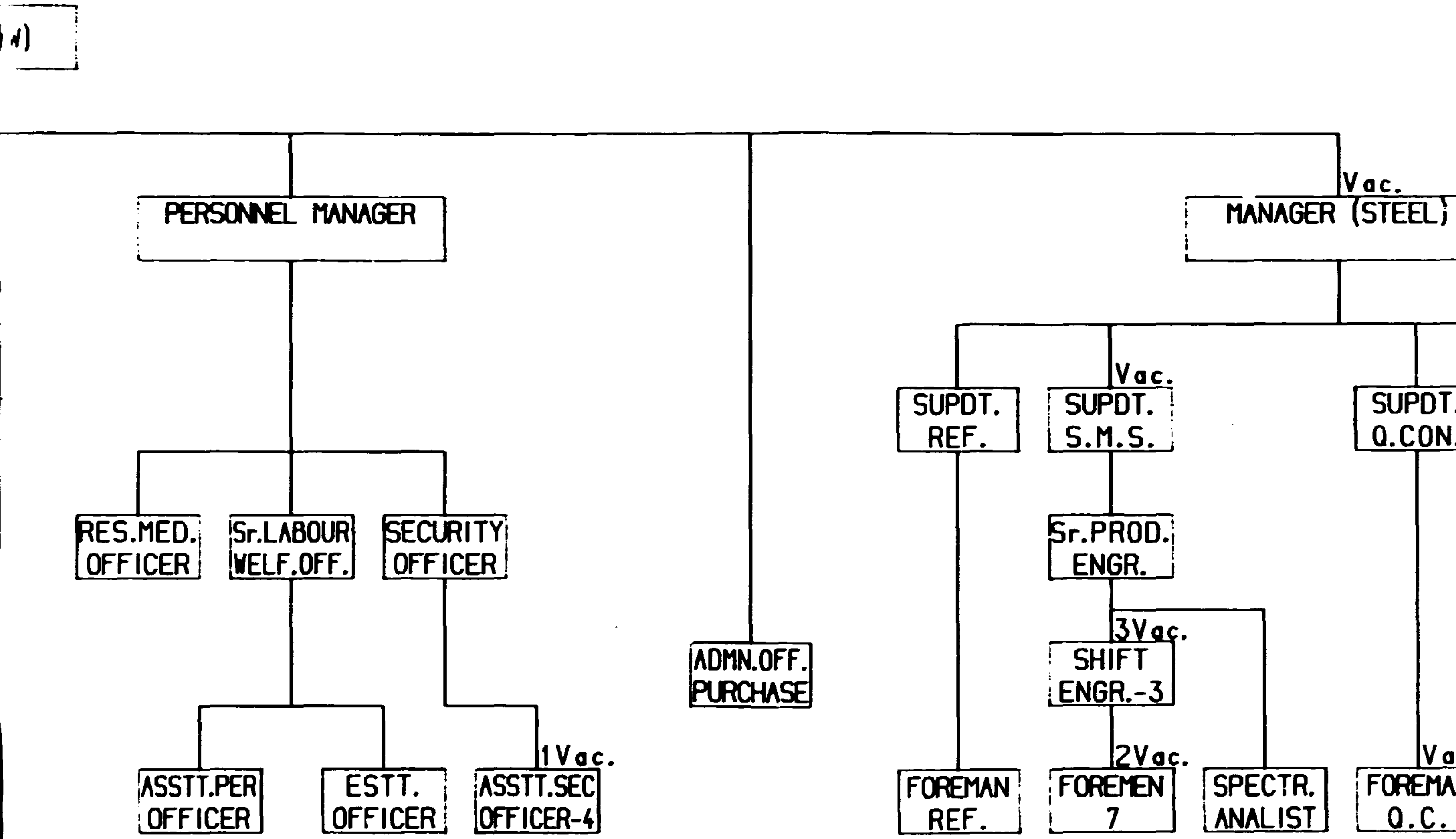
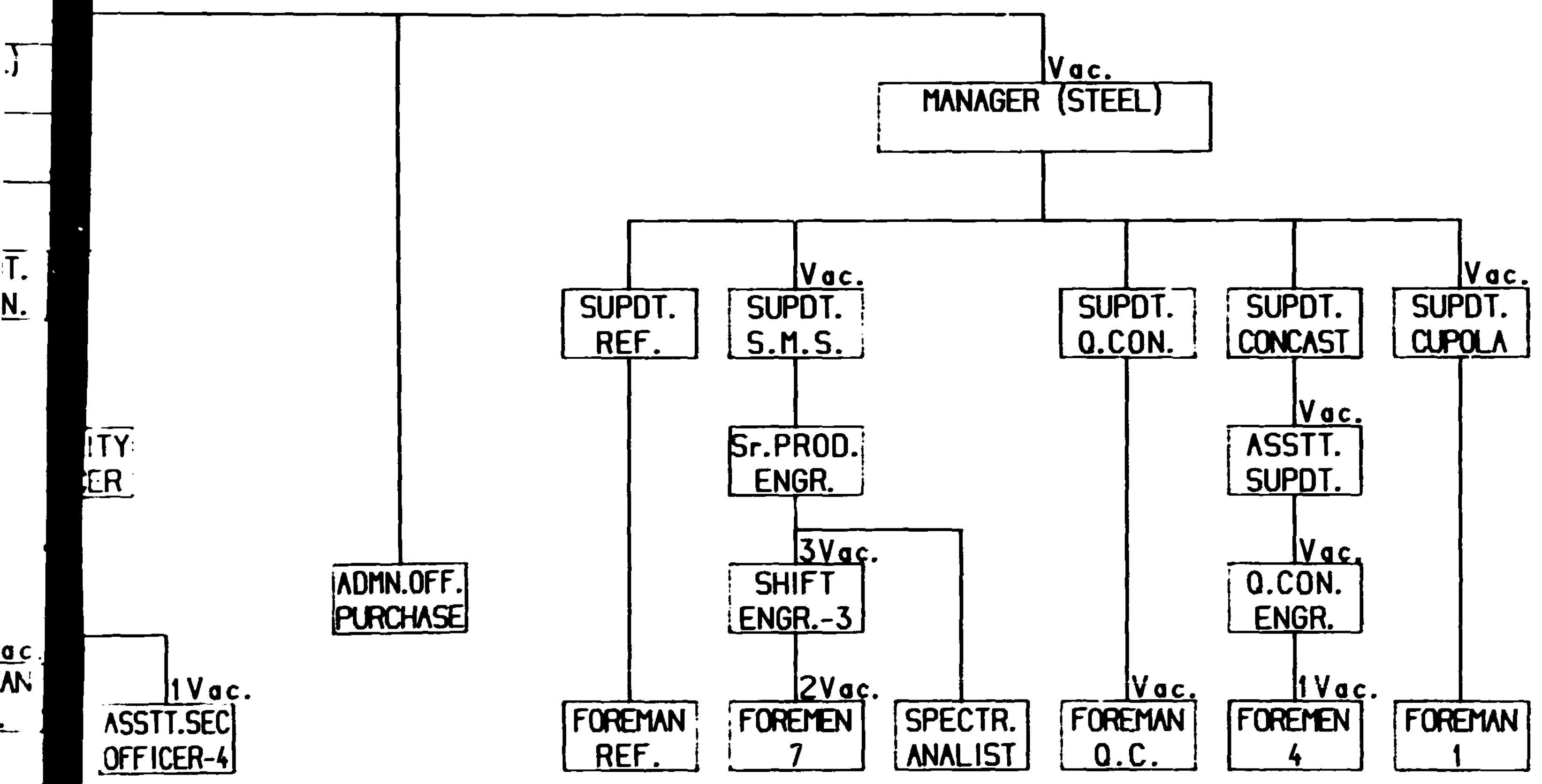


SECTION 3

Enclosure 4.a

APUR

SECTION 4



5

5. SELECTION OF PRODUCT AREAS AND PROCESSES

5.1 FERROMANGANESE AND MEDIUM CARBON FERROMANGANESE, FERROCHROME

The ferromanganese furnace is the only working unit at present in the plant. The furnace is running half load only, because of the general recession in the steel production in India and market quota systems imposed by the Central Government.

5.1.1 The charge balance

The plant is contractually obliged to take 60% of the ore for manganese alloys production from Manganese Ore (India) Limited (MOIL) Encl. 5.1.a. They buy ores from several other sources as well (Encl. 5.1.b) Reduction materials are:

- Pearl Coke from Steel Authority of India Ltd. (SAIL)
- Tisco Pearl Coke from Tata Iron & Steel
- Singarani Low Temperature Coke (LTC)
- Beehive Hard Coke (Blast furnace coke)

The charge mix and material balance sheets are shown in Encl. 5.1.c and the cost of production is shown in Encl. 5.1.d.

Both the manganese ores and the reduction materials are screened to remove fines, and the fines are sintered in a sintering plant with a capacity of 15.000 tonnes per year adjacent to the plant. The sintering plant is built, owned and operated by Paramount Sinters Pvt. Ltd., a Nagpur engineering company. It is more or less a pilot plant for further development of Paramount's engineering of sinter plants and it makes sinter for MEL from the ore and coke fines (+ some lime) for a fixed price of 200 Rs per tonne.

The Paramount Sinters Pvt. Ltd. is a rather remarkable research and engineering organization aiming at making use of the huge amounts of manganese ore fines which now apparantly are stored at the various manganese mines. It is an effort that should be given all possible support and attention, considering that the manganese ore deposits in India are limited resources.

Ref. "Recent Trends in Ferro-Alloys Technology". All India seminars held in Nagpur Dec 17-18 1977.

We suggest that the research will be conducted on two levels:

- upgrading of the ore fines to remove impurities, essentially silica and other gangue materials. This may be done at the Visvesaraya Regional College of Engineering, Metallurgical Dept., Professor dr. M.S. Jakkiwar.

- Sintering tests at the sinterplant in Chandrapur on the produced, upgraded ore fines and furnace tests in the FeMn furnace with various amounts of sinter in the burden.

The first comment about the standard ferromanganese operation at MEL is that there seems to be little control of the charge mix and analysis. There is a variety of different ores and cokes used simultaneously, and even if the charging and weighing system allows for 8 different components it is bound to be too frequent changes in charge composition.

Under these circumstances it must be very difficult to maintanin control of the furnace operating conditions. Slag analyses take time to be done by the laboratory, and uncontrolled changes in the charge composition are difficult to correct in time.

A well defined and constant charge composition is imperative to the operation of large electric smelting furnaces to obtain optimal results.

Then there is a question of the selection of suitable ores. In the charge mix reported there are too much of ores high in silica. This is very unfavourable for standard ferromanganese production. High silica ores should be used for silico-manganese, and not for standard Ferromanganese. However, looking at MOIL's "menu" for different manganese ores it should be possible to select low silica ores, the "D2" for instance, and to avoid the mixing in of so many various types of ores in the burden.

The MOIL ore type "D-4" which is reported used to 36% in the charge is a high silica ore (13% SiO_2). This also is a friable ore, producing fines which go to the sinter plant - and a high silica sinter is produced. Therefore the normally good influence on furnace operation which are reported from other ferromanganese plants using sinter, will not be experienced at MEL with this high silica sinter, because this sinter produces larger slag volumes, higher manganese losses and higher coke consumption.

In the production of standard ferromanganese the ratio slag/metal should preferably be below 1.0. At the MEL furnace the ratio was about 1.3 - almost the double of normal operations. A high slag/metal ratio will lead to large variations in slag levels in the furnace, and especially on low load it may lead to the formation of separate craters and slag pockets, supressing the metal and giving tapping difficulties as well as unstable electrical conditions.

The furnace electrodes under these conditions tend to ride high and will also have excessive electrode movements. The dust losses and temperatures in the furnace off-gases also increase markedly, and even more so because the furnace is run with excessive reduction materials in the charge (see later).

The effects of poor furnace operation on off-gas temperatures and dust losses are illustrated in curves enclosures 5.1.e and 5.1.f.

5.1.2 The slag composition

According to information received the slag is unusally basic at MEL. Our basisity formulae:

$$B_3 = \frac{(CaO + 1,39\ MgO + 0,79\ MnO)}{SiO_2}$$

gives a basisity number of 2,75. The figure should rather be kept at 1,8 - 2,3.

The MgO-content in itself is another matter. MEL charges more dolmite than limestone to the mix. Substituting MgO for CaO lowers the liquidus temperature and the viscosity, and increases the electrical conductivity in the slag. As the electrical conductivity also increases markedly with the MnO-content, a high amount of MgO+MnO is unfavourable. Only in slags with low MnO we do recommend to substitute CaO with MgO, to optimize liquidus temperature, viscosity and slag/metal.

5.1.3 Reduction materials - Fix Carbon

According to our analyses of the operation the Fix Carbon (F:C.) ratio at the MEL furnace is 1.16% of the theoretical value.

This is a strongly "overcoked" furnace giving very poor operating conditions with high electrode positions and a tendency to slag boil. The electrode consumption will then also be high, and at MEL it is reported to be 22 kg/tonne FeMn, which is 2-3 times higher than normal. As mentioned before this also accounts for high off-gas temperatures and high dust losses.

Metal

The selection of ores reported will give a rather low Mn-content in the metal - 76-80% - lower than our specifications, - but of course, this depends only on what the market will accept.

5.1.4 Recommendations

The comments above are based on an analysis of the information received in Chandrapur in September 1984. The information was presented to the technical management at Elkem's ferromanganese plant, the Sauda Smelteverk A/S, and also discussed with metallurgists at Elkem's Beauharnois ferromanganese plant in Quebec, Canada.

Their recommandations are as follows:

Taking the same ores, but assuming that the ore mix can be changed to use less high silica and more D2 ore, optimal operating conditions and the lowest production costs will be obtained with 25-30% MnO in the slag. A curve giving metal cost (in rupies) as a function of MnO in the slag is shown om encl. 5.1.g. The corresponding kwh figures are also shown.

In these examples there is assumed a sinter made from D-2 fines instead of D-4 fines. The slag is regulated to right basisity and MgO+MnO amount and the coke amount is adjusted to the actual needs for the reduction.

It will be seen that the amount of coke per tonne of metal produced is reduced from about 615 kg to alternatively 510, 530, 512 kg. The slag amount is lowered from 1330 kg per tonne metal to alternatively 695, 670 and 643 kg.

The raw materials and other unit costs as well as the current power price of 60 Rs/kWh are used in the computerized cost calculations.

The manganese ores are supplied by MOIL in "parcel's" of approx. 5000 t each. These parcels consist of ores from various mines to give a mix of high silica ore and lower silica ore to meet a specification "less than 10% SiO_2" for the total parcel. The ores are not mixed, but delivered to the plant separately. Examples of such parcels are given in encl. 5.1.b.

Since good furnace operation requires that ore analyses do not vary excessively the different ores should be mixed - blended - to equalize the variations in ore quality. This is best done by "bedding" of the different ores in horizontal layers and retrieving ore charge from one end of the bed to the other. Negative economic effect is of course the need for higher inventories, but that should be more than offset by better furnace performance.

We would stress the importance of controlling - and keeping - the right carbon balance, and particulary not to "overcoke" the furnace.

In enclosure 5.1.d direct costs are given to 4.928 Rs per tonne and price ex-works to 5.900 Rs per tonne.

The recommended improvements in the ferro manganese production should result in some 800 Rs cost reduction per tonne (enclosure 5.1.g), and a confirmed production seems viable even with somewhat reduced load on the furnace.

5.1.5 Medium and low carbon Ferromanganese

Medium Carbon Ferromanganese and Low Carbon Ferromanganese have for many years been produced by reducing manganese ores with a silicon alloy, usually silicomanganese.

During the recent years a few companies have started to make medium carbon ferromanganese by blowing high carbon ferromanganese with oxygen and thus reducing the carbon content to the specification required for this alloy, normally to 1.0-2.0 %.

There are two principally different procedures, topblowing and bottomblowing and there are sereval patents on on both procedures. However, the technique is very different and requires special know-how or technology to obtain feasible results. The two main problems are low manganese recovery and heavy lining wear. A low manganese recovery also gives severe dust problems.

The technology in this field is difficult to obtain as the companies who have developed the process at substantial costs hesitate to sell their know-how to competitors.

Elkem's Engineering Division is not supplier of such technology, and does not know from whom it can be obtained.

Uddeholm has given some consideration to the use of the CLU reactor to make medium or low carbon ferromanganese. (Ref. List 4) Theoretically it should be possible, but the development work to establish the right process parameters could be substantial.

Production of medium or low carbon ferromanganese is therefore not recommended by us for the MEL plant.

5.1.6 Ferrochrome - Chargechrome

It has been suggested to look in to the possibilities for using one of the electric smelting furnaces to make chargechrome. Some of the produced chargechrome could be used for the proposed production of stainless steel, and the balance could be exported. Looking further into this concept it does not look viable. There is no suitable chromium ore for chargechrome to be found in Maharashtra or the neighbouring states (ref.: book on chromium ores published by Indian Bureau of Mines). Therefore the logistics would be against MEL both on raw materials supplies and for export of the product. The consumption of chargechrome for stainless in Chandrapur may increase to between 10.000 and 15.000 tonnes, while the ferromanganese furnace converted to chargechrome would produce approx. 30.000 tonnes per year. It is to be expected that the competitive situation for MEL in Chandrapur shall be to disadvantage for production of chargechrome, if the plant cannot get consessions on the power price from the nearby thermal power station.

To convert the ferromanganese furnace at MEL to chargechrome production would require some investments - in the order of 10 million Rs.

GRADES OF ORE PRODUCED BY MOIL

NAME OF MINE	GRADE OF ORE	QUALITY OF ORE Mn %	P %	SiO_2 %	Fe %
BALAGHAT	I Gr LP Lumpy	50.00	0.08	6.50	4.50
	I Gr LP Jigged	48.50	0.08	7.50	5.30
	I Gr HP Lumpy	49.00	0.30	8.00	4.50
	44-46% Mn Lumpy Ore (Dumps)	46.00	0.19	10.00	6.00
	L. G. H. S.	30.00	0.10	40.00	5.50
	Fines	46.00	0.10	10.00	6.00
UKWA	I Gr Bed LP Lumpy	50.50	0.08	5.20	5.20
	I Gr Bed HP Lumpy	50.50	0.15	5.60	5.00
KANDRI	I Gr Bed Ore	50.00	0.20	13.00	5.57
	L. G. H. S	31.00	0.27	32.00	5.50
TIRODI	I Gr Bed Ore	50.00	0.19	7.60	7.00
	II Gr Bed Ore	47.00	0.20	9.00	8.00
	Low Gr Dump Ore	40.00	0.18	15.00	7.75
	II Gr Dump Ore HP	43.00	0.27	11.00	9.00
	L. G. H. S.	28.50	0.30	32.00	6.75
CHIKLA	II Gr Bed	48.50	0.23	12.00	7.25
	II Gr Dump	45.90	0.107	13.00	8.75
	L. G. H. S.	35.00	0.24	23.50	7.10
DONGRI BUZURG (Manganese Ore)	D. R. O. M.	49.50	0.26	4.50	7.50
	L. G. H. S.	32.00	0.20	21.00	10.00
		MnO_2	SiO_2	Fe	
(Manganese Dioxide)	88-89% Dioxide Ore (low ferruginous)	89%	1.00	1.00	
	85-86% Dioxide Ore	85%	1.60	3.20	
	82-84% Dioxide Ore	82%	2.00	3.50	
	80-82% Dioxide Ore	81%	2.50	4.00	
	72-77% Dioxide Ore	74%	4.20	7.60	

GRADES AVAILABLE FOR EXPORT

MANGANESE		Mn	P	SiO_2	Fe	Al_2O_3
(1) Lumpy Ore		48/46	0.18 to 0.25	10 to 12	9 to 10	3 to 5
(2) Lumpy Ore		44/42	0.20 to 0.25	12 to 14	9 to 10	3 to 5
(3) Lumpy Ore		42/40	0.20 to 0.25	14 to 15	9 to 10	3 to 5
(4) Fines		44/42	0.15	15 to 16	8 to 10	3 to 5
DIOXIDE ORE	MnO_2					
	88/90	60	0.20	1.00	1.00	
	85/86	56	0.30	1.60	3.20	
	82/83	56	0.30	2.00	3.50	
	80/81	55	0.30	2.50	4.00	
	72/77	51	0.30	4.20	7.60	

Ferro Manganese

-ANNEXURE I-

Name of the source	Chemical Analysis Mn%	Fe%	SiO_2%	Al_2O_3%	Phos%	Sizes +75 mm Wt%	-75+10 mm Wt%	-10+6 mm Wt%	-6+3 mm Wt%	-3 mm Wt%	Availability %	Landed Cost Rs. PMT Rs. Ps.	
Manganese Ores :													
MOIL - D4 (Manganese Ore I.Ltd)	47.0	7.5	12.8	3.5	0.22	-	83.0	12.0	3.0	2.0	36	~~662=65~~ 622:65	
MOIL - D2	50.0	5.0	5.0	3.5	0.06	-	88.0	8.0	3.0	1.0	24	594=93	fines can be
Adilabad	45.0	2.50	9.0	3.0	0.08	-	86.0	9.0	3.5	1.5	-Part of D2(LP)	607=51	
Dongribuzurg (HG)	50.4	~~6~~7.20	5.0	3.5.~~0~~	0.26 ~~315~~	-0x28	83.0	12.0	3.0	2.0	2	634=96	fines available
---"--- (MG)	43.4	9.50	8.50	3.5	0.15	-	30.0	50.0	16.0	4.0	3	442=00	
Sandur	40.0	13.0	5.0	5.0	0.05	+100mm 5	-100+10 77.0	-10mm 18.0	-	-	10	432=83	
Bhansa Patel	46.0	8.0	9.0	3.0	0.15	-75+10mm 85	-10+6mm 10.0	-6mm 5.0	-	-	2	474=45	
Goel	42.0	16.0	3.0	3.5	0.06	-75+10mm 63	-10+6mm 7.0	-6mm 25.0	-	-	5	437=92	
Dandeli	43.0	10.0	4.0	3.5	0.06	+25~~x33mm~~ 49	+10mm 23	-10+6mm 18	-6+3mm 7	-3mm 3	3	573=17	
V.N.Bandekar (HG)	43.0	14.5	6.0	5.0	0.07	+75mm 10.0	-75+6Mm 87.0	-6mm 3.0				468=62	
V.N.Bandekar (MG)	~~XSXX~~ 45.0	~~XX~~ 13.0	6.0	5.0	0.07	10.0	87.0	3.0	-	-	5	510=52	
V.N.Bandekar (LG)	47.0	11.5	6.0	5.0	0.07	10.0	87.0	3.0				~~520x~~552=42	
Sinters	43.0	10.0	13.0	3.0	0.15						10	~~520=00~~ 216.00	
											100 %		

ANNEXURE I (Cont'd.)

Encl [illegible] (Cont)

Name of the source	VM%	ASH%	F.C.%	PHOS.%	Ash Analysis SiO_2 %	CaO %	MgO %	Al_2O_3 %	Fe_2O_3 %	R_2O_3 %	Screen Analysis +25mm Wt%	-25+10mm Wt%	-10+6mm Wt%	-6+3mm Wt%	-3mm Wt%	Landed Cost Rs./MT Rs.Ps.
Reductants :																
SAIL(Pearl Coke) (Steel Authority of India Ltd.)	2.50	27.50	70.0	0.17	16.0	2.0	1.0	4.0	1.5	3.0 %	3.0	59.0	18.0	9.0	11.00	838=24
TISCO(Pearl Coke) (Tata Iron & Steel Co)	3.00	26.00	71.0	0.19	16.0	2.0	1.0	4.0	1.0	2.0	4.0	62.0	16.0	8.0	10.00	817=34
LTC Coke, Singarani (Low Temp.Carbonisation).	6.0	32.0	62.0	0.03	18.0	3.0	1.5	5.0	1.5	3.0	40.0	40.0	10.0	7.0	3.0	700=00 (Dec.83)
Beehive Hard Coke	2.50	38.0	59.50	0.15	20.0	4.0	2.0	6.0	2.0	4.0	+200mm 27.0	+125mm 44.0	+100mm 14.0	+50mm 11.0	-50mm 4.0	1000=00 (Dec.83)

Fluxes:	CaO%	MgO%	SiO2%	Al2O3%	Phos%	Fe%	-80+25mm/Wt.%	Landed Cost Rs/MT Rs. Ps.
Limestone	47.0	3.0	5.5	1.0	0.02	1.0	5% tolerance on either side.	97=00(Dec.83)
Dolomite	31.0	19.0	2.5	1.0	0.02	1.0	5% tolerance on either side.	[illegible]

STATEMENT SHOWING TONNAGES AND AVERAGE ANALYSIS OF HIGH GRADE MN ORE SUPPLIED BY M/S. MOIL AGAINST VARIOUS PARCELS.

Parcel No:	Tonnages	Mn%	Phos%	SiO_2%	Fe%
ME/1/84-85	5996.559	48.498	0Q170	8.405	6.605
ME/3/84-85	4153.433	48.732	0.165	8.45	6.83
ME/4/84-85	5091.409	48.545	0.159	10.31	5.84
ME/5/84-85	5329.739	48.808	00175	8.04	7.17

Maharashtra Elektrosmelt Limited

Encl. 5.1.c
Page 1

Consumption figures PMT FeMn

Raw Materials	Gross Consumption PMT FeMn (MT)	Unit Cost Prevailing in 1983-84 (Rs)	Cost/MT FeMn (Rs)
Manganese Ore:			
MOIL D4	0.853	547=48	467
Dongribuzurg (HG)	0.073	542=00	40
—"— (MG)	0.113	439=00	50
Adilabad	0.099	551=00	55
MOIL (D2)	0.412	551=00	227
Hansa Patel	0.012	460=00	6
-6mm D2 fines	0.010	270=00	3
Sandur	0.555	443=24	245
Regular Sinters	0.467	426=00	199
High grade D2 Sinters	0.073	620=00	45
FeMn fines	0.002	500=00	1
Reclaimed Ore	0.006	424=00	3
A) Total Mn Ore	2.675		1342
Coke :			
SAIL (Pearl Coke)	0.522	803=85	418
TISCO (Pearl Coke)	0.171	842=10	144
Hard Coke	0.015	1116=00	17
Coke Briquettes	0.035	300=00	10
B) Total Coke	0.743		589
Fluxes :			
Limestone	0.085	87=00	7
Dolomite	0.611	102=00	63
C) Total Flux	0.696		70
D) Electrode Paste	0.022	8346=00	183
Grand Total - Basic raw materials			2184
E) Electric Power	3092 KWh	0.6041	1868

Note:- Gross consumption includes furnace consumption, fines screened out and handling losses.

MATERIAL BALANCE FeMn

74% Mn burden

Maharashtra Elektrosmelt Limited

Mn = 74
Mno = 27
Phos = 0.383
B = 1.0

Mn/Fe ratio (Ore) = 5.87
Mn/Fe ratio (Burden) = 5.34
Burden No :

Date :

Material	Marking	Kgs	Mn	MnO	Fe	FeO	Si	SiO_2	Al_2O_3	CaO	Mgo	Phos
Ore 1	MOIL	1650	792		107			157	58			2.64
Ore 2	SC(LG)	350	137		49			17	17			0.17
Ore 3												
Ore 4	Sinters	200	86		17			32	7			0.28
Ore 5												
Ore 6												
Ore 7												
Ore 8												
Reducing agent	Coke	600			12			96	24	12	6	0.96
Flux	Dolomite	540			5			13	5	173	97	0.1
Sum			1015		190			315	111	185	103	4.165
Fume Losses			81		6			21	5	5		.333
Rest			934		186			294	106	180	103	3,83
In FeMn			740		182			(11				
In Slag		927	1(98	250	(4)	5		283	106	180	103	677
Slag %				27		0.5		30.5	11.5	19.5	11	100%
FeMn%			74.0		18.2							0.38

$$BASICITY = \frac{CaO + MgO}{} = 1.0$$

ANALYSIS OF RAW MATERIALS

MANGANESE ORES

MAT / %	MOIL	S (LG)	Sinters		Average
Mn	48	39	43		46.14
Fe	6.5	14	8.5		7.86
SiO_2	9.5	5	16		9.36
Al_2O_3	3.5	5	3.5		3.73
Phos	0.16	.05	.14		0.141

MAT / %	FLUX		PEARL COKE		
CaO	32		2		
MgO	18		1		
SiO_2	2.5		16		
Al_2O_3	1		4		
Fe	1		2		
Phos	.02		.16		

REMARKS

Maharashtra Elektrosmelt Limited

COPY

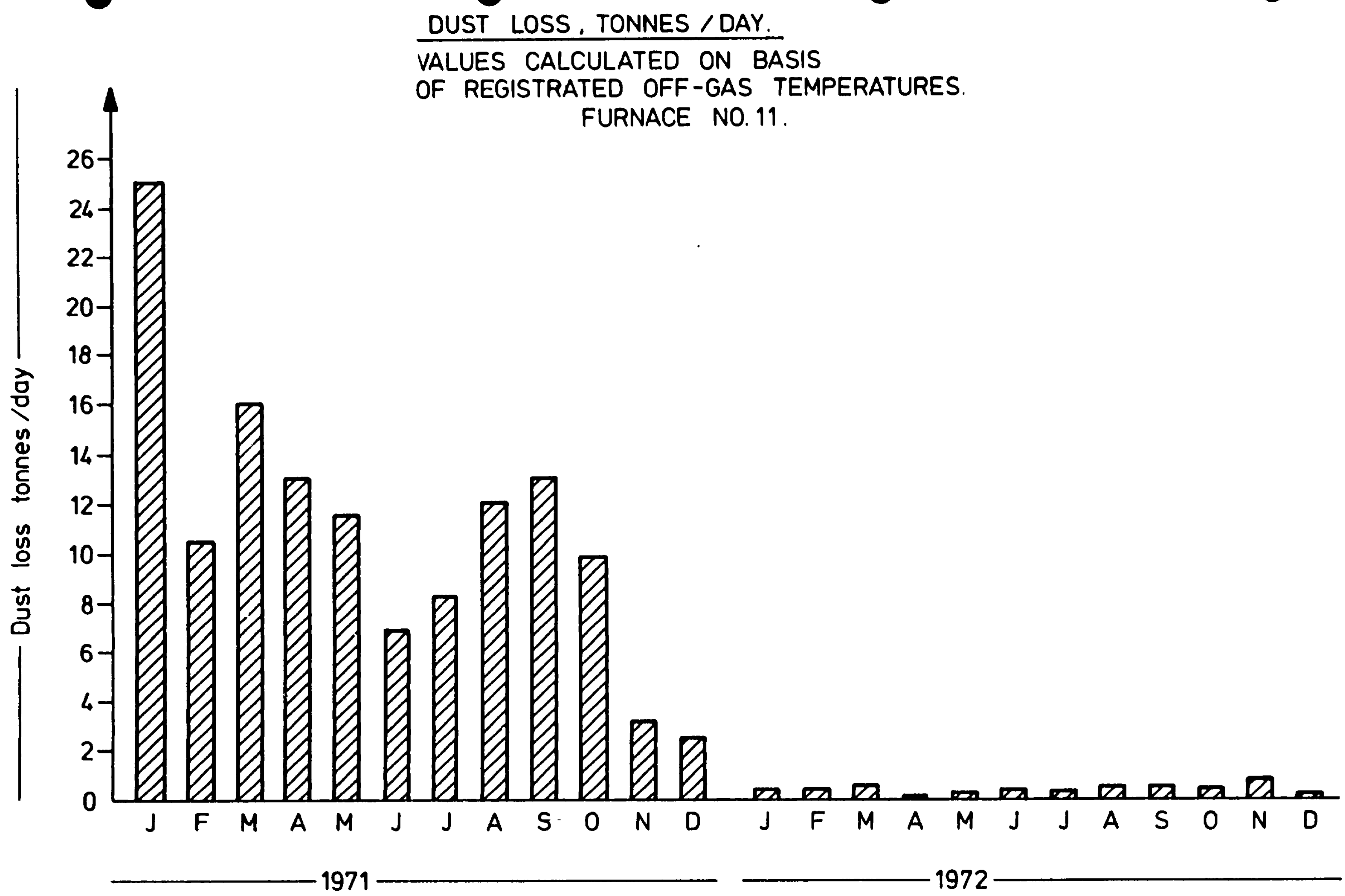
Encl. 5.1.d

Cost of production (1983-84) :

Description	Rs./MT	
1) Basic raw materials	2184	
2) Power	1868	
3) Consumables/Refractories	20	
4) Contract Labour	30	
5) Stores & Spares	149	
6) Head Office/Factory Wages/Expenses	677	
		4928

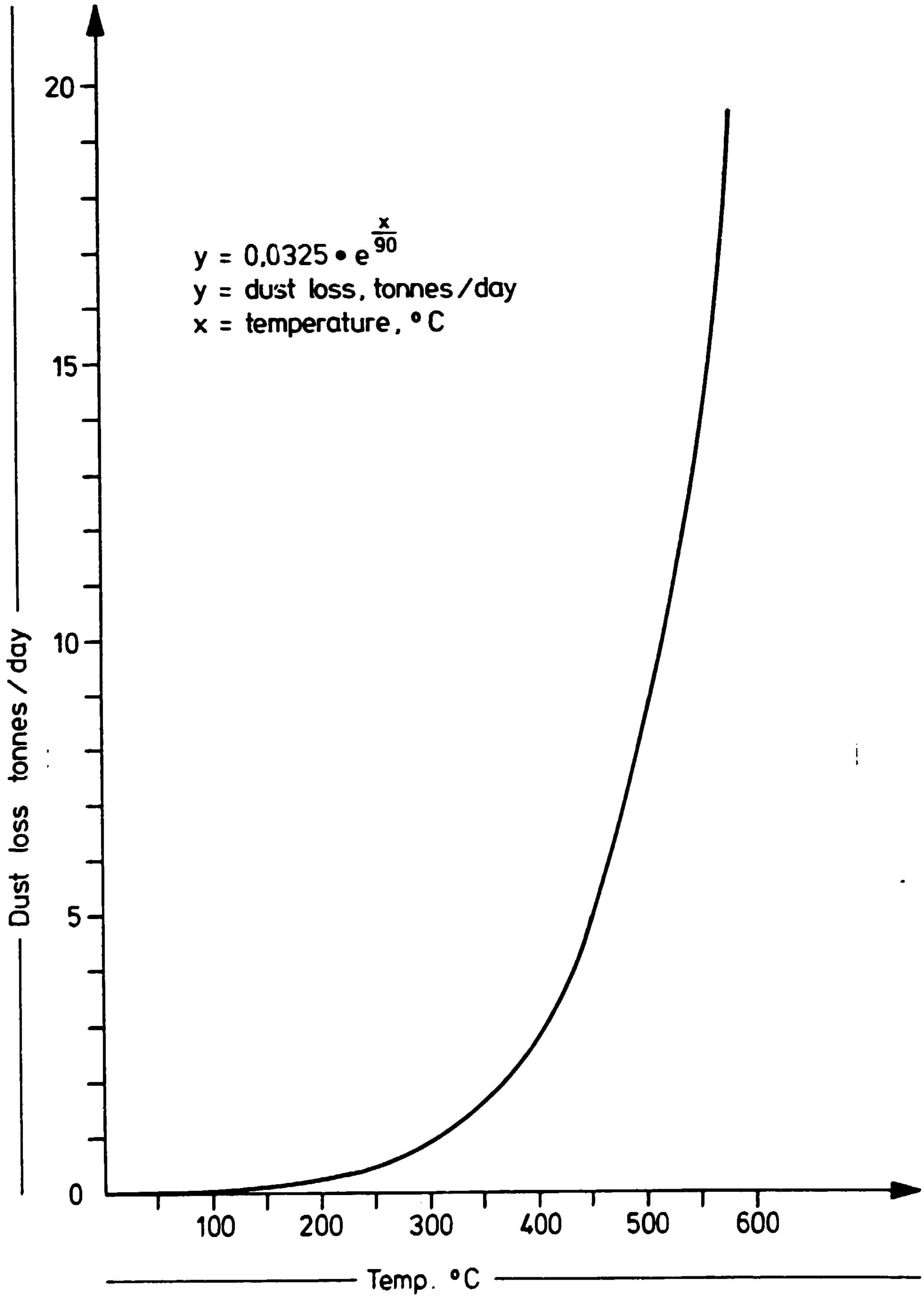
— Price for High Carbon Fe Mn at works -- Rs. 5900/- PMT

1) Normal furnace load : 18000 - 20000 KW
2) Maximum furnace load : 23000 KW
3) Minimum furnace load : 6000 KW
4) Present furnace load : 10000 - 12000 KW



Enclosure 5.1.e

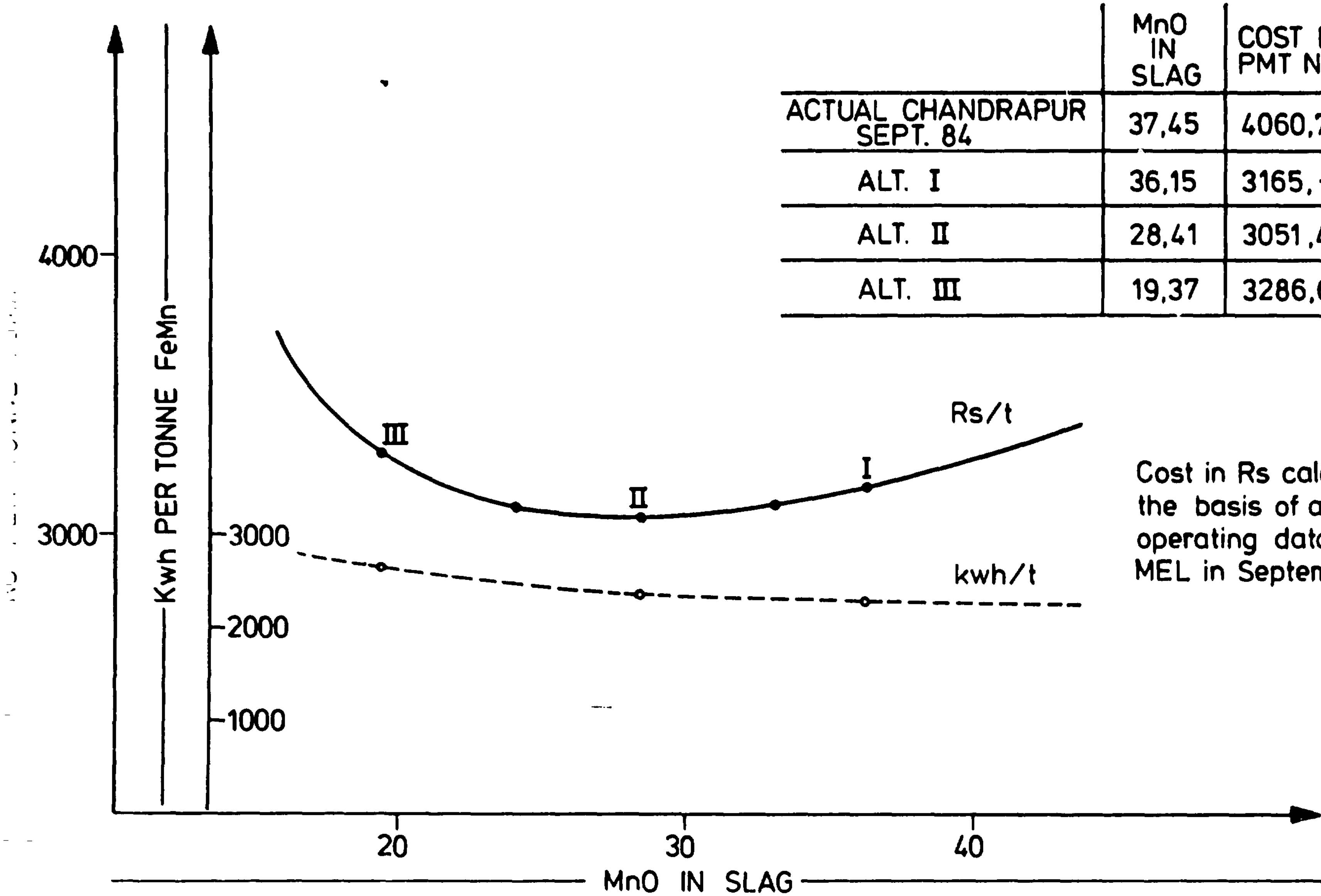
DUST LOSS — OFF-GAS TEMPERATURE.
FURNACE NO. 11.



COST IN RUPIES PER TONNE FeMn.

"LANDED COST Rs/MT"

	MnO IN SLAG	COST Rs. PMT NET.	RED. %
ACTUAL CHANDRAPUR SEPT. 84	37,45	4060,72	0,00
ALT. I	36,15	3165,-	22,05
ALT. II	28,41	3051,40	24,85
ALT. III	19,37	3286,60	19,06



Cost in Rs calculated on the basis of actual operating data at MEL in September 1984.

Enclosure 5.1.9.

5.2 SMELTING OF KHURSIPUR TITANIFEROUS ORE AND RECOVERY OF VANADIUM

5.2.1 Introduction

In "Substantive Terms of Reference" (see Ex.summary) it is requested that a study of the smelting of Khursipur titaniferous iron ore is included. No mining has yet started, but the deposit is explored by diamond drilling to some extent, and evaluated by the Exploration Division of Century Cement in a report prepared for Maharashtra State Mining Corporation Ltd. dated January 1984. (enclosure 5.2.a shows excerpts)

The issue was discussed with dr. B.R. Nijahawan * in Vienna in August 84, and in Ranchi in December 84. We have obtained more information on the ore deposits, analyses and physical characteristics from Maharashtra State Mining Corp. (MSMC) and from meetings with professor dr. M.S. Jakkiwar** in Nagpur.

5.2.2 About the ore deposit

The ore deposit is apparantely divided into many different sections having been explored by diamond drilling.

The upper portion estimated at about 50% of the deposit is weathered ore. About 35% underneath the weathered ore is a massive ore, and below that again there is a lower 15% of banded ore.

By analysis of ores from diamond drillings at 45° through the ore body from both sides, it is found that there are very great variations in TiO_2 content and V_2O_5 contents.

I	19%	of	the	ore	body	estimated	at	1,8% V_2O_5
II	51"	"	"	"	"	"		0,5-0,8 "
III	16"	"	"	"	"	"		0,3-0,5 "
IV	4"	"	"	"	"	"		< 0,3 "

* Dr. B.R. Nijhawan, Senior Inter-regional Advisor to United Nations Industrial Development Organization.

** Dr. M.S. Jakkiwar, Professor in Metallurgy, Visvesvaranja Regional College of Engineering, Nagpur.

The enclosed excerpts from Century Cements report (encl. 5.2.a) gives an account of the variations in V_2O_5 contents analysed in the drilled core samples. The deposit has consequently been defined into 11 different ore sections and the indicated cut-off grades and mineable depths have been estimated in each, on the basis of V_2O_5 analysis,- taking 0,5% V_2O_5 as the minimum cutoff grade. The total mineable reserves then comes to about 4,5 million tonnes from this estimation.

It is not known to us to which extent the deposit has been proven by diamond drilling, but according to the State Mining Corporation too little diamond drilling has been done. It would be expected that further exploration of this deposit has to be done before a proper evaluation can be made.

5.2.3 Ore benefication and analyses:

The analyses of the core samples indicate very great variations both in TiO_2 and V_2O_5. TiO_2 is reported to vary between 11 and 19% and V_2O_5 from < 0,3 to 1,8%. In addition 2-3% S (pyrite) is found in zones.

Professor Jakkiwar has done some preliminary tests with magnetic separation of the ore and found that it may be possible to upgrade the ore to some extent. The ore samples were crushed and ground to 150 mesh. Tylor and treated on a laboratory scale, high intensity magnetic separator. He got 3 fractions: One high magnetic fraction with 11% TiO_2, 56% Fe and about 1% V_2O_5. One low magnetic fraction where some of the free-crushed ilmenite was collected - low in V_2O_5. One non-magnetic fraction where hopefully most of the pyrite and gauge would be found, although this was not analysed.

Enclosure 5.2.b gives a summary of prof. Jakkiwar's laboratory results.

We would agree that more exploration should be done to prove reserves and ore values (analyses) and to make estimates of mining costs - both investments and operating costs. The findings so far indicate selective mining, which of course influences the mining costs.

It is further suggested that the metallurgical department of Viswesvaraya College is given the resources to do an independent study of the ore benefication problem, to establish optimal grinding and milling for minerals separation and to estimate costs and analysis of the V_2O_5 rich concentrate.

Mining costs has roughly been guestimated at abt. 100 Rs per tonne, grinding milling and magnetic separation was estimated at 60 Rs per tonne of ore and transportation cost to Chandrapur from Khursipur would be approx. 100 Rs per tonne of concentrate.

Concentrate cost at plant, roughly according to above:

	Rs.pr. tonne ore	Rs.pr. tonne concentrate
Mining	100	167
Magnetic separation		120
Transport		100
Handling, ...		15
Landed cost per tonne concentrate:		402

These are of course very rough and uncertain figures!

5.2.4. Process considerations

There are two processes industrially developed for this type of concentrates:

- Smelting of prereduced, hotcharged pellets in electric furnace, followed by oxygen lancing of the pig iron to collect the vanadium into a V_2O_5 containing slag and further treatment of this slag to vanadium products (FeV or V_2O_5) or sale.
- The Otanmäki leaching process

In the Otanmäki process, as developed in Finland by Rautaruukki Oy, the concentrate is agglomerated with alkali or ammomium salts followed by roasting, leaching and precipitation of ammonium vanadate, which is subseqently fused into a saleable V_2O_5 product. The Otanmäki process may be an alternative for Khursipur and other vanadium containing ores in India, but it is considered no alternative for vanadium rich slag produced by the smelting of ore in an electric furnace. For MEL the Otanmäki process therefore is no alternative.

5.2.5 Notes on the smelting process

In its research laboratories in Kristiansand, Norway, Elkem a/s has studied the smelting of titaniferrous ores in many pilot trials on various ores from all over the world. For most of the projects the aim has been to produce a slag rich in titanium oxide for the production of pigment, but sevaral projects in later years have also been concerned with ores containing vanadium, normally too low in TiO_2 to produce a valuable TiO_2 - rich slag. For many years Christiania Spigerverk in Norway, now merged with Elkem, have smelted a TiO_2 - and V_2O_5 containing iron ore from its own iron mine in its Bremanger Smelteverk on the west coast of Norway. The ore was upgraded to a concentrate containing only 2-3% TiO_2 and approx. 0,5 % V_2O_5. The purpose was initially to produce a special foundry pig iron.

Because of its low content of TiO_2 this concentrate could be smelted directly, without prereduction, in an electric furnace, but first it was agglomerated by sintering. Oxygen lancing was introduced in the early 60ies to collect the vanadium in a V_2O_5 - rich (12 - 15%) slag, and a Silicothermic process was developed to produce ferrovanadium from the slag. The process is available for licencing from Elkem a/s.

The process was licenced to Highveld Steel and Vanadium Corporation in Witbank S.A. This company developed a smelting technique for more TiO_2 - rich vanadium containing ore, also in the 1960-ies. This process applies prereduction of of the ore in a 60 m long 4 m dia. rotary kiln followed by submerged arch smelting in an electric furnace. The process has been developed to a high degree of automation and comprises today 6 complete units with 4 extra rotating kilns, to increase the availability of the plant.

In other words: the Highveld plant comprises today 6 large smelting furnaces and 10 rotary kilns. The electric smelting furnaces are supplied by Elkem a/s and have a rated capacity of 30 to 45 MVA each. The plant is now being extended further.

The capacity of the Highveld plant is close to 1 mill. tonnes of steel and approximately 6000 tonnes of V_2O_5 per year. The company dominates the World market and controls the market prices.

In New Zealand a process is developed for titanium and vanadium containing iron sand which is upgraded and smelted without agglomeration (because the sand is rather coarse). The process involves preheating of the sand and simultaneous charring of coal in a multiple hearth furnace. Further the hot charge is fed to a 75 m long rotary kiln where the iron oxide is prereduced to at least 80% metallization, followed by melting and carbonization of the charge in electric furnace. A pig iron containing the vanadium is produced. The vanadium is collected in a V_2O_5 rich slag by oxygen blowing in LD converters with bottom gas stirring, and the iron is converted into steel. In India the National Metallurgical Laboratories in Jamshedpur have done pilot tests with direct smelting in electric furnace with Bihar & Orissa Ores.

Industrial tests have been done at Viswesvaraya Iron & Steel Ltd. in Bhadravati, in a 10 Mw electric pig iron furnace. Difficulties with slag boils and high viscosity slags were reported. These difficulties are well known also from the pilot tests in Elkem with direct smelting of titanium containg ores. A certain reduction pressure is necessary to get the vanadium oxide reduced to the iron phase, but on the other hand too much carbon reduction pressure will reduce TiO_2 to lower oxides and produce slag boils and sticky slags. The balance is very delicate, and has been possible to maintain by accurate control of the smelting conditions in pilot plant operation only.

No direct smelting of titaniferous ores of these types has been done successfully on industrial scale as yet.

It should be mentioned here that Elkem was engaged by The Industrial Development Corporation of Orissa to do pilot smelting of the Orissa deposits of titaniferous, vanadium containing Ore in 1971. The smelting tests were done both directly on ore pellets and on prereduced ore pellets alternatively. The ore pellets were sintered.

5.2.6 Smelting of Khursipur ore at MEL in Chandrapur:

If Khursipur ore should be processed in the MEL iron & steel plant in Chandrapur, we must recommend the following process steps, based on the available experiences with similar ores.

- Upgrading of the ore to produce a concentrate with essentially all V_2O_5 where some of the ilmenite and most of the pyrite minerals are removed. Apparantly this is best done by magnetic separation.

- A program for finding the optimal ore benefication conditions and design parameters should be initiated, and the expected concentrate cost evaluated.

- The concentrate must be agglomerated by pelletizing and sintering of the pellets, followed by

- a prereduction in a rotating kiln, using the electric furnace gas and additional coal, and

- the electric furnace finally, to carbonise the iron to a pig iron and reduce the vanadium content to this pig iron. The slag, containing some 30% TiO_2 will be without value.

- The LD - plant has to be used to produce a vanadium rich slag (12 - 15%) for eventual further treatment to FeV or for sale.

- After the removal of the vanadium rich slag, the pig iron is further processed to steel in the conventional way.

5.2.7 Investments and operating costs:

A very rough estimation of the necessary installations for the plant in Chandrapur to treat the Kursipur ore concentrate gives a figure of:

approx. NOK 180 million
or Rs 250 million

This estimate includes equipment costs, design and engineering, purchasing, foundations and erection of the equipment. The complete rotating kiln alone will cost approx. 65 million Rs.

Operating costs (Enclosure 5.2.c), calculated on the same basis as for pig iron cost from normal iron ores in chapter 5.3., (Enclosure 5.3.e), will amount to Rs 2600 per tonne.

This is very near to the cost of the MEL pig iron from Lohara ore (see chapter 5.3).

5.2.8 A rough estimation of vanadium values

Of the approx. 18 kg vanadium per tonne of pig iron originally contained in the ore concentrate, approximately 45% or 8 kg pr. tonne pig iron will be recovered in the oxygen blown slag with 12-15% V_2O_5.

At full furnace load - 20 Mw power input - 96000 tonnes of pig iron will be produced.

The corresponding amount of V_2O_5 containing converter slag at say 15% V_2O_5 will be 4.800 per year. We assume that vanadium slag would be the logical sales product from MEL.

The current price for V_2O_5 slag in India has been given as 15 Rs per kg for 20 - 22 % V_2O_5 slag. (ref. professor Jakkiwar at the University of Nagpur). Corresponding to this a 15% slag will have a value of approx. 10.000 Rs per tonne. 4.800 tonnes V_2O_5 slag will then give aproximately 48 mill. Rs per. year.

In other words: Approx: 50 million Rs per year will be available to carry capital costs and profits, compared to the present operation. With a roughly estimated 5 years pay-back period the project actually looks viable.

5.2.9 Analysis of project viability

Looking at the development of prices for vanadium, enc. 5.2.d, it seems that in constant (1984) US$ value, the average price has been varying around a pretty constant figure of approximately US$ 13 per kg corresponding to Rs 156 per kg V. Accordingly V_2O_5 would be priced at 86 Rs and a 15% slag at approx. 13 Rs per kg. Subtracting operating and investment costs in the various steps to arrive at ferro-vanadium, approx. US$ 2.15 per kg V, the price for V in slag would be 10.85 US$ per kg. Prices have been declining lately.

This figure checks well with the figure deducted from dr. Jakkivar's 15000 Rs per tonne slag with 20-22% V_2O_5, corresponding to 11-12% V, giving appr. 130 Rs or 10.90 US$ per kg V.

The various project steps from ore concentrates to the vanadium enriched slag are well investigated in many pilot operations on similar concentrates, and a succesful industrial operation on a very large scale is established by Highveld Steel and Vanadium Corporation.

There are, however, richer sources of vanadium containing titanomagnetites in India (encl. 5.2.e).

For instance, the deposits in Bihar and Orissa are reported to contain 1% V and the Masanikere deposit in Karnataka reports 0,63% V compared to only 0,4-0,5% V in Khursipur. The question then arises whether Khursipur is the deposit that first should be attacked and whether Chandrapur is the right place for the first project of this kind in India. It will take time, at least 3-5 years, before a production of ore concentrates from the Khursipur deposits may be developed. Until the ore body is better explored and benefication of the ore has been studied in more detail, it is of little value to go further into a feasibility study of smelting the Khursipur ore in Chandrapur at this time.

A NOTE ON VARIATION OF GRADES IN SUBSURFACE AND ITS BEARING ON MINABILITY OF VANADIFEROUS TITANOMAGNETITE DEPOSITS OF KHURSIPAR

FOR

MAHARASHTRA STATE MINING COPRORATION LIMITED

EXPLORATION DIVISION
CENTURY CEMENT
BAIKUNTH-493 116.

JANUARY, 1984.

A NOTE ON VARIATION OF GRADES IN SUBSURFACE AND ITS BEARING ON MINABILITY OF VANADIFEROUS TITANOMAGNETITE DEPOSITS OF KHURSIPAR

The main constituent of the vanadiferous titanomagnetite ore is V_2O_5 and on the basis of which different grades have been determined. An overview of nature and variation of grades of ores has already been given in chapter 15 of the main report. Based on the basic exploration data, a further review on variation in grade is being furnished from mining standard point. For this, the following factors have been emphasised:-

1. Average grade for every 5 Mtr. depth of each ore body hasbeen computed.

2. In view of 0.5% V_2O_5 as acceptable ore - cut off grades and minable depths for each ore body have been discussed.

VARIATION OF GRADES IN SBSURFACE

This factor has been considered separately for each of the ore bodies. To compute average grades for every 5 metres depth, analytical data of bore hole cores were used and following procedure was adopated.

Top level of ore body was considered as the starting point from where 5 Mtrs. each downward depth levels were fixed. Corresponding to these levels, lengths of boreholes which have intersected the ore body were also determined. Since these boreholes were drilled at 45° inclination as per trigonometric calculations. 7.07 Mtrs. of inclined length equals to 5 Mtrs. of vertical length. This was arrived at by dividing inclined length with a trigonometrical function of 1.414. Analytical data falling in each such corresponding lengths of boreholes were weighted and averaged. All such average analysis of different bore holes in an ore body falling in a particular 5 Mtr. level were further added and their mean was calculated. Thus, subsurface variation in grade for each 5 Mtr. depth for different ore bodies has been computed(Table-I).

While deducing any conclusion from this data, inherent properties of the ore bodies regarding their three dimensional chemistry are also to be taken into account. Accordingly, there are not much variations in weathered zones either laterally or vertically. In hard ore zones, grade varies from footwall to hanging wall i.e. from east to west. Since the boreholes are inclined cutting across the orebodies from either side, they show intersection from rich to lean ores and vice versa. In this situation to get more representative data, number of intersection by bore holes from either side of the ore bodies should ∠ sufficiently more. In the present ∠ be case where boreholes could not be monitored in the above fashion in some of the ore bodies, the data regarding grade variation have their own limitations.

CUT OFF GRADES AND MINABLE DEPTHS

In the previous report while discussing grades of ores, the following classification was made (P.83).

Grade-I Ore .. V_2O_5, 0.8% and above

Grade-II Ore .. V_2O_5, 0.5% to less than 0.8%.

Grade-III Ore .. V_2O_5, 0.3% to less than 0.5%.

Grade-IV Ore .. V_2O_5, less than 0.3%

It was estimated that in the explored portion of the ore bodies most prevalent is grade II ore, amounting to 51%, followed by grade-I ore 19%, grade III ore 16% and grade IV ore 14%. Taking 0.5% V_2O_5 as minimum economic grade of the ore, entire I and II grade ores become marketable ore. Overall average of these two grades will be more than 0.5% V_2O_5. Thus, some lower grade ore can be blended to bring it down to level of 0.5% V_2O_5. In that case the lowest grade which can be mined economically i.e. cut off grade will be less than 0.5% V_2O_5.

When different ore bodies are considered seperately it is pointed out that in some of them the grades of ore comes out to be more than 0.5% V_2O_5 in all the levels of 5 Mtr. depths (Orebody Nos. I, II, IV, V, VII, IX). Ores from these deposits can be blended with lean ores from other ore bodies. Question of cut off grade for these ore bodies does not arise. For other ore bodies, cut off grades have been computed on the basis of mean averages of grades for every 5 Mtr. depths. Accordingly, cut off grades and minable depths of ore bodies have been coputed(Table.2)

Table-2

Average grades, Cut Off Grades and Minable Depths of ore bodies.

Ore body No.	Average grade V_2O_5 %	Cut off Grade V_2O_5 %	Minable Depth (M)
I	0.813	-	30
II	0.609	-	30
III	0.709	0.155	35
IV	0.937	-	35
V	0.722	-	25
VI	0.634	0.034	90
VII	0.717	-	10
VIII	0.586	0.293	40
IX	0.690	-	20
X	0.487	0.391	75
XI	0.586	0.091	80

Cut off grades shown in the above table are applicable to the concerned ore bodies.

TABLE I

VARIATION OF V_2O_5 % FOR EVERY 5 METRES DEPTH

Relative Levels.	Average V_2O_5 % in various bore holes								Mean average V_2O_5 %
ORE BODY NO.1 (TOP LEVEL 360.21M)									
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
R.L.	BH5	BH25							
360.21	-	-	-	-	-	-	-	-	-
355.21	0.671	0.925	-	-	-	-	-	-	0.798
350.21	0.850	0.828	-	-	-	-	-	-	0.839
345.21	0.784	1.155	-	-	-	-	-	-	0.969
340.21	0.836	-	-	-	-	-	-	-	0.836
335.21	0.707	-	-	-	-	-	-	-	0.707
330.21	0.738	-	-	-	-	-	-	-	0.738
ORE BODY NO.2 (TOP LEVEL 368M)									
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
R.L.	BH.26	BH.28	BH.4						
368	-	-	-	-	-	-	-	-	-
363	-	-	-	-	-	-	-	-	-
358	0.413	0.713	-	-	-	-	-	-	0.572
353	0.568	0.692	-	-	-	-	-	-	0.630
348	0.565	0.640	-	-	-	-	-	-	0.602
343	0.602	0.668	-	-	-	-	-	-	0.635
338	-	-	-	-	-	-	-	-	-
333	-	-	-	-	-	-	-	-	-
328	-	-	-	-	-	-	-	-	-
323	-	-	-	-	-	-	-	-	-
318	-	-	-	-	-	-	-	-	-
313	-	-	- Low	-	-	-	-	-	-
308	-	-	- grade.	-	-	-	-	-	- Low
303	-	-	-	-	-	-	-	-	- grade.
298	-	-	-	-	-	-	-	-	-

Contd...

Page N...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10
ORE BODY NO.3(TOP LEVEL 364M).									
R.L.	BH.8								
364	-	-	-	-	-	-	-	-	-
359	0.806	-	-	-	-	-	-	-	0.806
354	-	-	-	-	-	-	-	-	-
349	-	-	-	-	-	-	-	-	-
344	-	-	-	-	-	-	-	-	-
339	0.155	-	-	-	-	-	-	-	0.155
335	0.938	-	-	-	-	-	-	-	0.938
330	0.938	-	-	-	-	-	-	-	0.938
ORE BODY NO.4 (TOP LEVEL 366M).									
R.L.	BH.9								
366	-	-	-	-	-	-	-	-	-
361	0.719	-	-	-	-	-	-	-	0.719
356	1.032	-	-	-	-	-	-	-	1.032
351	0.972	-	-	-	-	-	-	-	0.972
346	-	-	-	-	-	-	-	-	-
341	-	-	-	-	-	-	-	-	-
336	0.981	-	-	-	-	-	-	-	0.981
331	0.951	-	-	-	-	-	-	-	0.951
ORE BODY NO. 5 (TOP LEVEL 393.20M).									
R.L.	BH.21	BH.13	BH.20	BH.10					
393.20	-	-	- -	-	-	-	-	-	-
388.20	0.503	0.810	-	-	-	-	-	-	0.656
383.20	0.541	0.523	-	0.964	-	-	-	-	0.676
378-20	0.648	-	0.605	0.947	-	-	-	-	0.733
373.20	0.854	-	0.557	-	-	-	-	-	0.705
368.20	-	-	0.840	-	-	-	-	-	0.840

Contd....

Page No.3.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10
ORE BODY NO.6 (TOP LEVEL 382.32M).									
R.L.	BH.14	BH.16	BH.7	BH.32					
382.32	-	-	-	-	-	-	-	-	-
377.32	0.406	-	-	-	-	-	-	-	0.406
372.32	0.605	-	0.828	-	-	-	-	-	0.716
367.32	0.672	-	0.714	0.454	-	-	-	-	0.613
362.32	0.794	-	0.785	0.552	-	-	-	-	0.710
357.32	0.943	-	0.773	0.746	-	-	-	-	0.820
352.32	1.008	0.034	0.736	0.829	-	-	-	-	0.651
347.32	0.830	0.047	0.693	0.967	-	-	-	-	0.634
342.32	-	0.157	0.791	-	-	-	-	-	0.474
337.32	-	0.645	0.765	-	-	-	-	-	0.705
332.32	-	0.871	0.812	-	-	-	-	-	0.841
327.32	-	1.520	0.733	-	-	-	-	-	1.126
322.32	-	-	0.705	-	-	-	-	-	0.705
317.32	-	-	0.617	-	-	-	-	-	0.617
312.32	-	-	0.570	-	-	-	-	-	0.570
307.32	-	-	0.510	-	-	-	-	-	0.510
302.32	-	-	0.485	-	-	-	-	-	0.485
297.32	-	-	0.411	-	-	-	-	-	0.411
292.32	-	-	0.419	-	-	-	-	-	0.419
ORE BODY NO.7 (TOP LEVEL 361.50M).									
R.L.	BH.31								
361.50	-	-	-	-	-	-	-	-	-
357.32	0.716	-	-	-	-	-	-	-	0.716
352.32	0.781	-	-	-	-	-	-	-	0.718

Contd...

1.	2.	3.	4.	5.	6.	7.	8.	9.	10	1.
ORE BODY NO.8(TOP LEVEL 368M).										
R.L.	BH.30	BH.6	BH.24	BH.3						
368	-	-	-	-	-	-	-		-	
363	-	0.350	-	0.648	-	-	-	-	0.499	
358	0.753	0.581	0.638	0.496	-	-	-	-	0.617	
353	0.808	0.871	-	0.596	-	-	-	-	0.758	
348	0.898	1.006	-	0.558	-	-	-	-	0.820	
343	-	-	-	0.293	-	-	-	-	0.293	
338	-	-	-	0.548	-	-	-	-	0.548	
333	-	-	-	0.498	-	-	-	-	0.498	
328	-	0.824	-	0.490	-	-	-	-	0.657	
ORE BODY NO.9(TOP LEVEL 373.70M).										
R.L.	BH.22	BH.29	-	-	-					
373.70	-	-	-	-	-	-	-	-	-	
388.70	0.769	-	-	-	-	-	-	-	0.769	
363.70	0.854	0.609	-	-	-	-	-	-	0.731	
358.70	-	0.566	-	-	-	-	-	-	0.566	
353.70	-	0.695	-	-	-	-	-	-	0.695	
ORE BODY NO.10(TOP LEVEL 376M).										
R.L.	BH.27	BH.2								
376	-	-	-	-	-	-	-	-	-	
371	0.391	-	-	-	-	-	-	-	0.391	
366	0.531	-	-	-	-	-	-	-	0.531	
361	-	-	-	-	-	-	-	-	-	
356	-	-	-	-	-	-	-	-	-	
351	-	-	-	-	-	-	-	-	-	
346	-	-	-	-	-	-	-	-	-	
341	-	-	-	-	-	-	-	-	-	
336	-	-	-	-	-	-	-	-	-	
331	-	1.040	-	-	-	-	-	-	1.040	
326	-	-	-	-	-	-	-	-	-	
321	-	-	-	-	-	-	-	-	-	
316	-	0.599	-	-	-	-	-	-	0.599	
311	-	0.543	-	-	-	-	-	-	0.543	
306	-	0.498	-	-	-	-	-	-	0.498	
301	-	0.466	-	-	-	-	-	-	0.466	
296	-	0.165	-	-	-	-	-	-	0.165	
291	-	0.151	-	-	-	-	-	-	0.151	

Contd...

Page No.5.

ORE BODY NO.11 (TOP LEVEL 406M)

1	2	3	4	5	6	7	8	9	10
R.L.	BH.12	BH.17	BH.11	BH.19	BH.15	BH.23	BH.18	BH.33	
406	-	-	-	-	-	-	-	-	-
401	-	-	-	-	-	-	-	-	-
396	0.317	0.893	0.758	-	-	-	-	-	0.656
391	0.460	0.836	0.759	-	-	-	-	-	0.685
386	0.753	0.465	0.680	0.246	-	0.660	-	-	0.560
381	0.716	0.689	-	0.326	-	0.595	-	-	0.581
376	0.788	0.546	-	0.323	-	-	-	-	0.552
371	-	-	0.088	-	-	0.468	-	0.719	0.425
366	-	-	0.091	-	0.546	0.602	0.365	0.625	0.445
361	-	-	0.148	-	0.445	0.506	0.447	0.700	0.449
356	-	-	0.158	-	0.484	-	0.670	0.917	0.555
351	-	-	0.128	-	0.456	-	0.644	-	0.408
346	-	-	0.292	-	0.663	-	0.657	-	0.537
341	-	-	0.159	-	0.883	-	0.740	-	0.594
336	-	-	-	-	0.994	-	0.727	-	0.835
331	-	-	-	-	0.984	-	0.646	-	0.815
326	-	-	-	-	0.695	-	-	-	0.695

DVRR

21811 Encl.5.2.b
February 1985

EXCERPTS FROM THE FINDINGS OF THE UTILISATION OF VANADIFERROUS TITANI MAGNETITE FROM KHURSIPAR DISTRICT BHANDARA, MAHARASHTRA STATE, INDIA

(Based on the tests caried out at the Departmetn of Metallurgy, Visvesvaraya Regional College of Engineering, Nagpur, Maharashtra State, Nagpur)

1. **ANALYSIS OF HEAD SAMPLES**

CHEMICAL			MINEROLOGICAL		
Fe	-	54.44	Magnetite	-	50-52
TiO_2	-	12-20	Ilmenite	-	35-38
Al_2O_3	-	5-12	Martite	-	5-8
S	-	0.096	Amphibole	-	8-10
			Quartz		
			Chlorite		
P	-	0.028			
V_2O_5	-	0.6-1.0	V_2O_5	-	0.6-1.0

2. **SPECIFIC GRAVITY** - 4.42

3. **WORK INDEX** - 16.31 Kwh/t.

4. **LIBERATION OF ILMENITE:-**

1 at 60 mesh - 50%
2 at 150 mesh - 60%
3 at 270 mesh - 75 %

5. **DRY MAGNETIC SEPARATION:-** (At - 150 Mesh martitized sample).

		Magnetic	Weakly Mg.	Non Mag.
Wt%		58.91	40.93	0.56
Distribution%				
	Iron	68.23	31.53	0.16
	TiO_2	34.06	65.75	0.18
	V_2O_5	92.26	7.65	0.09
Grade%				
	Fe	56.38	41.15	
	TiO	11.21	32.15	
	V_2O_5	1.05	0.01	

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21811
February 1985

Encl.5.2.c

Cost of pig iron from prereduced Khurisipur concentrate - comparable figures.

1.	Concentrate	1670	400	668
2.	Agglomaration and sintering	1670	170	284
3.	Coke	50	719	36
4.	Coal	779	480	374
5.	Limestone & Dolomite	460	110	50
6.	Power, furnace Power, auxilliary	1500	60	900
7.	Electrodes	10	7100	70
8.	Labour			55
9.	Refractories			50
10.	Consumables			20
11.	Stores and spares			60
12.	Interest on working cap.			50
13.	Transport			15
Cost of pig iron				2632

Compared to 2700 Rs/tonne for pig iron produced by direct smelting of Lohara ore this calculation shows about same operating costs.

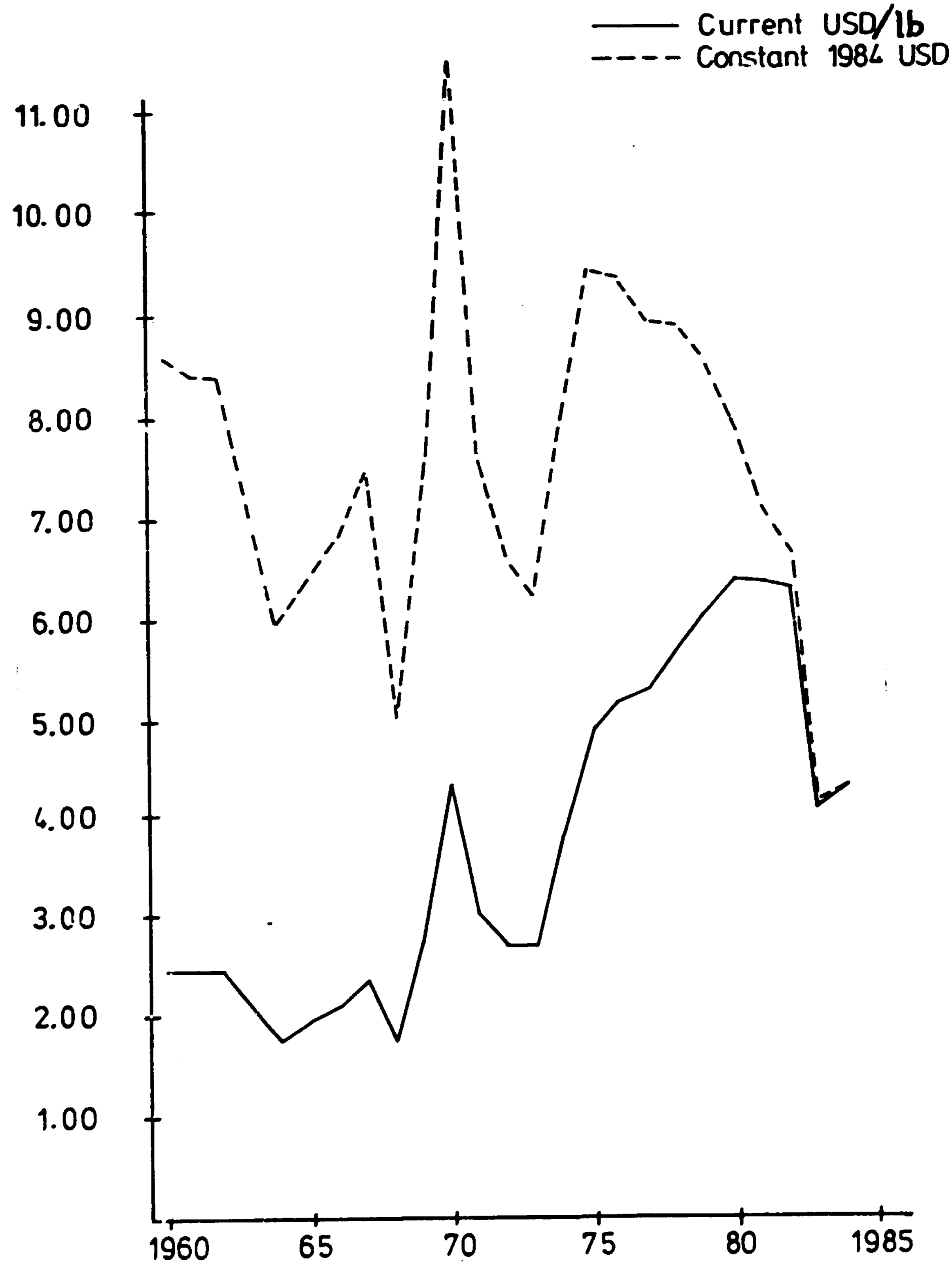
1811C52EC1

Elkem a/s
Engineering Division
Oslo, Norway

Enclosure 5.2d

2.1811
Februar 1985

Table Annual U.S. Price of vanadium contained in vanadium pentoxide



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February 1985

Encl.5.2.e

TABLE

Oxide	Singbhum & Mayurbhang Deposits, Bihar & Orissa	Khursipar Depoosit Maharastra	Masanikere Deposit, Karnataka
Total Fe	57.12	55.68	53.8
TiO_2	12.52	13.6	8.76
V	1.0	0.40	0.63
SiO_2	1.2	2.71	5.40
Al_2O_3	2.21	3.54	1.64
CaO	trace	trace	trace
S	trace	0.008	0.01
P	trace	0.01	0.011

1811C52EE1

5.3 ELECTRIC PIG IRON SMELTING

5.3.1 Introduction

The main idea for the Maharashtra Elektrosmelt Company to be established, was to make use of local iron ores and thermoelectric power based on the waste resources of coal in the area to produce mild steel.

As mentioned in chapter 3 an electric pig iron furnace of 33 MVA or approximately 20 MW capacity was built and ready for start in 1977 to supply liquid pig iron to the steel production.

However, the electric pig iron production was not started in 1977. Instead the furnace was used to produce standard ferro manganese. Only from December 1981 till May 1982 was pig iron produced. Then the furnace was stopped and has not been restarted since.

The power cost has shown a very unfortunate development for the plant since it was planned (1974). Enclosure 3.a, chapter 3, shows the development in power price from 16 paisa in 1977 to 60 paisa in 1984. This probably was the main reason why the company decided to stop the pig iron production in 1982.

5.3.2 Raw materials and operation

Enclosure 5.3.a shows analyses and prices for the iron ores, reductants and flux materials used at the plant 1981/82.

During the short period the furnace was operated on pig iron difficulties were experienced with low tapping temperature and too great variations in Si-content of the iron.

We feel that the main reason has been insufficent metallurgical and operational control of the furnace.

It should be said, however, that during the short period the furnace was in operation, it would hardly be expected that operators and technical supervisors would be sufficiently trained for the various jobs and problems normally encountered in metallurgical operations.

In a rather comprehensive report dated June 9, 1982 Elkem's metallurgical engineer Mr Per Hyldmo commented upon the operation at MEL. Here are some excerpts from this report:

To obtain a better raw material control the following should be considered:

- Limiting the ore supply to one or possibly two suppliers.

- Keeping sufficient ore in stock to allow operation at constant ore mix ratio. In addition bedding of the ores should be introduced. (see Section 5.1).

- As the ratio of coarse ore and fines normally may vary considerably, sampling of ore fractions -10 mm and +10 mm should be carried out on a routine basis. If significant difference in chemical composition is found, the ore should be screened and fed from separate day bins to get a constant ratio of coarse and fine ores to the furnace.

Considerable prereduction is carried out by the CO-gas in the charge layers above the smelting zone. Therefore relatively small size of ores is preferential. Good results are obtained at Norsk Jernverk with iron ore pellets 10-20 mm in 40 MW furnaces. On the other hand the contents of fines are more pronounced with decreasing ore size, hence a compromise has to be made. For MEL we recommend an ore sizing of 20-50 mm with 5% below 10 mm.

The same sizing is recommended for the fluxes: dolomite, limestone, etc.

Reductants

What is said about consistency of ore supply above should also apply for reductants (cokes). Purchase of coke should be limited to 2-3 suppliers and sufficient stocks be kept at site to avoid frequent changes.

We have found up to 12% difference in fixed carbon the fines and the coarser particles in different types of reductants. As carbon control is of main importance for control of Si in metal, this should emphasize the importance of well screened and homogeneous reductants.

Sizing of reductants is equally important. Two different coke sizes is normally required, a coarse fraction 27-75 mm and a fine fraction 10-25 mm. The coarse coke is required partly for stabilization of the necessary coke bed in the furnace and partly to counteract segregation in the furnace due to different sizing of the other raw materials. Normally 40-50% of coarse coke is required. The correct ratio coarse to fine coke will depend on the actual screen analysis of the two fractions.

When more stable furnace operation is obtained, the different cokes available should be tested, and an optimal coke mixture should be established. One difficulty in the MEL case is that the total phosphorous content of the cokes must be controlled to avoid too high phosphor in metal.

It is of vital importance to the metallurgist to know any changes in composition of the products, metal and slag. Thus, correct sampling and analysis is important.

Metal

Variations in metal composition (i.e. Si-content), do occur during tapping. Thus, a single sample of metal from the runner may deviate considerably from the average. Sampling of metal should preferably be done from the full ladle at the hot metal mixer. If this is not possible, a composite sample from three runner samples taken at intervals should be taken and forwarded to the lab.

In the range 0,9-2% Si in metal it is possible to judge the Si-content fairly accurate from sparks and fumes. The shift foremen and furnace operators should train themselves by observing the tappings to enable them to judge the Si-level and note this in the log book. This is valuable information when conditions are changing, and the approx. Si-content will be available as soon as the metal is tapped. This is a valuable signal to the steel plant operators.

Slag

Reliable information on slag composition is as important for the metallurgist as metal composition. The importance is illustrated by the fact that at Norsk Jernverk slag from every second tapping is analysed, in spite of more stable raw materials than at MEL and with many years of experience in pig iron production.

Composition of slag will also vary during tappings. Thus, to obtain a representative slag sample, the sample should be taken only after approx. 1/3 of the slag has been tapped. Samples taken from the first slag running and towards the end of the tapping may give erratic results.

To obtain higher metal temperature it is normal to increase slag melting point by increasing the slag basicity. However, increased temperature will normally also result in increased Si-reduction. In practice the basicity should probably be kept in the range 1.2-1.3 with Si-metal approx. 1.3%. It should in this context be mentioned that a stable si-content of 1.3 is impossible to obtain. To control the Si-content within 1.1 to 1.5 is possible with good operational control. However, with the variations in raw material composition which seem to prevail, even that may prove to be difficult.

5.3.3 Recommendations:

Based on the comments above, the following recommendations are given to obtain more stable and consistent furnace control:

- Better raw material control is necessary. More stable supply and homogenization of raw materials is essential (bedding/screening of ores and reductants).

- Part of the coke (40-50%) has to be coarse coke 25-75 mm. The remaining coke should be 10-25 mm. The two coke fractions should be charged from different day silos and the ratio adjusted to regulate the metallurgical and electrical parameters in the furnace operation.

- The available data from the furnace operation so far cannot be used to determine operation strategy. However, as mentioned, a basicity of 1.2-1.3 should be aimed for. Operating resistance should be chosen to give C_3-values in the range 10.8 to 11.6. (See encl. 5.3.b).

  Correct basicity range and C_3-values should be tested out when other factors has been brought under control and stabilized.

- Sampling procedures for slag and metal should be changed to obtain representative samples.

- The cperational staff should train themselves to estimate Si in metal during tapping and to evaluate appearance of slag samples to enable faster evaluation of furnace conditions.

- Control analysis of raw materials and products (slag and metal) should be implemented to check performance of lab.

- Tapping procedures should be improved:

  Tapping at regular intervals in one ladle only with sufficient capacity for one metal tapping.

  Taphole to be opened with drill with preferable 90 mm diameter drilling bit. The use of the oxygen lance should be reduced to a minimum.

  Preheating/use of lid on ladle in between tappings to reduce scull formation.

  We suggest that for the restarting of the pig iron production MEL should employ engineers and foremen experienced in electric furnace operation to give advice and instruct the operating crew.

5.3.4 Electric pig iron price

The following prices were given to us during our stay in Chandrapur in September 1984:

	Cost at plant
Basic grade pig iron	2775.-
Pig iron chips	2550.-
Bottom plates (50 kgs pieces)	2400.-
Cast iron scull scrap	2250.-

Using the prices from enclosure 5 3.a and unit prices from cost calculations received in discussions with MEL - enclosure 5.3.c and 5.3.d, we arrive at comparative prices for pig iron at the plant:

	Cost at plant (Rs)
Basic grad pig iron	2775.-
Electric furnace pig iron (liquid)	2663.-
Cupola furnace metal (liquid)	3025.-

The operating cost breakdown is shown in enclosure 5.3.e and 5.3.f.

From this it has become clear that the plant can produce liquid pig iron for its steel production cheaper from its own electric pig iron furnace than from any other source. Furthermore, own production of pig iron give a basis for better special steels with better control of impurities.

5.3.5 Low shaft blast furnace

It has been suggested to install a low shaft blast furnace at MEL similar to the furnaces installed at Kalinga Iron Works in Orissa. (Terms of Reference, page 7)

This project has been considered by MEL and discarded on the basis of information received from Kalinga (see letter to MEL dated 12th July 1983, enclosure 5.3.g.).

A low shaft blast furnace uses approx. 1500 kg nut coke per ton of pig iron compared to approx. 500 kg coke for electric pig iron.

	Low shaft	Electric
Electric power		1500 Rs/t
Nut coke 1200 Rs/t	1800 Rs/t	
Coke 800 Rs/t		400 Rs/t
	1800 Rs/t	1900 Rs/t

With the prevailing prices reported for electric furnace coke, nut coke for low shaft furnace and electric power it would appear that an investment in a low shaft furnace is not advisable.

It should also be noted that blast furnace iron will contain more unwanted impurities (from the coke) than electric pig iron.

Since an electric furnace of modern design is already installed, good iron ores are available from nearby mines and the consumption of reduction materials is less than for any other process, it seems logical to use this advantage to produce good quality pig iron for the production of good quality steels in the steel plant.

5.3.6 Iron ores

According to enclosure 5.3.a quite a number of iron ores have been used in the short period pig iron was produced in 1981/82. We have recommended to select only a few sources (in fact, preferably 2 at the most) and to use bedding techniques if more ores shall be mixed, to give a constant feed to the furnace.

According to information received from MAHARASHTRA STATE MINING CORPORATION in Nagpur the ore at LOHARA MINES is a very pure hematite of hard, massive, lumpy character and as such a very desirable feed for the electric furnace.
This ore was used, mixed with other ores.

However, the proven reserves are rather limited, only 1.5 mill. tonnes. If more ore cannot be proven by prospecting, diamond drilling, etc. at this mine, investigations into other sources suitable for MEL's electric pig iron production for special steels should be started soonest.

Ore reserves of 1,5 million tonnes will last for 5-7 years of operation only, and it will take that long to prospect, evaluate and start a new mine.

MSMC has pointed to another source, The SURGAGARH deposit of a very pure hematite ore. The reserves here are reported to be 75 mill. tons, proven by diamond drilling. There is no railroad to the deposit, and road transport is estimated at 100 Rs/tonne. The location is about 150 km from Chandrapur. This could be a logical source for MEL's production in the future. Encl. 5.3.h.

The iron ores referred to are hematite ores. The Lohara ore is said to be hard and lumpy, producing little fines, but the Surgagarh ore is brittle and presumably a quantity of the ore will have too much fines and will have to be screened before being used in the furnace charge. The fines should be agglomerated.
What is said about sinter under chapter 5.1 also applies to iron ore fines. Paramount Sinters will be in position to study the sintering of hematite ore fines and to supply a sinter plant to MEL when Surgagarh ore is considered for the pig iron production.

5.3.7 Preheating/prereduction of furnace charge

Pre-reduction of iron ore is suggested in Terms of Reference, page 6.

An evaluation was done by M.N. DASTUR's Engineering Company in Calcutta for MEL in 1979. At that time the cost of electric power in Chandrapur was 30 paisa per kWh. It was found at that time that the investments in the prereduction equipment could not be justified by the reduced power consumption.

Now, when the power price is doubled, the picture may be different. A calculation of the necessary equipment costs and erection of same is shown in enclosure 5.3.i and the expected operating costs, compared to the operating data from the 1981/82 pig iron operation are shown in enclosure 5.3.j.

This project should therefore be studied in more detail when the iron/special steel plant has been operating for some time and the production and market developments are well advanced. With an investment of approximately 130 mill. rupies and a saving in operating costs of approx. 800 Rs per tonne of pig iron produced, the project seems to be very interesting, also taken into consideration that the production capacity will increase from 66000 tonnes to 100 000 tonnes per year.

5.3.8 Cupola furnaces

We have found no use for the two installed cupola furnaces. They could be used as basis for a mild steel operation in periods when the electric pig iron furnace is down for a scheduled maintenance job (yearly) or when it is stopped for major repairs, but this operation would hardly give any contribution.

Rebuilding to hot blast is not recommended. (Terms of Reference, page 7)

Electric Pig Iron Production

Analyses and landed costs of raw materials (june 1982)

Name of the source	Fe%	SiO2%	Al2O3%	Phos%	Sulphur%	+50mm	+25m	+15mm	+12mm	-12mm	Landed Cost Rs./MT in June'82
IRON ORE:											
Tawakkal Stores	66.5	2.5	2.5	0.04	0.03	7.0	55.0	-	30.0	8.0	126=30
Lohara Mines	65.5	3.5	4.0	0.05	0.06	51.0	35.0	-	11.0	3.0	141=37 (By Road) 104=87 (By Rail)
Manjunath Traders	68.2	1.0	1.0	0.025	0.010	4.0	-	-	87.0	9.0	229=73
Vibhutigurla Minerals Bellary	66.2	1.3	2.18	0.047	0.038	23.0	43.0	18.0	12.0	4.0	174=71
Dodanwar Bros Bagalkot	65.66	2.7	3.36	0.046	0.028	9.0	43.0	29.0	7.0	12.0	197=51
Khyrsipar (Titaniferrous)	Fe - 53-54%, TiO2 - 14 to 20%, V2O5 - 0.88 to 1.66 %										

	Sio2%	R2O3%	CaO%	MgO%	+100 mm	+75 mm	+50 mm	+25mm	-25mm	
Quartz	97.0	1.0	1.5	0.5	-	11.0	65.0	30.0	4.0	167=90

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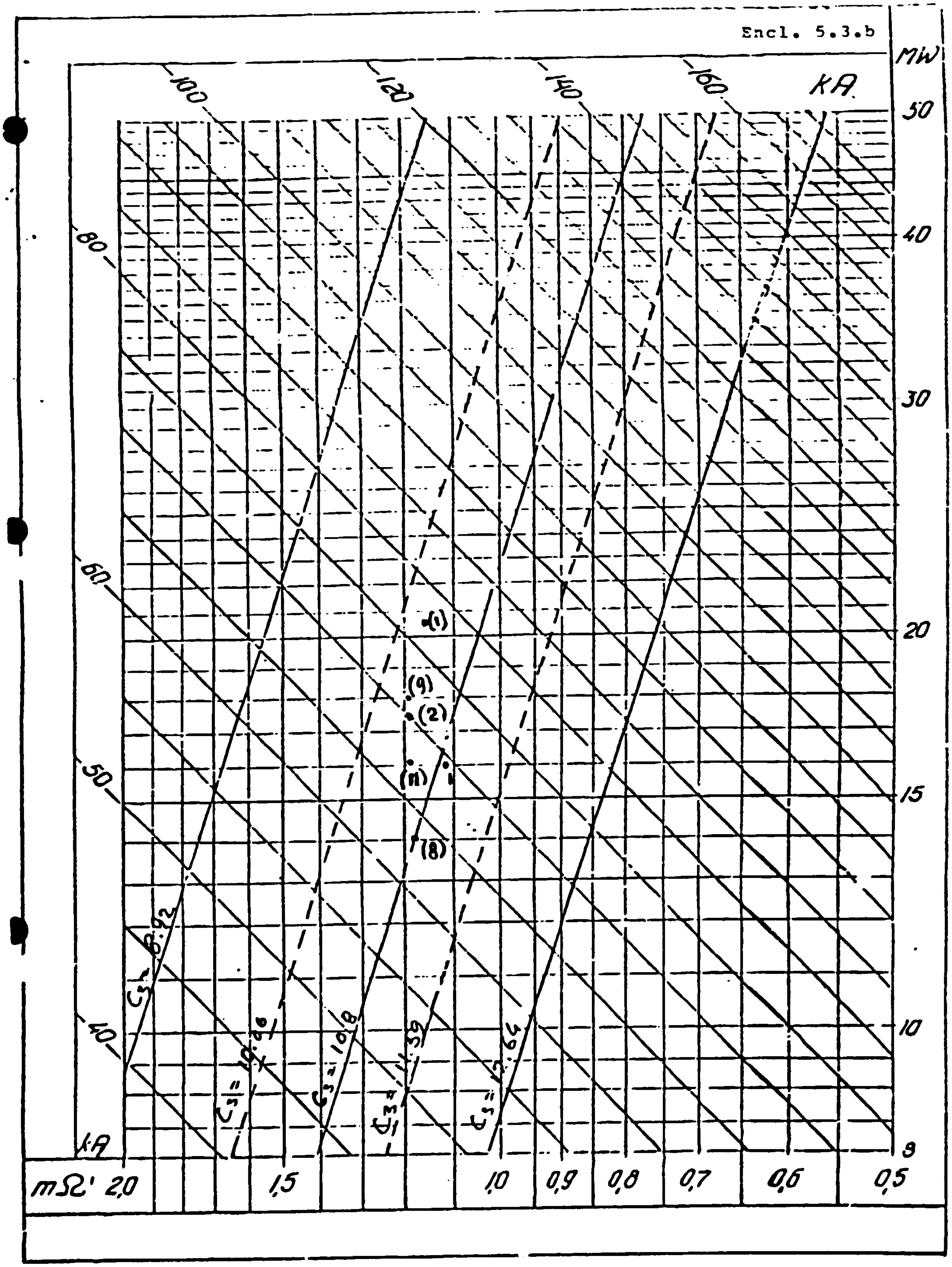
Enclosure 5.3.a1

Name of the Source	VM%	ASH%	F.C.%	PHOS.%	Ash Analysis: SiO_2 %	CaO %	MgO %	Al_2O_3 %	Fe_2O_3 %	R_2O_3 %	Screen Analysis: +25mm	-25+10mm	-10+6mm	-6+3mm	-3mm	Landed Cost Rs./MT Rs.Ps.
Reductants:																
SAIL (Pearl Coke) (Steel Authority of India Ltd).	2.50	27.50	70.0	0.17	16.0	2.0	1.0	4.0	1.5	3.0	3.0	59.0	18.0	9.0	11.00	838=24
TISCO (Pearl Coke) (Tata Iron & Steel Co).	3.00	26.00	71.0	0.19	16.0	2.0	1.0	4.0	1.0	2.0	4.0	62.0	16.0	8.0	10.00	817=34
LTC Coke, Singarani (Low Temp. Carbonisation).	6.0	32.0	62.0	0.03	18.0	3.0	1.5	5.0	1.5	3.0	40.0	40.0	10.0	7.0	3.0	700=00 (Dec.83)
Beehive Hard Coke	2.50	38.0	59.50	0.15	20.0	4.0	2.0	6.0	2.0	6.0	+200mm 27.0	+125mm 44.0	+100mm 14.0	+50mm 11.0	-50mm 4.0	1000=00 (Dec.83)
Coal	30-35	18-25	45-50	0.06	0.8											

	CaO%	MgO%	SiO2%	Al2O3%	Phos%	Fe%	-80+25mm/Wt.%	Landed Cost Rs/Mt
Fluxes:								Rs. Ps.
Limestone	47.0	3.0	5.5	1.0	0.02	1.0	5% tolerance on either side.	97=00 (Dec.83)
Dolomite	31.0	19.0	2.5	1.0	0.02	1.0	5% tolerance on either side.	116=38

1811C53EA2

Encl. 5.3.a
Page 2



Data from MEL's furn. 1.

PIG IRON OPERATION

26 obs.: C_3 = 10,802; S = 1,117

19-7-78 J.W.

March/April 1982.

Number of days in brackets.

DIRECT COST OF LIQUID PIG IRON THROUGH SMELTER

Sr. No.	Description		Kg/MT of Liquid Pig Iron	Landed cost at works Rs./MT	Total cost (Rs)
1.	Iron ore		1834	120.00	220.00
2.	Coke -	LTC Coke (25 - 40mm)	121	700.00	85.00
		Pearl Coke (10 - 20mm)	400	825.00	330.00
3.	Flux		400	120.00	48.00
4.	Power -	Main	2542	0.62	1576.00
		Auxiliary	100	0.62	62.00
5.	Electrode Paste		22	7300.00	160.00
6.	Labour		-	-	50.00
7.	Refractories		-	-	35.00
8.	Consumables		-	-	20.00
9.	Stores & Spares		-	-	50.00
10.	Interest on W.C.		-	-	50.00
11.	Transport		-	-	15.00
	Direct Cost of Liquid Pig Iron				2702.00

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Encl. 5.3.d

ANNEXURE 1A

DIRECT COST OF HOT METAL THROUGH CUPOLA

Sr. No.	Description	Kg/MT of Hot Metal	Landed cost at works Rs./MT	Total Cost (Rs)
1.	C.I. Skull Scrap	1000	1875	1875.00
2.	Steel Scrap	112	2000	224.00
3.	Beehive Coke	236	1425	336.00
4.	Limestone	75	120	9.00
5.	Soda Ash	4	3000	12.00
6.	Brix B	-	-	8.00
7.	Fire wood	-	-	8.00
8.	Refractories	-	-	18.00
9.	Power & Fuel	-	-	27.00
10.	Labour	-	-	10.00
11.	Consumables	-	-	20.00
12.	Stores & Spares	-	-	20.00
13.	Interest on WC	-	-	40.00
14.	Transport	-	-	15.00
			Cost of Hot Metal/MT	2622.00

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Encl. 5.3.e

Electric Furnace Pig Iron and Foundry iron

Production cost figures (1980/81 - updated)	kg/t	unitcost Rs	Total
1. Iron ores			
Tawakkal	1270	126	160
Lohara	564	141	80
2. Reduction			
LTC coke	121	700	85
Pearl coke	400	838	335
3. Limestone	400	97	39
4. Power, furn.	2540 }	0.6	1584
" , aux.	100 }		
5. Electrodes	22	7100	156
6. Labour			50
7. Refractories			35
8. Consumables			20
9. Stores & spares			50
10. Interest on working capital			50
11. Transport			15
Direct cost pig iron			2659

Purchased pig iron cif Chandrapur: 2775

Note: For comparison purposes only.

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Encl. 5.3.f

Cupola Furnace Pig Iron Cost
(Updated 1980/81 figures)

Various pig iron scrap	2400
112 kg steel scrap	210
236 kg beehive coke	236
75 kg limestone	7
4 kg soda ash	12
Bricks B	8
Firewood	8
Refractories	18
Power & fuel	22
Labour	10
Consumables	20
Stores & spare parts	20
Interest on working capital	40
Transport	15
	3025

Note: For comparison purposes only

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Encl. 5.3.g

KALINGA IRON WORKS

Ref. No. 4600

Date 12 th July 1983

To

The General Manager (Projects)
Maharashtra Electrosmelt,
Nirmal, 2nd floor
Nariman Point
BOMBAY: 400 021

Dear Sir,

Ref. your letter No. Tech/NB 14/AKK dt. 21.st June'83.

We have got three Low Shaft Furnaces designed to use for coke. Due to non-availability of required quantity of Nut Coke one of the Furnaces is always kept shut down. As a result we are always forced to operate wich 2/3 of our rated capacity and thereby increase our cost of production by increased overheads due to lower capacity utilisation.

Pig Iron users in our country in general are not prepared to pay higher price for foundry grade Pig Iron (High silicon) as a result we have to sell our Pig Iron in J.P.C. price. Since the coke consumption in low shaft furnaces is bound to be higher than conventional blast furnaces, the cost of production is higher than Pig Iron in conventional blast furnaces. Since May, 1982 there has been an increase in B.P. Coke price by Rs. 350/- per M.T. thereby increasing our cost of production by about 550/- per tonne and since then our cost of Raw Materials alone per tonne of production is nearly eqaal to on loss and we are forced to think of diversification. To use about 40 percent of our own Pig Iron we have already started producing C.I. Spun Pipe and going to manufacture doctile Iron Pipes shortly.

However, if you are interested in visiting our plant with your Managing Director, you are welcome to come on any workingday with prior intimation to us.

With kind regards,

Yours faithfully,
For: KALINGA IRON WORKS

Sd/-
(GENERAL MANAGER)

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Encl. 5.3.h
Page 1

BRIEF NOTE ON WURREA HILLS IRON ORE DEPOSIT OF SURJAGAD HILL RANGE

DISTRICT GADCHIROLI, MAHARASHTRA STATE

This iron ore deposit occurs on the top and southern slopes of the Wurrea hills which from the central part of the Surjagad hill range in Gadchiroli District, Maharashtra State. The deposit is approachable by road from Chandrapur (where the plant of Maharashtra Elektrosmelt Ltd., is located) via Allapalli and Etapalli and is 165 Km. from Chandrapur.

The deposit has been prospected by geolocial mappping, core drilling and analysis by the Directorate of Geology and mining, Govt. of Mahharashtra between the period 1963-64 to 1970-71. This prospecting has shown that there are six major ore bodies which have been covered by drilling and where reserves and grade of the ore has been arrived at on "proved" basis. Reserve of ore on "indicated" basis has also been calculated for these ore bodies which have been disignated as "blocks" numbering serially from (i) to (vii). In addition, there are 18 small ore bodies which have not been covered by drilling and where reserve of ore has been estimated on "indicated" basis. Float ore is seen on the low ground to the south of the Wurrea hills and the reserves of float ore has been calculated on "indicated" basis.

The summary of iron ore reserve calculated for in-situ ore and float ore in the proved, indicated and inferred category is as below:

		Proved	Indicated	Inferred
		(in Million Tonnes)		
1)	Reserves of in situ ore included in the various blocks.	75.297	16.136	---
2)	Reserves of in situ ore in Small Lenticular Ore bodies.	---	4.00	---
3)	In situ ore under cover.	---	---	15.00
	Total in situ ore	75.279	20.136	15.00
4)	Float Ore	---	12.73	---

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Blockwise reserves and average grade of the proved iron ore in the Wurrea hill is as below:

Sr. No.	Block No.	Proved Reserves in million Tonnes	Fe	Al2O3 %	SiO2	P	S
1.	I	37.92	63.43	5.115	1.997	0.11	0.042
2.	II	20.726	65.19	1.65	2.89	0.046	0.014
3.	III	1.291	66.36	1.33	2.55	0.0367	0.0273
4.	IV	13.314	63.83	2.28	2.91	0.0891	0.0128
5.	V	1.30	66.06	1.67	1.76	0.0433	0.0165
6.	VI	0.728	65.61	0.976	1.49	0.039	0.005
		75.279					

The average grade (%) of the float ore is as below:

Fe	SiO2	Al2O3	P
64.62	3.39	2.14	0.034

EXTRACT OBTAINED FROM DGM's REPORT NO. 16

LOHARA IRON ORE DEPOSIT, TAH. BRAHMAPURI,
DIST. CHANDRAPUR, MAHARASHTRA STATE.

Lohara Iron Ore Deposit is located about 1 mile South of Lohara village in Chandrapur District. The deposit lies about 2½ miles north east of Alewahi Railway Station on Nagbhir-Chandrapur narrow gauge railway line of the South Eastern Railway. The deposit is under mining lease rights of the Maharashtra Elektrosmelt Limited.

The Iron Ore Deposit occurs on a hillock which rises to a hight of about 205 feet from the general ground level, associated with banded hematite -quartzite rock and surrounded by granitic intrusion with anaureole of composite and injection gneisses. The strike of the ore body is generally N30°W with steep dips of 60° to 80° both towards due to East and West, but predominently towards east. The length of the ore body along strike is about 1350 feet. The width of the ore body varies greatly at different places along the strike with maximum width of 430 ft. near the peak of the hillock, and about 200 feet at the North end of the ore body. The ore outcrop comprises of massive and compact boulders of crystalline hematite and at places both hematite and magnetite. Float ore is seen on both the slopes of the hill. A considerable portion of the iron ore at the southern end of the hill is seen to have been completely spoiled by intrusive granite.

The deposit was prospected by diamond core drilling in 1963 by the Directorate of Geology & Mining, Govt. of Maharashtra, Nagpur. In all 9 bore-holes were drilled with agregate footage of 957 feet 2 inches. The determination of grade of ore was done from the bore-hole samples as well as surface samples from reef ore, spoiled ore and float ore. For the purpose of calculation of ore reserves, the area of the deposit was divided into seven different blocks. The reserves and the grade of Iron Ores is stated as below:

Block No.	Category of Ore	Estimated Reserves (Million Tons)	Average Analysis			
			Fe	SiO2	Al2O3	Ph.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
I	Reef Ore	0.89	62.21	4.46	3.55	0.049
II	Reef Ore	0.09	60.98	8.10	2.17	0.018
III	Reef Ore	0.20	62.26	6.00	2.81	0.053
IV	Float Ore	0.048	59.97	7.31	1.77	0.02
V	Float Ore	0.016	----------- " -----------			
VI	Float Ore	0.231	----------- " -----------			
VII	Spoiled Ore	0.088	44.11	34.90	0.73	0.021

The combined reserves of the reef and float categories of ore with average Fe content of these categories is as below:

Sr.No	Category of Ore	Reserves	Average Fe Content
1.	Reef Ore	1.18	61.81
2.	Float Ore	0.30	59.97
	TOTAL:	1.48	

Spoiled ore having 0.088 million tons of estimated ore has not been taken into account because of loss iron content in it.

1811C53EH4

1) CHEMICAL ANALYISIS OF SURJAGARH IRON ORE

Fe	60.14	-	68.42
SiO_2	0.35	-	6.10
Al_2O_3	0.68	-	7.32
P	0.017	-	0.196
S	0.005	-	0.033
TiO_2	Trace		

2) CHEMICAL ANALYSIS OF LOHARA IRON ORE

	Fe	SiO_2	Al_2O_3	P	TiO_2
Bore holes	61.31	6.19	2.84	0.040	0.089
Float ore	59.97	7.31	1.77	0.021	-

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Chapter 5.3
Encl. 5.3.i

Cost estimate for a prereduction unit for the pig iron furnace, comprising raw material handling from the present day silos, foundations, transport systems, rotary kiln with auxiliary electrical and mechanical equipment, gas cleaning, spare parts, erection costs and engineering:

	in 1000 Rs
Foundations, site preparations	3.800
Foundations for the elevated rotary kiln	10.200
Transport equipment	18.900
Electronic weighing control	6.800
Rotary kiln with auxiliary equipment	47.000
Service crane and steel constructions	10.000
Gas cleaning plant	6.800
Transport of hot charge	10.500
Refractory lined furnace bins	7.200
Spare parts	5.400
Misc. & Contigencies	20.000
Design, enigneering, purchasing services, etc.	40.000
Grand total	176.000

Approximately 180 mill rupies.

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Encl. 5.3.j

Pig iron production
Prereduced and hot furnace charge
Comparative operating costs (see encl. 5.4.c)

1.	Iron ore	1834	120	220
2.	Pearl coke	310	719	220
3.	Coal	400	480	192
4.	Limestone	200	97	20
5.	Dolomite	200	120	24
6.	Power	1500kwh/t	0.6	900
7.	Electrodes	10	7100	70
8.	Labour			55
9.	Refractories			50
10.	Consumables			20
11.	Stores & Spares			60
12.	Interest on W.Capital			50
13.	Transport			15
14.	Misc.			-
	Cost of liquid pig iron			1896

Compared to liquid pig iron cost of Rs. 2700 (encl. 5.4.c) for normal cold charge the savings would be in the order of Rs 800 per tonne of pig iron. The production capacity would increase from 66.000 tonnes to approx. 100.000 tonnes per year.

Conclusion: The project warrants further studies

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5.4 Steel operation

5.4.1 Introduction

The steel production at MEL was started in December 1979. The operation of 2 LD converters were then based on hot metal from 2 cupola furnaces.

The electric smelting furnace no. 1, originally planned for pig iron production, had been producing ferromanganese since February 1977, and MEL wished to continue this production.

The electric smelting furnace no. 2 was commissioned on FeMn production and pig iron production could be taken up on furnace no. 1 in November 1981.

Lack of metallurgical control, both in pig iron production and in LD operation, made a consistent production of steel grades with premium prices impossible. The hot metal bases were expensive, the cupola hot metal because of expensive raw materials, the pig iron because of high and increasing power price.

The ordinary mild steel grades produced had higher direct costs than the ex-factory realization value, and the loss-bringing pig iron/steel operation was shut down in May 1982.

More recent studies of the market conditions and up to date production costs which have been conducted by MEL in September '84, showed that the contribution from mild steel billets production also at that time would be around 250 Rs per tonne negative (ref. list 2).

When considering the possibilities for reopening of the steel operation at MEL, it seems obvious that a product mix of steel grades must be sought that:

- have a premium price
- have a sufficient demand in the Indian market
- could be produced without major changes in existing production facilities.

In this study we will try to reach a conclusion whether or not the MEL steel operation can be reopened on a sound basis. Considerations must in the following sections of this chapter be given to:

- the market situation
- the raw material situation
- the existing process equipment
- necessary modifications in process and process equipment with investment costs

Recommended process routes will be described and production capacities and production costs will be calculated.

Product mix will be discussed and total ecomomy of the steel operaton will be discussed.

5.4.2 Market conditions

5.4.2.1 General considerations

Market investigations are not a part of this study, and market considerations will be based on informations from investigations made by MEL personell:

Ref. list 3: K.K. Banerjee:
Market survey on stainless steel and other alloy steels. Aug/Sept 1984.

Enclosure 5.4.a: Nishant Tanksale:
Letter of 7 th Nov. '84 giving sale potential for different steel grades.

The special steel market of India is strongly influenced by government policy with strict import control and duty regulations. The price level is high compared with international market prices and deliveries of imported products are hampered by bureaucratic procedures.

The domestic production is in this way strongly promoted. For some special steel grades the domestic quality level has been inferior.

With strong marketing efforts and a good quality level of products, there should be good possibilities for substancial penetration into interesting market segments.

Enclosure 5.4.b gives a list of steel grades of interest for MEL.

5.4.2.2 Stainless steel market

The Indian stainless steel market seems to offer interesting possibilities, with a volume of approximately 100.000 tonnes in 1984 and a yearly growth of approximately 10%.

Stainless steel import is restricted and duty is high, giving a high price level and hampered deliveries of imported products.

The domestic production is partly inferior in quality level.

In Enclosure 5.4.a a forecast for potensial sales is given for the years 1985/86 to 1990. The tonnages given are estimates for what the market could absorb from MEL provided a sufficient quality level of products.

It will be noted that billets sale would be very limited. Flats would be the main product with some rounds and heavy gauge sheets in addition. MEL would accordingly be marketing rolled products, based on hire rolling of MEL-produced billets.

The obvious disadvantage for MEL in lack of self-controlled rolling operation must be best possible compensated by close cooperation with rolling mills with high standard of equipment and procedures, and with an open mind for giving feedback for development of billet quality.

The forecast for potential sales of stainless steeel corresponds roughly with market shares from 20% in the first year of operation to 30% in the fifth year. This high degree of market penetration must be regarded as very opitimistic and can most likely not be achieved.

In general a market share of 20% obtained in a 5 year period is regarded as a good result for a new producer in an established, but rising market.

The table in Enclosure 5.4.c gives a summary of total stainless steel market and estimated MEL sales potential of different products for 1986-1991. The contributions for different products are calculated from market prices, direct billet production costs and hire rolling fees given in Ref. list 3.

The resulting contributions are within the range of 1.90 Rs per kg to 5 Rs per kg.

The rolling fees and figures for scrap arising during rolling are uncertain, and contributions figures must be taken as approximates. An overall contribution of 2 Rs per kg will be used in further calculations.

According to information received about the stainless steel market we will draw the conslusion that MEL stainless steel tonnages increasing from around 10.000 t to 36.000 t during the first 5 years of operation can be sold, providing that an adequate quality level is secured and that strong marketing efforts are performed. This corresponds to market shares from 8% to 21%. High contribution values point out the stainless steelmarket as most interesting.

5.4.2.3 Carbon and low-alloyed special steels market

MEL will, with full operation of the pig iron furnace, have appproximately 65.000 tonnes of pig iron per year as basis for the steel production. Even with 36.000 tonnes of stainless steel produced there will be a surplus of approximately 40.000 tonnes of pig iron.

Some tonnages can be sold as special foundry iron, but with a substancial surplus production capacity for steel making, other steel grades than stainless has to be sought which can give a higher contribution than special foundry iron.

The market situation for carbon and low-alloyed special steels are discussed in the second part of Ref. list 3 and a forecast of potensial sale figures for MEL is given in Enclosure 5.4.c.

The table in Enclosure 5.4.d gives a summary of total market and estimated sale potensial for MEL for some interesting steel grades. Market prices and production plus delivery costs are also given to calculate the contributions for the most interesting steel grades. Market prices are mostly given for groups of steel grades and the calculated contributions must be taken as approximate.

The contribution from ordinary grade mild steel is most likely negative.

When establishing a product range for MEL, the contribution values indicate that the steel grades should be given priotity in the following order:

		Contribution Rs/Kg
1.	Wire rod	1.25
2.	Constructional carbon steels	1.05
3.	Constructional alloyed steels like EN 24	0.90
4.	Case hardening steels like 16 Mn Cr 5	0.60
5.	Spring steels	0.60

Welding electrodes/cold-heading steels are difficult to produce and will give a small contribution. These grades are not recommended as a part of the product specter.

A certain tonnage of ordinary mild steel will always be actual, at least as an outlet for heats not filling the special steels specifications.

Again the sales potential suggested by MEL seems to be very optimistic, Enclosure 5.4.c.

The tonnages given can, however, be substantially reduced without affecting the validity of the conclusion that market conditions will not be an important limiting factor for special steel produciton from MEL.

One condition is essential, however, - namely to develop and maintain the necessary level of quality. If this can be achieved, it seems to be outlet in the market for any actual production tonnages from MEL, and the contribution that can be obtained should be well above 0.50 Rs per kg.

5.4.2.4 Special foundry iron market

At present special low phosphorous pig iron for foundries is in good demand. However, the situation is somewhat special because an important producer is temporarily out of operation.

Several units for spun pipe and S.G. iron castings are expected to come into operation in the near future and the good demand for low phosphourous pig iron is expected to continue.

According to forecast from MEL, increasing tonnages from 15.000 tonnes in 1986/87 to 25.000 tonnes in 1990/91 can be sold. (Enclosure 5.4.e).

It is possible that sales can be arranged on a cost + profit basis, giving a steady contribution, but MEL has estimated the contribution so far, to only 250 Rs per tonne. This is based on lump castings. Investment in a pig casting machine is necessary to market these qantities of foundry iron. The corresponding price increase for foundry iron in pigs is expected to be 50-100 Rs per tonne.

Before reaching any conclusion regarding an optimal product mix we have to consider several aspects in the following sections of this chapter.

5.4.3 Raw materials for steel production

The oxygen blowing process for steel making demands a basis of liquid hot metal.

This could be produced either in the electric arc furnace or in the existing cupola furnaces.

In Ref. list 2 the direct costs for liquid pig iron and cupola hot metal are given to respective 2702 and 2622 Rs per tonne.

Our calculations in Section 5.3.4 are showing direct costs being respectively 2663 and 3025 Rs per tonne. The reason for discrepancy is mainly different prices used for the cupola raw material, cast iron scrap. The cost relationship between pig iron and cupola hot metal can obviously vary with the price situation for cast iron scrap, but there will most likely not be a cost advantage of any significance by using cupola hot metal in the steel production.

Both materials are representing a high cost starting material, demanding a further processing into high quality products.

That is possible only with the high quality electric smelted pig iron.

Besides being the base for steel production, the pig iron can be cast and sold as a special low phosphorous foundry iron, thus giving flexibility in the product mix.

The pig iron operation is delt with in chapter 3, from where it can be concluded that an improved metallurgical controlled smelting operation should give a pig iron with consistent composition of approximately 3.8 % C, 1.2 % Mn, 1.4 % Si, 0.09 % P and 0.02 % S.

The electric pig iron smelting furnace will have a capacity of approximately 8.3 tonnes per hr. or 65,000 tonnes per year.

The oxygen blowing process will give a scrap melting capacity more than sufficient to melt all internal scrap arising, and additional scrap for cooling has to be purchased, probably up to around 15% of the need for iron-bearing materials.

The availability of steel scrap seems to be poor according to investigations conducted by MEL in July/August 1984. Limited quantities were offered, and the lowest price was 2000 Rs per tonne. Iron ore could be used for cooling, but in smaller quantities because of the higher cooling effect. Increased consumption of pig iron would then give a more costly raw material mix.

Compared to other steel producers - scrapbased electric arc melting and blastfurnace based oxygenprocesses - MEL has a high cost iron-bearing raw material basis.

For production of stainless steel the cost of chromium - and nickel - bearing raw-materials, are far more important than the cost of the iron bearing basis.

A producer of stainless steel operating in the international market would have a serious disadvantage in being dependent on only primary chromium and nickel.

The possibility to play on fluctuation in market prices for stainless steel scrap and for primary chromium/nickel sources can make all the difference between loss and profit.

Facilities for melting of stainless scrap are in general very important.

In the scrap-based stainless steel production in electric arc steel furnaces, the chromium and nickel-bearing raw materials can be a costwise optimal mixture of stainless steel scrap and primary nickel- and chromium sources. Primary chromium has to be mostly the expensive low-carbon grade.

The actual process for making stainless steel at MEL will be either the AOD-process or the CLU-process. Both processes can use the cheaper chargechrome with high content of silicon and carbon. This can more than compensate for the missing ability to melt stainless steel scrap.

Limited amounts of stainless steel scrap are available in India, and the price is high, 15.000 Rs per tonne. The value of one tonne 18/8 stainless steel scrap, corresponding to the price for raw materials to be used at MEL, will be less than the scrap price:

Cr: 180 kg, as 56% charge chr., 330 kg at 12 Rs/kg	3960 Rs
Ni: 85 kg, as NiO-90% at 105 Rs/kg Ni	8925 "
Fe: 740 kg, as steel scrap at 2 Rs/kg	1480 "
	14.365 Rs

The MEL raw material situation for the steel production is characterized by:

- Main iron-bearing basis is a high-cost, high-quality pig iron.

  Competition situation towards blast furnace based and scrap based production is costwise rather weak. Quality level may compensate for this.

- Chargechrome as the mai.. chromiumbearing raw material for the stainless steel production makes the raw material situation for stainless steel competitive.

5.4.4 Existing production equipment.

The main production equipment is listed in chapter 2, also for the steel melting plant.

Enclosure 5.4.f shows the steel melt shop layout.

The layout is well planned with a good logistic. The different production units - pig iron furnace - LD converters - castig machine are matching well in capacity.

The 300 t hot metal mixer has sufficient capacity as a buffer. Availability of overhead cranes is good, especially with the ladles moving on cars.

There is sufficient space for auxilliary equipment and activities.

The LD converters are small, 15-20 tonnes, giving relatively higher heat loss and higher production costs than large scale converters, but the size is not uncommon and must be regarded as exceptable - especially for special steels.

The plain LD process is however, in principle not very well suited for special steel production. The lack of metallurgical balance in this process makes close control of the finished steel difficult.

The casting machine has a sufficient bow radius to cope with most steel grades. The strand dimension range from 100 x 100 mm up to 180 x 220 mm should satisfy most rolling mills specifications.

Lack of automatic steel level control in the mould and automatic cutting of the strand to billet length are disadvantages that to a large extent, can be compensated for by a skilled and reliable crew.

There are no facilities for sequence casting, but the need for regular sequence casting is not very likely.

Laboratory facilities and billet controlling procedures are adjusted to and sufficient for controlled production of ordinary steel grades.

The steel melting shop is a well planned shop with production equipment that can be adjusted to production of special steels with minor efforts.

5.4.5 Modifications in processes and process equipment.

5.4.5.1 General aspects

The market situation as outlined in Section 5.4.2 points toward a product range of stainless steel and some special grades of carbon and low-alloyed steel as interesting.

Steel processes and production facilities must be modified to allow a production with sufficient flexibility to meet variations in market demand.

Special processes for stainless steel are developed and are commercially available on a licencing basis.

The LD operation can with minor changes be substantially improved regarding metallurgical control, and ladle refining processes can further increase the quality controlling ability.

Casting operation and billet inspection/trimming must be adjusted to the steel grades.

5.4.5.2 Stainless steel production process

There are two commercially available processes for processing hot metal to stainless steel, which can fairly easy be taken up by MEL:

1. The AOD process.
   (Argon oxygen decarburization, developed by Union Carbide.)

2. The CLU process.
   (Developed by Creusot-Loire-Uddeholm)

Both of the two processes are aiming at decarburization of chromium-rich melts with reduced loss of chromium.

During decarburization by oxygen injection two reactions will take place simultanuesly.

I $C + 1/2\ O_2 = CO$

II $2\ Cr + 3/2 O_2 = Cr_2O_3$

By reducing the partial pressure of CO by deluting with a gas inert to the reactions, the reaction I will be promoted and less chromium will go to the slag.

In the AOD process argon was originally used as the diluting gas, but has lately been replaced by nitrogen to a large extent.

At the end of blowing, argon must be used to flush out the nitrogen that has been picked up.

In the CLU process superheated steam is added for dilution. The water vapour reacts to give hydrogen gas as the diluting gas. The hydrogen picked up by the melt must be flushed out with argon or an argon/nitrogen mixture. Hydrogen will be flushed out more easily than nitrogen, and therefore the CLU process has a lower argon consumption than the AOD process.

Some chromium will be oxidised in both processes and this is reduced by ferrosilicon addition in the final stage.

In the CLU process more ferrosilicion has to be added due to a somewhat higher degree of chromium oxidation during the oxygen blow.

The extra heat loss due to water dissociation must also be compensated.

The addition of nitrogen/argon or steam has a double effect by also cooling the oxygen orifices and controlling the heat evolved by the oxygen injection.

Steam will have a higher cooling effect than nitrogen/argon, an advantage when regarding heat control, but a disadvantage when regarding the total heat balance.

In the AOD process, the injection orifices are placed in the reactor wall, while in the CLU process they are placed in the reactor bottom. There should, however, not be a substantial difference between the two processes with regards to efforts to rebuild a LD reactor.

The refractory wear will follow different patterns, but the lining life wil be almost equal. Normally 60 heats per lining is obtained.

The main difference in production costs for the two processes seems to be dependant on relationship between argon and ferrosilicion in price and availability.

MEL has a production capacity for crude argon of $35 Nm^3$ per hour in their oxygen plant.

Additional facilities for purifying and storing this argon will demand a heavy investment (several mill. Rs.)

To purchase argon seems to be the best solution, at least for the first years of operation. Transport and handling of great quantities will cause problems and the landed cost will be high, 60 Rs per Nm^3.

Savings in argon consumption is therefore important for MEL, but this has to be considered against the ferrosilicon consumption and price.

Normal consumption figures given for the AOD process and the CLU process can be summerized to:

	Ar-consumption	75% FeSi-consumption
AOD	5 - 10 Nm^3/t	22 kg/t
CLU	2 - 3 Nm^3/t	30 kg/t

With the given argon price and with the MEL price for 75% ferrosilicon at 10 Rs per kg., a saving of less than 1.5 Nm^3 of argon will compensate for the increased consumption of ferrosilicon in the CLU process. A larger saving than that is expected.

The choise between these two processes will also be influenced by the licencing costs, and the very important know-how assistance and training program that is offered.

We know that MEL has found the CLU-process and the contract conditions for this process most attractive, and we have no objections to this choise.

Uddeholm International has given a feasibility study for MEL (Ref. list 4) where converting the MEL LD melt shop to a combined LD-CLU melt shop for stainless steel production is suggested.

In that study the conclusion is drawn that one LD converter can be rebuilt to CLU reactor, while one LD converter is kept unchanged and is used for dephosphorization.

The production capacity is matched to the oxygen plant capacity and is estimated to 12 tonnes of liquid stainless steel per net hr. of production. This gives some surplus of pig iron.

A shortness of lime from the calcining kiln is foreseen if all steelworking capacity should be utilized for stainless steel production.

Investment costs for converting to the CLU process are given to be 7.480.000 Rs.

Production costs are calculated and the payoff time for the investment is very short - 15 days of operation on stainless steel.

Break even point when considering the total fixed costs is 12.000 tonnes of stainless steel production per year.

In a consideration given by MEL (Ref. list 5)calculations of total investment costs are showing around 10 million Rs to take up the CLU process. With corrections of production costs, the pay-off time is given to 68 days of operation and the break-even point to 18.000 tonnes per year.

In this study we will go into an examination of the full process from pig iron to billets when a combined production is foreseen of stainless steel and special carbon and low alloyed steels. The LD-operation is the first step for both product groups, and will be discussed in the first place.

5.4.5.3 Modifications in the LD-plant

To meet the demand of production of both stainless steel and special quality steel, the most suitable solution will be a steel plant built up of one LD-converter and one converter specially modified for stainless steel production. The LD-converter will then be used as a dephosphorising unit when stainless steel is produced, and as a steel producing unit in the special steel production.

To meet these two applications in the best possible way, we would recommend a modification of the LD-converter to a converter with bottom stirring by inert gases.

By doing this, the following important advantages appear:

- less spluttering during blowing
  better mixing of the steel
  faster slag formation
  better possibilities for process control leading to:

- less dissolved oxygen in the steel
  less iron oxide in the slag
  lower alloying costs because of improved yields
  less slag inclusion in the steel
  more accurate steel analysis
  higher scrap melting rate, and the size of scrap added can be increased

Some extra costs will follow a modification to an LD with bottom stirring, but the installation costs and extra gas costs will be considerably lower than the savings.

Scandinavian practice usually shows savings around 10 SEK/tonne steel produced, when all the production costs are included (corresponding to approximately 15 Rs/tonne).

A bottom-stirred converter is arranged with an inert gas system through the converter bottom either by bottom nozzles or by porous plugs. The inert gases to be used should either be nitrogen or argon, or both of them as the best alternative. If a system with both nitrogen and argon is arranged, it will give a flexible blowing practice and increase the range of steel grades that can be procuced.

When it is used as a dephosphorising unit, only nitrogen stirring would be necessary, just to obtain some mixing effect and to keep the gas channels open.

For the production of some special steel qualities, a stirring practice in two steps would be preferable, with nitrogen stirring during the oxygen blowing and argon to adjust the steel analysis.

The process gas system which can be used for the two gases will be the same, only the supply to the plant will need to be done separately.

The argon requirement for special steel production will be in the range of 0.8-1.0 Nm^3/tonne of steel. With a converter capacity of 20 tonnes and a tap-to-tap time of 50 minutes, the argon flow rate will be approximately 24 Nm^3 per hour.

The investment costs will be in the range of 1-1.5 mill. Rs. The Metallurgical Research Station (Mefos), in Luleå, Sweden has been giving knowhow in such rebuilding cases and is also recommended for assistance to MEL.

5.4.5.4 The Stainless Steel Process Route

Dephosphorization in the LD Converter

The MEL pig iron will have a phosphor content of around 0.1%, while specifications for stainless steels are max. 0.045%. A dephosphorising step must therefore be laid into the process line.

Some development work is going on in Sweden to reach a process for phosphor removal from stainless steel melts, but today there is no feasible way to remove phosphor from a chromium rich steel melt. The phosphor refining must take place before the chromium is added to the stainless steel reactor.

Processes for dephosphorising of pig iron by injection of dephosphorising agents like lime-based fluxes or soda exist, but the silicon content must be removed before such injection treatment.

Removal of the rather high silicon content in the MEL pig iron will be a difficult and time-consuming process if performed in the ladle.

The LD process is regarded as the most convenient first dephosphorising step in the stainless steel process. To secure a sufficient phosphor refining, the pig iron has to be oxygen blown down to a carbon content below 0.1% under a highly basic slag.

Nickel is added as nickeloxide during the blowing operation and scrap is added to control the temperature.

A material balance for 1 tonne of stainless steel billets is given in Enclosure 5.4.g and a heat balance is given in Enclosure 5.4.h.

4% reclaimable internal stainless steel scrap is thought to be added in this step. It can be discussed whether or not this is the best usage of this scrap, taking into consideration chromium loss and prices for selling scrap.

In addition 2.5% purchased scrap is taken into the material balance. The heat balance is showing a heat surplus of approximately 10% (155 MJ) per tonne and more scrap can most likely be added.

The foreseen tapping temperature of 1700° C is disadvantageous for the phosphor refining, but a sufficient refining can be expected with a slag basicity above 3, low carbon content and a good stirring action at the end of the blow.

The slag amount will be approximately 2400 kg per heat. Good slag removing possibility is important and some device to withhold the remaining slag in the vessel may be necessary (the floating ball is an example). The receiving ladle must be very well preheated.

The CLU process performance

The pre-blown metal from the LD converter is a very uncommon starting material for the CLU process. Most commonly used is a hot metal with carbon content of around 1.5% carbon and with all chromium and nickel added.

The low carbon content, complete lack of silicon and the neccessity to add all chromium in the CLU process, indicate that a heat shortness can occur.

Material balance is given in Enclosure 5.4.i and heat balance in Enclosure 5.4.j.

Approximately 15 tonnes of pre-blown metal is charged to the well preheated CLU reactor. Metal temperature in the reactor is estimated to 1650°C. Chargechrome with 56% Cr, 7% C and 4% Si is added during oxygen blowing. Steam is added during the decarburising period, to reduce the chromium oxydation. Lime is added to ensure a minimum basicity of 2 in the slag (approximately 60 kg per tonne).

At the end of the decarburising period the chromium content of the slag must be reduced by adding ferrosilicon together with lime.

In the last step in the process the melt must be purged by argon to flush out hydrogen.

The material and heat balance are mostly based on data given from Uddeholm. They prescribe a very high ferrosilicon consumption of 50 kg per tonne of steel.

We would recommend a chargechrome with a high silicon content, 4%, and reduce the ferrosilicon addition to 40 kg per tonne.

The silicon in the chargechrome is cheap, if not free, and with portionwise addition there should be no problem in keeping the slag above 2 in basicity during oxygen blowing.

The heat balance shows a large heat surplus, and we think that Uddeholm has exaggerated the heat needed. A reduction in ferrosilicon addition and/or increased scrap addition seems to be possible, but we have not taken this benefit into the calculations. Addition of internal stainless steel scrap seems possible.

The slag amount will be high during the reduction step and a good stirring action and good facilities to remove slag from the vessel is important.

The final adjustments of analysis and tapping temperature are made in the vessel while the melt is purged with argon.

Casting operation

The tapping temperature from the CLU vessel should preferably not exceed 1700°C. The casting ladles have to be very well preheated. Preheating stands exist, but should preferably be moved to stand alongside the ladle car track to reduce heat loss during ladle transport.

Use of stopper rods in the ladles will set up limitations for the preheating and should be replaced by sliding gate nozzles.

Porous plug in the ladle bottom should be introduced for gas purging. This will be necessary for the special steel production and will be advantageous for the stainless steel production, mainly for temperature equalisation.

Installing of sliding gate nozzles and porous plugs in the 5 casting ladles will represent an investment of approximately 1 million Rupees.

Ladle lining can be either dolomite or high alumina bricks.

All the steel production is foreseen to be continuously cast. The casting pits for ingots can be removed. One emergency pit would however be needed.

During the casting operation the steel streams from ladle to tundish and from tundish to moulds should be protected from air oxidation.

The use of immersed casting tubes sets a lower limit for the mould sizes to 140-150 mm square. Strand dimension of minimum 150 mm square is well within the casting machine range and is acceptable for most actual rolling mills. If smaller dimensions are actual, some stream shielding device must be used.

Stopper rods must be introduced in the tundishes when using immersed casting tubes.

The gas-oxygen torches for cutting the billets to length must be replaced by powder torches when cutting stainless steel. Mechanical or hydraulic shears would have given nicer cuts and a better yield of steel, but the investment costs are regarded as prohibitive.

For internal soundness and surface quality of the billets, the casting temperature must be closely controlled.

Mould condition and well adjusted, even secondary water cooling is important.

Process cycle times

The production capacity for stainless steel foreseen by Uddeholm to 12 tonnes of liquid steel per net operating hour is considered as realistic.

With batches corresponding to 20 tonnes of billets the following cycle times will be actual:

Dephosphorization in the LD converter

Approximately 15 tonnes heat

Blowing rate:
$3 m^3N$ per tonne min. = 45 m^3N/min

Oxygen consumption per heat:
42 m^3N per tonne of billets = 840 $m^3N/heat$

Blowing time:
840 m^3N : 45 m^3N/min = 19 min.

Total treatment time, estimated = 40 minutes.

CLU-process

Blowing rate:
1 m^3N per tonne min = 20 m^3N/min

Oxygen consumption per heat
49 m^3N per tonne of billets = 980 m^3N/heat

Blowing time:
980 m^3N : 20 m^3N/min = 49 min

Total treatment time, estimated = 80 minutes

Casting:

Casting speed, estimated	1.4 m/min.
2 strand, 150mm square, gives	480 kg/min.
20 t of billets corresponds to 20:0.95 of strands	21 t
Casting time per heat: 21,000 kg : 480 kg/min	44 min
Real casting time, estimated	50 min
Preparing for next heat, estimated	30 min
Total time, estimated	80 min

Production capacity of 12 tonnes liquid steel per hour corresponds to 100 min cycle time and there is a safe margin for all three process steps.

A diagram of the stainless steel process cycle is given in Enclosure 5.4.k.

5.4.5.5 Production of carbon and low-alloyed special steels

The LD process

The introduction of bottom stirring in the LD reactor will be most advantageous for the special steel production. After finished treatment in the bottom stirred LD reactor a low carbon steel melt in good metallurgical balance should represent an excellent base for further treatment to finished steel.

Material balance, as an example for wire rod billets, is given in Enclosure 5.4.1 and heat balance is given in Enclosure 5.4.m.

In the material balance a scrap addition of 14% is foreseen.

The heat balance shows a heat surplus of 129 MJ corresponding to relting of approximately 9% more scrap. There should accordingly be no heat shortness, even with the foreseen tapping temperature of 1700°C.

From the list of interesting steel grades in Enclosure 5.4.b it will be seen that most steel grades are characterised by a medium carbon content and a low phsphor content. This is not possible to achieve with a catch carbon procedure in the LD converter. The carbon content has to be brought down to a low level to secure a low phosphor content. The lime-rich phosphor-containing slag must be separated from the steel before the steel can be recarburised.

In the bottom-stirred reactor the possibility exists to deoxidise, recarburise and alloy the steel up to specifications before tapping. There are however two main reasons for doing these operations in the ladle.

Steel treatment in the ladle

By doing the recarburising and the alloying in the ladle two important advantages are achieved:

1. Production capacity of the reactor vessel can be increased by shortening the process time

2. Remaining slag can be kept within the reactor vessel and back reduction of phosphor from the slag to the steel can be avoided.

In this case the increase in production capacity for the reactor vessel can hardly be utilised. With a cycles time for the caster of approximately 80 min. there is ample time for the extra operation in the reactor vessel.

It is, however, very important to avoid the back reaction of phosphor from the slag. There is in practice almost impossible to deslag a LD reactor completely. Even if the steel surface is slag-free, some slag penetrated into the vessel lining can give an increased phosphor content in the steel during the deoxidation.

Our recommendation is to tap the LD-reactor after a sufficient slag-off has been performed and after the remaining slag has been stiffened by lime addition, and do the finishing of the steel in the ladle.

With this practice there should be only minor amounts of slag coming into the ladle, and the deoxidation, recarburising and alloying can be performed in the ladle under controlled conditions.

The ladles must be equipped with sliding gate stoppers and with porous plugs for gas stirring.

Due to injection the ladles should be increased in height to obtain more freebord. Preheating of the ladles with the bulk of the alloying additions is very important.

Recarburising must be done by injection.

A full injection plant like the Scandinavian Lancer system (see sketch in Enclosure 5.4.n) will cost approx. 6 mill Rs based on delivery FOB Swedish harbour, without duty and taxes. The limited injection work in this case should however be managed with less sophisticated equipment.

With the ladle standing on a car, the mast for guidance of the lance-holding arm can be fixed, not swingable. Lance changing can be done by the overhead crane, and the ladle hood should not need connection to a fume-extraction and cleaning system.

Carbon material and calcium silicon should be the only agents that have to be injected, and one single powder dispenser should do with a 250 litre volume, placed on weighing cells.

The dispenser can be filled by screw/belt feeders or even by hand from day siloes.

Instrumentation could be limited to weighing facilities for the dispenser and metering devices for the carrier gas stream to give a controlled feeding rate.

Lime injection should be necessary only for steel grades with extra low phosphor or sulfur, and these steel grades are not likely taken into the product range during the first years of operation.

A platform in steel construction is needed with day siloes for alloying elements and weighing equipment beside the injection equipment. This can be erected alongside the track for the ladle car from the LD converter.

The area is indicated as item 33 on the drawing, Enclosure 5.4.f.

One heating stand for the ladle should preferably be moved to a stand alongside the same track, between the refining station and the LD tapping station to minimise the heat loss during ladle transport to the tapping position.

The investment costs connected to the injection and preheating equipment are estimated to approximately 2.5 million Rupees.

Casting operation

Some rolling mills demand special steel billets with dimensions less than the lower limit for use of immersed casting tubes.

If the steel grades in question demand gas protection of the steel streams from tundish to mould, some shielding arrangement must be used.

A simple T-shaped tube that can be swung in to enclose the steel stream, has given good results at the Elkem plant, Christiania Spigerverk, Oslo. The arrangement is cheap and the steel level in the mould can be followed optically. This makes manual control of the strand withdrawal speed possible, while most shielding arrangements demand automatic level control.

If skilled and reliable operators can be made available, the manual casting speed control is satisfying, and the investment cost for an automatic system can be avoided.

The cold tundish practise has been used. This is in most cases more expensive than a hot-tundish practise and a slightly higher starting steel temperature (5-10°) is needed for a troublefree casting start.

A good nozzle-blocking practise with fiber rope and sand is important when stopper rods are not in use.

Casting temperature control, mould condition and closely controlled secondary waterspray is very important for billet quality.

The control of billet quality has been based on visuall inspecton and spot grinding with manually operated grinding machines of the pendulum type.

Removal of millscale may be necessary by shot blasting or brushing to improve the inspection, and more grinding capacity may be needed.

Testing equipment for controlling internal soundness of billets may also be needed. (Ultra sound apparatus).

A prediction of the need for upgrading in this area is difficult to do. Operating experiences only must prove the need.

Production cycle times and capacity

The pig iron furnace will tap approximately 40 tonnes every 4.5-5 hrs, giving an average of 8.3 tonnes per hr.

The cycle times for the steel making process steps for heats corresponding to 20 tonnes of billets will be approximately:

LD - operation	50 min
Ladle refining - max.	45 min
Casting + preparing time	80 min

The casting operation will be the capacity limiting process step.

Sequence casting is not regarded as actual, because of bad influence on flexibility in production program and high investment costs for facilities for ladle change during casting.

The steel making process capacity will roughly be 20 tonnes of billets every 80 min, corresponding to 15 tonnes per hour.

From the material balance for a carbon steel (Enclosure 5.4.1) it will be seen that 1 tonne of pig iron will be needed for 1 tonne of billets.

The day production of approximately 200 tonnes of pig iron corresponds to 200 tonnes of steel billets. With a steelmaking capacity of 15 tonnes per hour, the 200 tonnes can be produced in 13.3 hours, or on a 2 shift per day operation.

The 300 t pig iron mixer has sufficient capacity to act as a pig iron reservoir.

A diagram for the process cycles is given in Enclosure 5.4.o.

5.4.5.6 Production of special foundry iron

A part of the pig iron production can be sold as a special low phosphorous foundry iron with some contribution. With the foreseen combined production, there will be a surplus of approximately 5-7000 tonnes of pig iron per year which cannot be processed to steel. Relining of the LD converter is the main reson.

The outlet for pig iron as special foundry iron beyond this tonnage can be advantageous from a marked point of view and in situations with steel making troubles.

Without facilities for pig casting the special foundry iron must be sold as lump castings. This is maybe possible for marketing minor tonnages, but marketing actual tonnages of 10-25 tonne can hardly be done in irregular lump form. A pig casting machine is regarded as necessary.

MEL has a cancelled order for a pig casting machine and this can maybe be reopened for a sum of 3.5 - 4 million Rs. A contribution value of minimum 300 Rs per tonne will give a short pay off period for the casting machine.

The pig casting machine has been part of MEL development plans and is shown on the drawing, enclosure 5.4.f.

5.4.5.7 Outline of the combined production

The combined production of stainless steel, special steels and speical foundry iron must be performed in a flexible way, according to the marked demand.

A main pattern for the production planning can, however, be outlined:

A steady pig iron production is setting a frame with the hot metal mixer as a buffer.

40 tonnes of pig iron will be tapped and transferred to the mixer every 4.5 - 5 hour.

The stainless steel production is foreseen to be performed in campaigns and the CLU converter lining life is deciding the number of heats in each campaign.

60 heats heat are foreseen, corresponding to roughly 100 operating hours, during which both converters are in use. The full crew is working on 3 shifts. Some 1150 tonnes of stainless steel billets are produced per campaign and 790 tonnes of pig iron are consumed, while around 830 tonnes are produced.

The CLU converter has to be relined, after these 60 heats, but the LD converter lining is foreseen to take 200 heats more.

Special steel production is then taken up in the LD converter, with the LD converter, injection plant and casting machine operating on 2 shifts per day. Extra crew for the CLU operation are then operating the injection plant. Surplus crew from the 3. shift are engaged in maintenance, training, etc.

The hot metal mixer must have room for approximately 100 tonnes of fluctuation in content.

Around 10 heats of steel are produced per day, corresponding to 200 tonnes of billets.

A complete stop in the steel produciton is foreseen during the relining of the LD converter. Principally the CLU converter could be used for special steel produciton during these relining periods. This would complicate the production routes and is not recommended.

Steel production potential will be dependant on the tonnages of stainless steel product. In the following table the possible sale/produciton of stainles steel is estimated. The full production of pig iron (65.000 tonn/year) is foreseen to be processed to steel except for the LD relining periods. Relining period is estimated to 72 hours.

1. year	tonnes/year
Stainless steel, 9 campaigns	10.000
LD production 12.6 campaigns	50.500
Foundry iron	7.500

2. year	
Stainless steel, 17.4 campaigns	20.000
LD production, 11.1 campaigns	44.600
Foundry iron	6.700

	tonnes/year
3. year	
Stainless steel, 23.5 campaigns	27.000
LD produciton, 10 campaigns	40.000
Foundry iron	6.000
4. year	
Stainless steel, 27.8 campaigns	32.000
LD production, 9.3 campaigns	37.200
Foundry iron	5.600
5. year	
Stainless steel, 31.3 campaigns	36.000
LD production, 8.7 campaigns	34.800
Foundry iron	5.200

5.4.6 Production costs

The direct production costs of the pig iron and steel products are calculated in accordance with the given process routes, material balances and updated processing costs given by MEL.

Stainless steel

The direct production costs are calculated for AISI 304 - 18/8 Cr/Ni. (Se Enclosure 5.4.p)

The preblown metal from the LD converter must carry the full costs of an LD operation and the CLU process costs are additional.

It is foreseen that 4 more men pr. shift is necessary to operate the two reactors simultaneously. Some additional ladle lining costs are taken into the account for the transfer of steel from the LD converter to the CLU reactor.

Total direct costs are calculated to 18.000 Rupies per tonne of billet. This is matching with the cost figure given by MEL.

It will most likely be possible to reduce the ferrosilicon consumption and/or increase the scrap additon. Any substantial reductions in production costs are, however not to be foreseen.

Special steels

The direct product' .ı costs are calculated for a wire rod steel grade with around 0.5 % carbon, (See Enclosure 5.4.g). The extra costs for ladle refining are taken into account, but it is foreseen that the extra men on shift when producing stainless steel will be engaged in ladle refining and injection when special steels are produced.

The calculations give 3.870 Rupies per tonne of billets.

This is also very close to the cost figure given by MEL for mild steel pr. Sept. 84 (Ref. list 2, 3.850 Rs per tonne) and the updated cost figures pr. Jan. '85, 3.900 Rs per tonne).

The higher scrap melting ability in our calculations is the main factor in compensation for the added ladle treatment costs.

The LD lining life of approximately 260 heats is short compared with European figures, but the Indian refractory materials may be somewhat inferior. Sustantial reductions in production costs are not likely.

5.4.7 Summary of investments

	Mill Rs.
1. Rebuilding of LD convertor to bottom stirring	1.5
2. Rebuilding LD convertor to CLU reactor	10.0
3. Installing sliding gate stoppers and porous plugs in 5 ladles, including spare parts	1.0
4. Installing injection station and moving ladle preheating stand	2.5
5. Tundish changes for use of stopper rods and casting tubes	0.3
Transferred	15.3

	Mill. Rs
Transferred	15.3
6. Powder burners for billet cutting	0.2
7. Miscellanceous and unforeseen	1.5
	17.0

Approximately 17 mill. Rs has to be invested to modify the production facilities at MEL to establish a combined production of stainless steel and carbon/low alloyed special steels.

A pig casting machine for special foundry iron in addition is strongly recommended. Investment costs are estimated to 4-5 mill. Rs.

5.4.8 Fixed costs

Basis for the calculations are found in Ref. list 5, page 5, where a summary of fixed costs connected to the pig iron and steel operation is given.

Capital for excisting assets	250 mill. Rs
Additional investment:	
CLU-connected rebuildings	10 mill.Rs
Additinonal rebuilding recommended:	
Steel operation	7 mill. Rs
Pig casting machine	5 mill. Rs
Total plant capital	272 mill. Rs
Capital costs per year, 16% =	43.5 mill.Rs
Overhead costs and other expences including fixed labour costs	10 mill.Rs
Total fixed costs per year	53.5 mill.Rs

5.4.9 Discussion

5.4.9.1 General considerations

In the previous sections of this chapter we have tried to give a background materials for discussing the main question:

Can a steel operation at the MEL works be restarted on a sound techno/economical basis?

The MEL situation as a steel producer can shortly be summerized:

- The MEL electric pig iron furnace, hot metal mixer, LD converters and casting machine represent a good basis for an effective, small scale steel production.
- High power price and small scale operation make the MEL competitive position generally weak, and mild steel and other ordinary steel grades can not be produced profitably.
- The MEL steel plant can with moderate investment be turned into a plant with equipment adapted for stainless steel and special steel production.
- The modified production equipment and the high quality pig iron represent a good basis for high grade steel produciton.
- A high level of steel technology must be built up by extensive recruiting and educating programs combined with purchased know-how assistance.
- The market conditions for both stainless steel and special steels give ample opportunities for market penetration with good quality products.
- The lack of self-controlled rolling operation is a disadvantage for quality development and marketing, but the possibilities for establishing close cooperation with hirerollers seem to be good.

For implementation of the equipment modifications and the new processes much attention has to be paid on know-how assistance and personnel recruiting and training. Some moments in this connection will be given:

- The equipment modifications and commissioning of the CLU process are relying on Uddeholm International. Know-how assistance and training program offered by Uddeholm must be fully utilized, and extended if necessary. Recruiting and/or selection of personel to undergo the training program is important and must be paid much attention.

- Rebuilding of the LD converter to bottom stirring must be planned to be finished at the same time or earlier than the CLU commissioning.

  Assistance for rebuilding and process know-how can be given by the Metallurgical Research Station (Mefos) in Luleå, Sweden. For practical training Norsk Jernverk A/S, Mo i Rana, Norway, could be contacted. They rebuilt their LD converter to bottom stirring one year ago.

- Regarding special steel production, know-how and practical training may be possible to buy from Ovako Oy, Kooverhar, Finland. They have extensive experience in special steel production based on blast furnace, LD converters and continuous casting, and they are familiar with this kind of assistance.

- Even if the special steel operation will have second priority from start on at MEL, personnel training could be taken up before the steel operation is started.

  We take for granted that the possibility for assistance from SAIL will be fully investigated and utilized.

- Cooperation negotiations should be taken up with potential hirerollers in due time.

  Training programs for MEL personnel in rolled product control should be part of the cooperation deal.

- Training programs should also include laboratory personnel.

5.4.9.2 Development in product mix and contribution

According to the most recent market information given by MEL (Enclosure 5.4.e) there will be a small contribution from mild steel production, and there will be good demand for special foundry iron, which also will give some contribution.

Regarding special steels there will be only the steel grades with high quality stringency that may give contribution up to approximately the same level as for stainless steel.

Accordingly the stainless steel must be the first priority product, and even more so, because the CLU-operation gives MEL a general good competitive position toward other Indian producers. None of these are operating the CLU or AOD process.

Development schemes for alternative product mix and the resulting contributions are given in Enclosure 5.4.r.

Trial production is foreseen to start in January 1986. The first half year is considered as a trial periode with no resulting contribution.

The regular production period starts in July 1986 and the first 5 year of operation are considered. In the production period 1986/87 a somewhat reduced pig iron production is foreseen, but full pig iron production of 65.000 tonnes are taken as the basis for the operations from the second year.

A penetration into the stainless steel market corresponding to market shares increasing from 8% in 1986/87 to 21% in 1990/91 is considered as obtainable with aggressive marketing efforts.

The strategy given in Development Scheme, Alt.1, is to concentrate maximal on stainless steel and regard production of special foundry iron and mild steel as marginal utilization of pig iron and steel production capacity.

The resulting contributions per year would be respectively:

31 - 52.8 - 65.7 - 75.1 - 82.5 mill. Rs.

It will be seen that a break-even point (53.5 mill. Rs) can almost be reached in the second year of operation and that the following years would give increasing profit.

Such a narrow product mix would be vulnerable for changes in mild steel prices and production costs relationship and for changes in demand in the limited special foundry iron market. Above all the alternative would be vulnerable for less sucess in the stainless steel operation.

This is shown in Development scheme, Alt. 2, where reduced market shares are foreseen - from 6% in 1986/87 increasing to 15% in 1990/91.

The resulting contributions per year would go down to:

27.4 - 43.3 - 49.5 - 54.9 - 60.3 mill. Rs

Break-even point would be reached as late as in the 4. year and just a small profit would occur in the 5. year.

A different strategy is given in Development scheme, Alt.3.

Full concentration - beside the well known routine production of mild steel and foundry iron - is given to the stainless steel operation the first year.

In the 2 year the production of small quantities of steel grades known from the previous steel production periode in 1979 - 82, are taken up.

The further development in increasing quantities of these steel grades and penetrating into the higher quality fields is regarded as possible without disturbing the stainless steel operation.

We consider this development into the special steel area as necessary and the resources to do so must be made available. The development rate cannot be predicted or nailed down in a fixed program, but the development scheme gives an example that would give contribution per year of:

30 - 56.2 - 72.7 - 85.8 - 96.5 mill. Rs.

The break-even point is reached in the 2 year of operation, and the profit made the following years are most satisfying.

The influence of a less sucessful stainless steel operation can with a somewhat intensified development in special steels, be substancially reduced.

This is shown in Development scheme, Alt. 4.

Market shares in stainless steel is foreseen to 6-15%, as in Alt. 2, but the contributions per year are maintained on an acceptable level:

30.2 - 52.4 - 63.2 - 73.5 - 82.0 mill. Rs.

The strategy in alternative 3 is most successful and should be aimed at. Besides the stainless steel operation spring steel should be a reliable product - no great problems in production and good demand in the market.

The "B/C" grades of the case hardening steel group and the carbon steel group should also create minor problems in produciton and marketing.

The MEL ambitions, however, should be to increase the production voulme of the grade "A" with high quality stringency and premium prices.

In our opinion the medium carbon steels for wire rod are interesting with good demand in the market and good prices. Sufficient level of steel technology to cope with quality claims must be developed anyway.

Regarding the further development beyond the 5. year of operation, we think that the same strategy should be followed, building up the technology in production and the reputation in the market for stainless steel and premium grades of special steels.

From the development scheme, Alt. 3, it will be seen that the stainless steel and special steel production will after 5 years, approach a level that leaves only the minimum of mild steel and foundry iron quantities in the product mix. With a continuing successful development more pig iron may be needed together with more steel-making capacity.

The MEL plant should at this stage have a steel technology, a production organisation and a market reputation that should be very competitive and a stepwise development as given below is considered as realistic with an existing 10% increase in market demand per year.

1. Step

Installing pre-reduction of iron ore prior to smelting in furnace no. 1.

Tonnage of pig iron per year: 100,000 tonnes. Changing from two shift operation to 3 shift operation for special steels/mild steel would give a product mix tentatively estimated to:
40,000 tonnes of stainless steel
55,000 tonnes of special/mild steel
10,000 tonnes of special foundry iron.

2. Step

Converting the furnace no. 2 from ferromanganese to pig iron. Tonnage of pig iron per year 165,000 tonnes, steelmaking capacity increase by installing one new bottom stirred LD reactor, 30 t capacity, and a new 2-strands casting machine, prepared for a later 3. strand. Production tonnages tentatively estimated to:
50-60,000 tonnes of stainless steel
90-100,000 tonnes of special/mild steel
10-15,000 tonnes of special foundry iron.

3. Step

Introducing pre-reduction on pig iron furnace 2.

Increase in pig iron production to 200,000 tonnes.
Rebuildling CLU reactor and LD reactor for dephosphorization to 30 t capacity.
Installing one more strand on each of the casting machines.
Tentative production figures:
60-70,000 tonnes of stainless steel
120-130,000 tonnes of special/mild steel
10-20,000 tonnes of foundry iron.

5.4.10 Conclusions

The pig iron and steel operation at MEL can be restarted on a sound techno/economical basis, providing that certain conditions are fulfilled:

- The pig iron operation must reach a level of good metallurgical control and give a pig iron with acceptable variations in composition and temperature.

- A pig casting machine has to be installed to sell important pig iron quantities as special foundry iron.

- Investment estimated to 17. mill. Rs is needed to modify the steel plant to a compined production of stainless steel and special steels.

- The stainless steel operation based on the CLU process is regarded competitive, and contract conditions regardig know-how assistance and training are satisfying.

Regarding special steel operation MEL should have high ambitions and go into areas where quality stringency is demanded.

Know-how and training assistance should be provided for, also in this field.

Establishing a highly qualified staff on all levels must be done by adequate recruiting and training programs. The MEL management must achieve a deep penetration of knowledge and skill into all staff levels and obtain a well controlled operation performance.

This represents a great challenge that has to be met successfully. Steel technology on a high level and a well organized operation are the only reliable weapons for MEL in the fight for a sucessful future in the steel business.

Encl. 5.4. a
Page 1

Maharashtra Elektrosmelt Limited

Registered Office: Nirmal, 2nd Floor, Nariman Point, Bombay 400 021.
Telephones: 2024285 (5 Lines) Grams: ELEKSMELT Telex: 011-5652

Ref: Tech/NC2/NT/ 9795

7th November, 1984

M/s. Elkem a/s.,
Middelthunsgt 27,
Oslo 3,
Norway.

Kind attn: Mr. Birger Ydstie/Mr. Magne Mohagen

Dear Sirs,

We have recently compiled most of the information desired by you and the same is enclosed in Annexure I and II. Kindly note that Annexure I is not sales plan, but gives realistic estimate of the quantities of different grades which can be sold provided we are able to produce them economically. The cost estimates for steels other than stainless steel are not available with us at present. Hence it is difficult to ascertain whether steels of other grades would give positive contribution or not.

We have received your telex informing about the proposed visit. We welcome you and Mrs. Ydstie to India.

Thanking you,

Yours faithfully,
for MAHARASHTRA ELEKTROSMELT LIMITED

Nishant

(NISHANT TANKSALE)
DY. GENERAL MANAGER

Encl: As above.

ANNEXURE I

SALES FORECAST

Sr.No.	STEEL	85-86	86-87	87-88	88-89	89-90
1)	**Stainless Steel**					
	Billets	200	100	100	150	Nil
	Flats	1500	2000	2500	2700	3000
	Rounds	300	350	400	450	500
	Heavy Guage	Nil	50	100	200	500
	Total:	2000 pm	2500 pm	3000 pm	3500 pm	4000 pm
		24,000 pa	30,000 pa	36,000 pa	42,000 pa	48,000 pa
2)	**Spring Steel**					
	Billets	1000	1200	1500	2000	2500
	Flats 80 x 10mm 100 x 12mm	-	100	-	-	-
	Rounds (40mm dia)	-	-	100	-	-
		1000 pm	1300 pm	1600 pm	2000 pm	2500 pm
		12,000 pa	15,600 pa	19,200 pa	24,000 pa	30,000 pa
3)	**HC Wire Rod Steel (0.4 - 0.6% C)**					
	Billet/Rod/Wire	500 pm	1000 pm	1200 pm	1400 pm	1600 pm
		6,000 pa	12,000 pa	14,400 pa	16,800 pa	19,200 pa

.....2/-

Sr.No.	STEEL	85-86	86-87	87-88	88-89	89-90
4)	Electrode Quality Steel					
	Billets/6/8mm wire	500 pm	750 pm	1000 pm	1250 pm	1500 pm
		6,000 pa	9,000 pa	12,000 pa	15,000 pa	18,000 pa
5)	Carbon Construction Steel					
	Billets/Rounds	1000 pm	1500 pm	2000 pm	2500 pm	3000 pm
		12,000 pa	18,000 pa	24,000 pa	30,000 pa	36,000 pa
6)	Alloy Construction Steel					
	Billets/Rounds	1000 pm	1500 pm	2000 pm	2500 pm	3000 pm
		12,000 pa	18,000 pa	24,000 pa	30,000 pa	36,000 pa
	TOTAL:-	72,000 pa	1,02,600 pa	1,07,600 pa	1,57,800 pa	1,87,200p

Detailed Chemical Composition of desired Finished Products (Steel)

Specification Type and Application		C	Mn	Si	Ni	Cr	Mo	S Max	P Max	Others
1. EN 8	"40" Carbon Controlled grain (Mo Quid-Ehn grain size of 5-8)	.35/.45	.6/1.0	.05/.35	-	-	-	0.03	0.03	-
2. EN 9	55 carbon steel suitable for cylinders, gears, machine tools, rifle barrels etc.	.50/.60	.50/.80	.05/.35	-	-	-	0.03	0.03	-
3. EN 24	For heat treated components of larger sections and subject to very exact requirements such as connecting rods, ear shafts, propeller shafts, camp shafts etc.	.35/.45	.45/.70	.10/.35	1.3/1.8	.90/1.40	.20/.35			

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Detailed Chemical Composition of desired Finished Products (Steel)

Specification	Type and Application	C	Mn	Si	Ni	Cr	Mo	S Max	P Max	Others
5. EN 45	Silicon Manganese Spring steel for oil hardening & Tempering	.50/.60	.70/1.0	1.5/2.0	-	-	-	0.03	0.03	
6. 20MnCr5	Case hardeing steel	.17/.22	1.0/1.4	0.1/0.35	-	1.1.3	-	.05	.05	
7. EN 45A	Silicon Manganese Spring steel for oil hardening & Tempering	.55/.65	.7/1.0	1.5/2.0	-	-	-	0.03	0.03	
8. 16MnCr5	Case hardening steel	.14/.19	1.1/3	0.1/.35	-	0.8/1.1	-	.05	0.05	
9. AISI 302	Austenitic Stainless steel	0.15	2.0	1.0	8.10	17.19	-	.03	.045	
10. AISI 304	Austentic Stainless steel	0.08max.	2.0max.	1.0 max.	8.5/10.5	18/20	-	.03	.045	
11. AISI 310	Austenitic Stainless steel	0.06max.	2.0max.	1.5max.	19/22	24/26	-	.03	.045	
17. SAE 1010	Cold heading steel	08/0.13	0.4	0.1				0.04	0.04	
18. SAE 1006	Electrode grade quality	.08max.	0.3	0.03				0.04	0.04	

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Market situation - Stainless steel

Estimated MEL sale potensials, prices and margins

Product	Est.MEL sales potential 1000 t/year years					Price Rs/kg	Prod. & delivery cost			Margin Rs/kg
	1.	2.	3.	4.	5.		billets Rs/kg	rolling Rs/kg	tot. Rs/kg	
Total market	86/87 117	89/88 128	88/89 140	89/90 155	90/91 170					
MEL sales potential										
Billets	2.4	1.2	1.2	1.5	0	20.50	18.6			1.90
Flats	18	24	30	32	36	24.55	18	4	22	2.50
Rounds	3.6	4.2	4.8	4.8	6	29	18	6	24	5
Sheets 22 gange						35	18	13.50	31.50	3.50
-- " -- 14-18 gange	0	0.6	1.2	2.4	6	33	18	12	3	3
SUM sales potential	24	30	37.2	40.7	48					

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Encl. 5.4.c

Market situation - Carbon and low alloyed steels

Estimated MEL sale potensials, prices and margins

Product	Total market pot. 1000 t/year 1985	Est.MEL sales potensial 1000 t/year years 86/87	87/88	88/89	89/90	90/91	Price Rs/kg	Prod. & delivery cost billets Rs/kg	rolling Rs/kg	tot. Rs/kg	Margin Rs/kg
Billets:											
Spring steel	80	12	15.6	19.2	24	30	5,50	5,0			0,50
Wire rod, 0,4-0,6%C	22	6	12	14.4	16.8	19.2	6	4,75			1,25
Welding electrodes Cold heading steel	36	6	9	12	15	18	5	4,70			0,30
Constructional:											
Carbon steel	150	12	18	24	30	36	5,80	4,75			1,05
Alloyed steel, EN 24	60	12	18	24	30	36	8	7,10			0,90
16MnCr5							7	5,10			0,60
Mild steel, ord.grade	great						4,20	4,45			- 0,25
Sum special/steels		48	72.6	93.4	115.8	139.2					

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Encl. 5.4.c

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CONFIRMATION OF ~~TELEGRAM~~/TELEX

From
MAHARASHTRA ELEKTROSMELT LTD.
Nirmal, 2nd Floor, Nariman Point.
Bombay 400 021.
Telephones : 2024285
Telex : 011-5652

To
M/S. ELKEM A/S.
MIDDELTHUNSGT 27
OSLO 3
NORWAY.

TLX: 78 229

Our Ref : Tech/NC2/NT/11346

Date 14th Dec. '84.

We Confirm having sent the following ~~Telegram~~/Telex

KIND ATTN: MR. BIRGER YDSTIE

AS REQUESTED BY YOU WE ARE GIVING HEREUNDER FORECAST FIGURES FOR 5 YR OPERATION.

THE CLU PROCESS IS EXPECTED TO START EARLIEST BY JAN '86. JAN '86 TO JUNE '86 ALL PRODUCTION WOULD BE TRIAL PRODUCTION. FOR 5 YRS STARTING FROM JULY '86 THE FIGURES WOULD BE AS FOLLOWS:-

(ALL FIGURES IN THOUSAND MT)

GRADE	86/87	87/88	88/89	89/90	90/91
STAINLESS	10	15	20	25	30
SPRING	-	5	6	6	6.5
CASE HARDENING	-	4	5	6	6.5
MS/CS	-	5	7	7	7
PI	15	18	20	22	25

N.B. THE GRADE CLASSIFICATION AS GIVEN ABOVE IS ON BROAD BASIS AND INCLUDING VARIOUS GRADES OF SIMILAR COST AND PRICE.

.....2/-

Encl. 5.4.e
Page 2

13

CONFIRMATION OF ~~TELEGRAM~~/TELEX

From
MAHARASHTRA ELEKTROSMELT LTD.
Nirmal. 2nd Floor. Nariman Point.
Bombay 400 021.
Telephones : 2024265
Telex : 011-5652

To

:: 2 ::

Our Ref : Tech/MC2/NT/

Date 14/12/84

We Confirm having sent the following ~~Telegram~~/Telex

(ALL FIGURES RS/MT)

GRADE	COST/TON BILLET	PRICE/TON BILLET
STAINLESS STEEL	18,000	20,000
SPRING	4,800	5,300
CASE HARDENING	5,000	5,600
MS/CARBON	4,000	4,200
PI	3,000	3,250

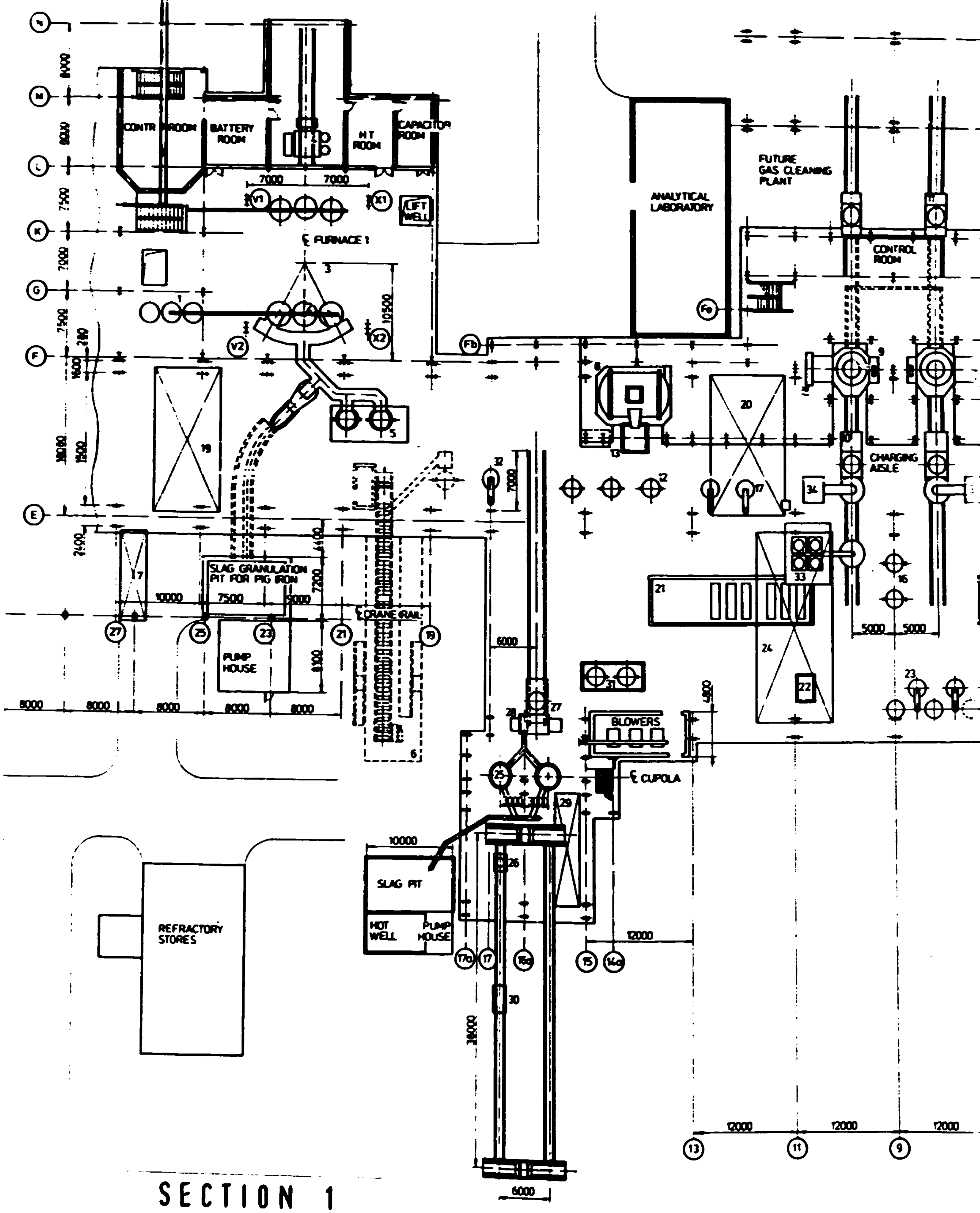
N.B. THOUGH PRODUCTION OF BILLETS, ROUNDS, STRIPS ETC. IS ENVISAGED THE FIGURES GIVEN ABOVE ARE AFTER CONVERTING BACK TO BILLET STAGE. COSTS AND PRICES ARE AS EXISTING AT PRESENT. IT IS ENVISAGED THAT INCREASE IN COST WOULD BE COMPENSATED BY INCREASE IN PRICE.

OUR M.D. IS EXPECTED TO BE IN OSLO ON 17TH DEC. THESE FIGURES MAY BE SHOWN TO HIM FOR ANY ALTERATIONS IF REQUIRED. I HOPE THAT YOU WILL FIND THE ABOVE AS PER YR REQUIREMENTS. SHOULD YOU REQUIRE ANY ADDITIONAL INFORMATION, WE WOULD BE PLEASED TO FURNISH THE SAME.

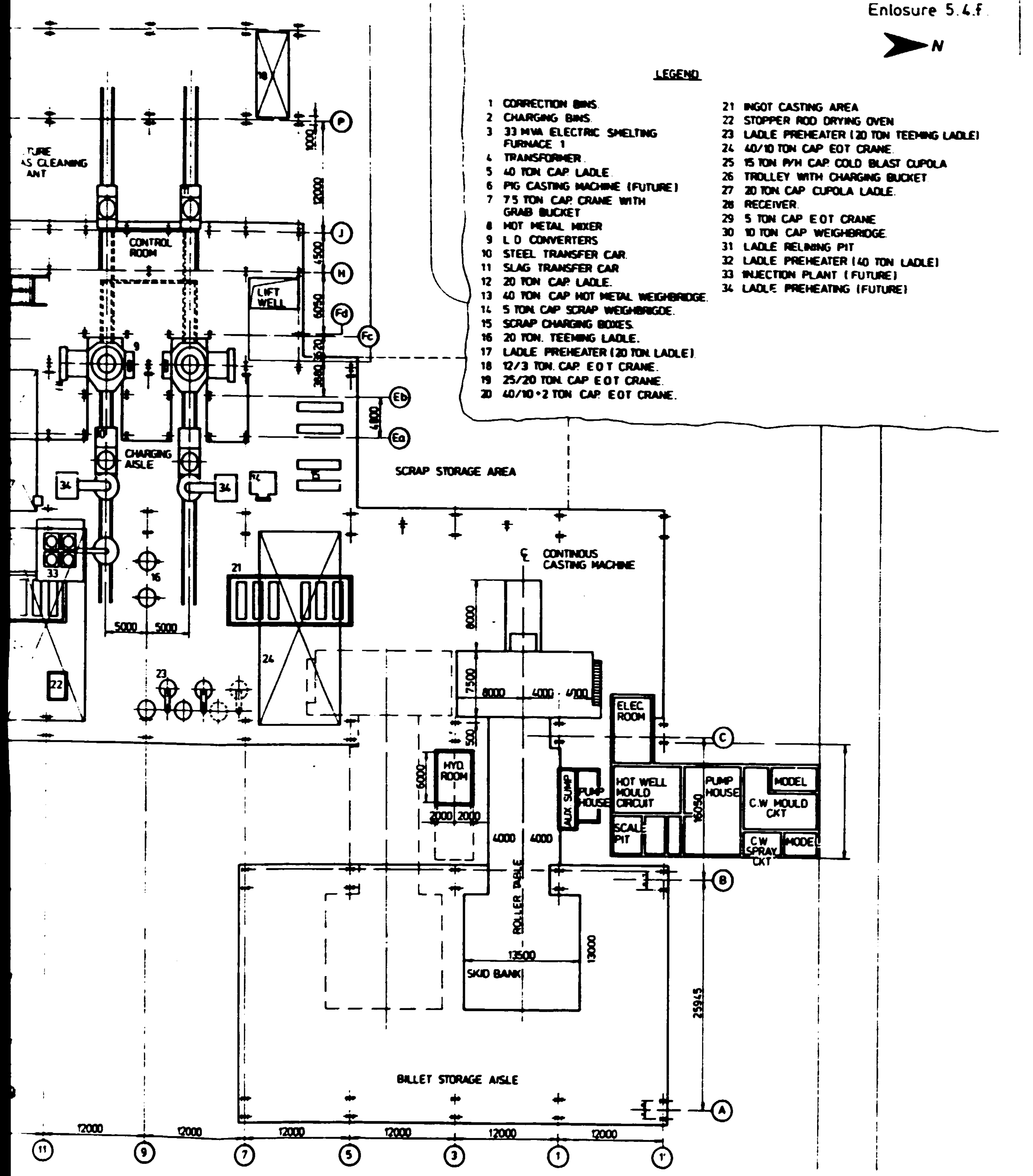
WARM REGARDS,

Nishant

(NISHANT TANKSALE)


CONTR ROOM
BATTERY ROOM
HT ROOM
CAPACITOR ROOM
7000
7000
LIFT WELL
FURNACE 1
10500
FUTURE GAS CLEANING PLANT
ANALYTICAL LABORATORY
CONTROL ROOM
CHARGING AISLE
SLAG GRANULATION PIT FOR PIG IRON
10000
7500
9000
CRANE RAIL
PUMP HOUSE
8000
8000
8000
8000
8000
6000
5000
5000
BLOWERS
CUPOLA
10000
SLAG PIT
HOT WELL
PUMP HOUSE
12000
REFRACTORY STORES
38000
12000
12000
12000
6000
SECTION 1

Enlosure 5.4.f



SECTION 2

MAHARASHTRA ELEKTROSMELT LTD., CHANDRAPUR
STEEL MELTING SHOP LAYOUT.

1-69909

Material balance - Stainless Steel - Dephosphorising step

Raw materials	Amount kg	Fe	FeO	C	Si	SiO_2	Mn	MnO	Cr	Cr_2O_3	Ni	P	S	CaO	MgO	Al_2O_3
Pig iron	688	635		26	9.5		8					0.6	0.3			
NiO	101										91					
Scrap international	40	29							7.5		2					
purchased	25	22														
Lime	80					2								72	3	1
O_2, Nm^3	42	-14	+ 18	-25.6	-9.5	+20	-5	+6	-1.5	+2						
Sum		672	18	0.4	0	22	3	6	6	2	93	0.6	0.3	72	3	2
Losses,dust etc.3%		22				1					2			3		
Sum, net		650	18	0.4	0	21	3	5	6	2	91	0.6	0.3	69	3	2
In metal	761	650		0.4	0		3		6		91	0.2	0.1			
%		86.5		0.05			4		0.8		12	0.026	0.013			
In slag	121		18			21		5		2	0	0.4	0.2	69	3	2
%			15			17.5		4.5		1.8		0.35	0.18	58	2.5	1.6

$$\frac{Ca + MgO}{SiO_2} = 3,5$$

Encl. 5.4.g

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Encl. 5.4.h
Page 1

Heat balance

1. step of stainless steel production

Dephosphorization in LD converter

Heat input			Heat output	
Pig iron, 688 kg,1300°C		778MJ	Preblowm metal	
Slag formation			606 kg Fe,1700°C	877 MJ
9.5kg $Si-SiO_2$	308		91 kg Ni 1700°C	110 "
5kg Mn-MnO	35		10 kg Mn/Cr, 1700°C	12 "
12kg Fe-FeO	57		Slag 121 kg, 1700°C	177 "
100kg Ca_3SiO_5	50	"	20 kg dust	30 "
			Offgases	135 "
1.6 kg $Cr-C_2O_3$	17	467 "	Heat loss through vessel 1)	120
			Heat surplus	155
Decarburising				
25.6kgC-CO/CO_2		326MJ		1606MJ
110.7kg NiO-Ni		35 "		
		1606MJ		

1) Heat loss though vessel calculated from measured value from Mefos:
Mefos: capacity 6 t, heat loss 25 MJ/min. Heat loss dependent on vessel surface, not volume, hence for 15 t vessel:

$$25 \times \frac{15}{6} \; 2/3 \qquad = \quad 45 \text{ MJ/min.}$$

40 min. treatment time	1800 MJ
Heat loss per tonne	120 MJ

Material balance - Stainless Steel - CLU step

Raw materials	Amount kg	Fe	FeO	C	Si	SiO_2	Mn	MnO	Cr	Cr_2O_3	Ni	P	S	CaO	MgO	Al_2O_3
Preblown metal	761	650		0.4			3		6		91	0.2	0.1			
Charge chrome 56%	340	110		23	13				190		0.1	0.1				
FeCr, LOW C, 65%	6	2							4							
FeSi, 75%	40	9			30											
Oxygen, Nm^3	42	5	6	-24	35	75	-3	4	-4	6						
Fe Mn	[illegible]	5		1			15									
Lime	130					2								117	4	2
Sum		79	6	0.4	8	77	15	4	196	6	91	0.3	0.1	117	4	
Losses, dust etc. 2%		20	-	-	-	2			3		2			2		
Sum, net		151	6	0.4	8	75	15	4	193	6	89	0.3	0.1	115	4	2
In metal	1057	751		0.4	8		15		193		89	0.3	0.1			
As billets, 1000kg, %				0.04	0.75		1.4		18.2		8.5	0.028	0.01			
In slag	212		6			75		4		6		0.3	0.1	115	4	2
%			3			36		1.9		2.8		0.13	0.04	55	1.9	1

$$\frac{Ca + MgO}{SiO_2} = 1,6$$

1811C54EM1

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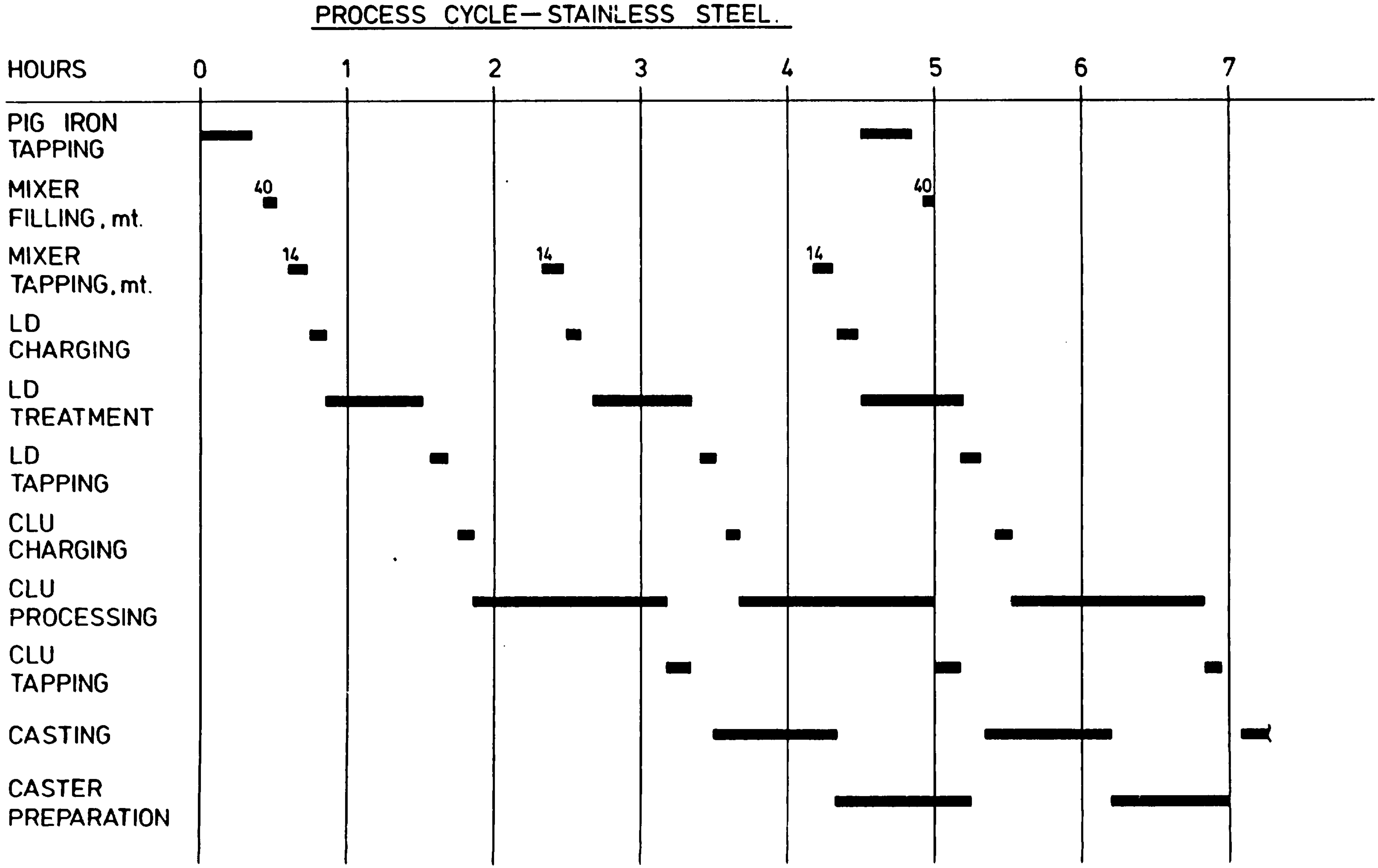
Encl. 5.4.j

Heat balance

Stainless steel - CLU-process

Heat input		Heat output	
Preblown metal		Metal	
650 kg Fe, 1650°C	931	751 kg Fe, 1700°C	1086
		193 " Cr, "	207 "
91 " Ni, "	110 "	89 " Ni, "	116 "
		8 " Si, "	26 "
		15 " Mn, "	24 "
Slag formation			
13 kg Si-SiO_2,ch.chr.	417 "	Slag	
22 kg Si-SiO_2,FeSi add.	706 "	115 kg CaO 1700°C	180
form. 2 CaO-SiO_2	128 "	75 " SiO_2 "	145 "
4 kg. FeO	15 "	22 " others "	35 "
4 " MnO	22 "	gases	
6 " Cr_2O_3	45 "	12 Nm3 H_2O-H_2	129 "
Decarburising		12 Nm^3 H_2 1500°C	24 "
24 kg C- CO/CO_2	276 "	45 Nm^3 CO/CO_2,1500°C	102 "
		3 Nm^3 Ar, 1500°C	4 "
	2650 MJ	Heat loss from vessel	
		45 MJ/min. 80 min:20t	180 "
		Heat surplus	392 "
			2650 MJ

1811C54N1



Enclosure 5.4.k.

MATERIAL BALANCE - WIRE ROD BILLETS

kg/tonne of billets

Raw materials	amount	Fe	FeO	C	Si	SiO_2	Mn	MnO	P	S	CaO	MgO	Al_2O_3	Anm
Pig iron	1000	935		38	14		12		1	0,2				
Scrap, internal	60	59												
Scrap, purchase	80	78												
Lime	105					2					95	3	2	
Oxygen, Nm^3	62	-20	+26	-37,5	-14	+30	-9	+11,5						
Sum		1052		0,5	0	32	3	11,5	1	0,2	95	3	2	
Losses, 2%		20				0,6		0,2			2			
Sum		1032	26	0,5	0	31,4		11,3	1	0,2	93	3	2	
In metal	1042,8	1032		0,5			3		0,2	0,1				As tapped
%				0,05			0,3		0,02	0,01				
In slag	167		26			31,4		11,3	0,8	0,1	93	3	2	
%			15,5			18,8		6,7	0,5	0,06	55,7	2	1	B = 3,1
Alloying, FeSi	3,5	1			2	1								Ladle
FeMn	7,5	1,5		0,5			4,5	1						additions
C				4,5										C-Injection
Sum metal	1049	1035		5	2		7,5		0,2	0,1				
Billets, 1000 kg, comp. %:				0,5	0,2		0,75		0,02	0,01				

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Encl.5.4.m

Heat balance

Wire rod billets production

MJ per tonne billets

Heat input			Heat output	
Pig iron, 1000 kg, 1300°C		1130MJ	Steel, 1700°C	1520
slag formation			Slag, 1300°C	270
14kg Si-SiO_2	454		Dust, 20 kg	30
9kg Mn-MnO	63		Off gases, 1500°C	190
20kg Fe-FeO	95		N_2/Ar-stirring gas	6
120kg Ca_3SiO_5	60	672 "	Heat loss vessel	135
			Heat surplus	129
Decarburising				2280MJ
37.5 kgC-CO/CO_2		478 "		
		2280MJ		

Treatment time 45 min.

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INJECTION SYSTEM LAY-OUT

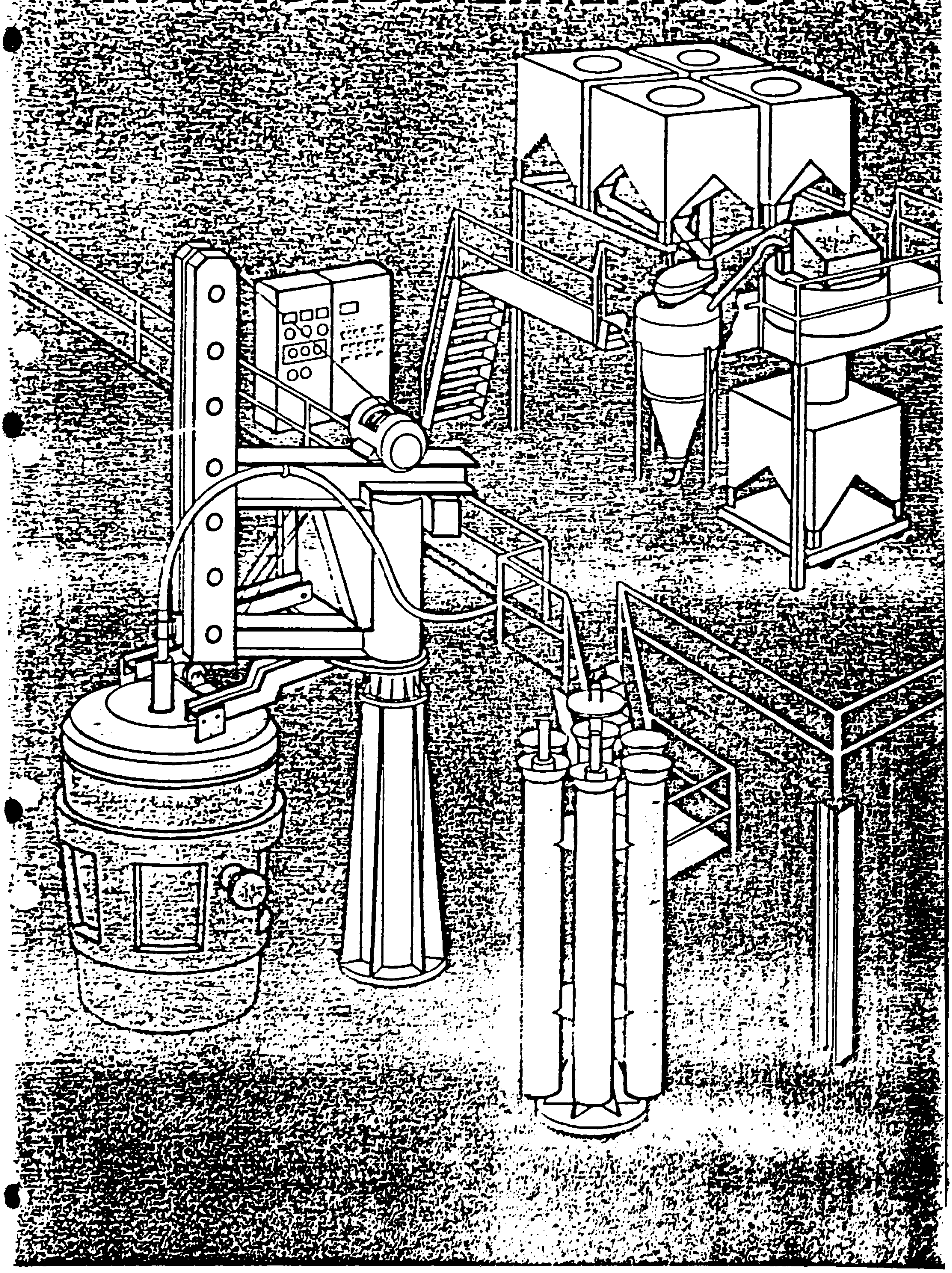
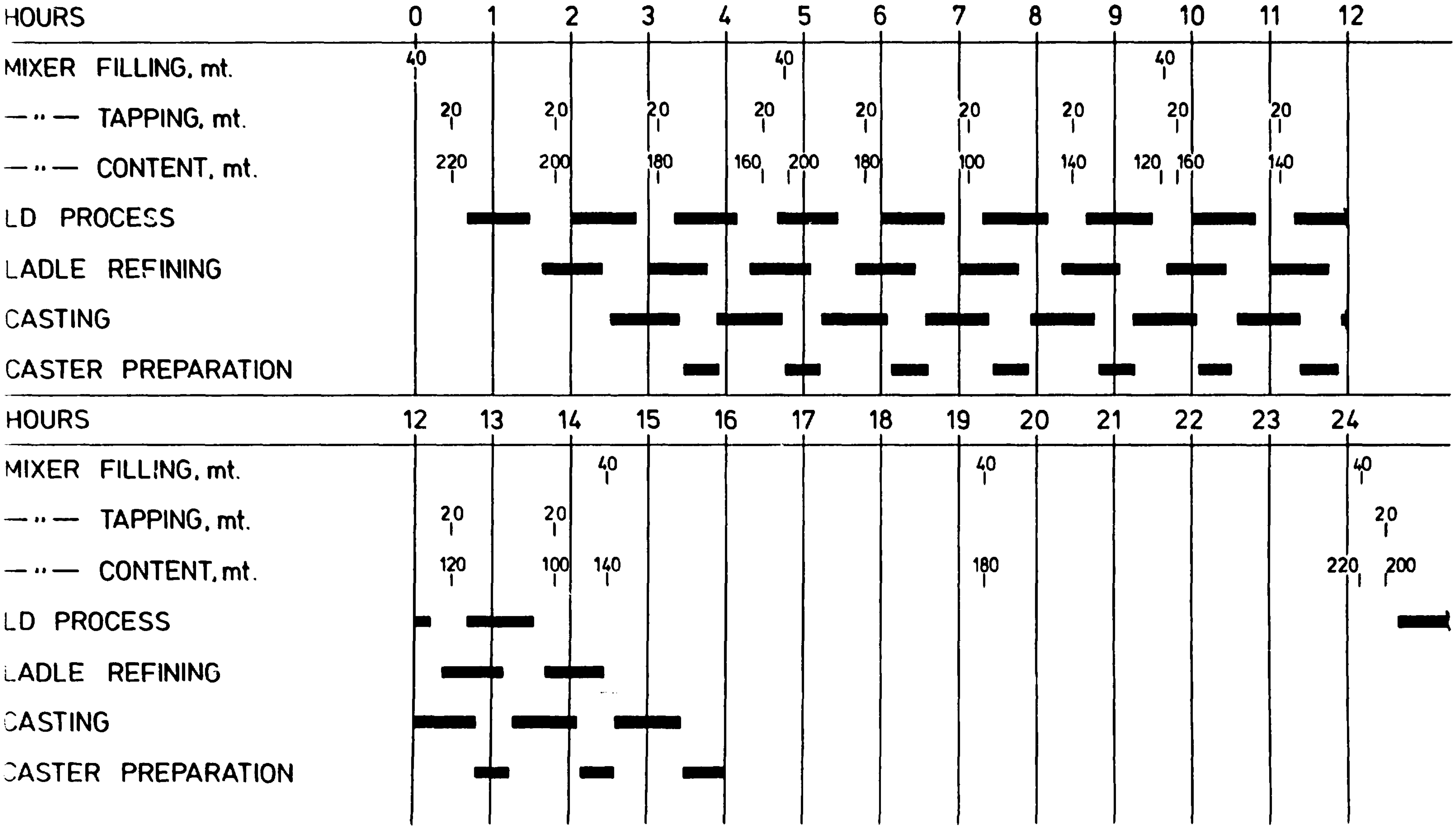


FIGURE 2

PROCESS CYCLE — CARBON AND LOW ALLOYED STEELS.



Enclosure 5.4.c

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Stainless steel billets

	Kg/t	Rs/Kg	cost, Rs/t
Pig iron	688	2.70	1858
Ni in NiO	91	105	9555
Scrap, internal	40		
Scrap, purchased	25	2	50
Lime	80	0.70	56
Fluorspare	6	4.35	26
Consumables			80
Refractories			225
Stores & spares			30
Power & fuel			60
Power fixed O_2 plant			118
Contract labour			50
Preblown metal			12.078
Chargechrome	340	12	4080
FeCr, low C	6	30	180
Ni	1	130	130
FeMn, HC	21	3.5	74
FeSi	40	10	400
Lime	130	0.7	91
Ar, Nm^3	3	60	180
Steam	12	0.50	6
Lining	27	5.00	135
Maintenance			50
Casting			200
			17.604
Royalty, CLU-process			54
15% interest on raw materials for 2 mths, based on 30.000 t/year			160
Selling expenses			15
Interest on working capital			135
Increase in labour force 4 men per shift			4
Increase in ladle refractory wear			10
Direct costs per tonne of billets			17.982

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Production costs

Carbon Steel billets

	Kg/t	Rs/Kg	cost, Rs/t
Pig iron	1000	2.70	2.700
Scrap internal	60	-	-
Scrap, purchased	80	2.00	160
Lime	105	0.70	74
Fluorspare	6	4.35	26
Consumables			80
Refractories			225
Stores and spares			30
Power and fuel			60
Power fixed 0_2 plant			118
Contract labour			50
Selling expences			15
Interest on working capital			135
Alloying and injection			
FeMn, HC	7.5	3.50	26
FeSi, 75%	3.5	10	35
Carbon, 80% yield	5.5	3	17
Lime	10	0.7	7
Lances			
Ar/N_2 for stirring and injection			90
Ladle refractory increase			10
Total direct costs per tonne of billets			3.873

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Development scheme for MEL steel operation

Alt.1

Year		1986/87		1987/88		1988/89		1989/90		1990/91	
Product	Contrib. Rs/kg	tonnage 1000 t	Contrib mill.Rs	Tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs
Stainless steel (Market shares.%)	2	10 (8)	20	20 (16)	40	27 (19)	54	32 (20)	64	36 (21)	72
Spring steel											
Case hardening steels											
grade A											
grade B/C											
Carbon steels											
grade A											
grade B/C											
Mild steel	0.20	25	5.0	31	6.2	21	4.2	18	3.6	15	3.0
Spec. foundry iron	0.30	20	6.0	22	6.6	25	7.5	25	7.5	25	7.5
Sum			31.0		52.8		65.7		75.1		82.5
Pig iron consumpitor		52		65		65		65		65	

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Development scheme for MEL steel operation

Alt.2

Year		1986/87		1987/88		1988/89		1989/90		1990/91	
Product	Contrib. Rs/kg	tonnage 1000 t	Contrib mill.Rs	Tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs
Stainless steel (Market shares.%)	2	8 (6)	16	14 (11)	28	18 (13)	36	21 (14)	42	24 (15)	48
Spring steel											
Case hardening steels											
grade A											
grade B/C											
Carbon steels											
grade A											
grade B/C											
Mild steel	0.20	27	5.4	39	7.8	30	6.0	27	5.4	24	4.8
Spec. foundry iron	0.30	20	6.0	25	7.5	25	7.5	25	7.5	25	7.5
Sum			27.4		43.3		49.5		54.9		60.3
Pig iron consumpitor		52		65		65		65		65	

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Development scheme for MEL steel operation

Alt.3

Year		1986/87		1987/88		1988/89		1989/90		1990/91	
Product	Contrib. Rs/kg	tonnage 1000 t	Contrib mill.Rs	Tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs
Stainless steel (Market shares.%)	2	10 (8)	20.0	20 (16)	40.0	27 (19)	54.0	32 (20)	64.0	36 (21)	72.0
Spring steel	0.50			2	1.0	5	2.5	6	3.0	7	3.5
Case hardening steels grade A	1.90							1	1.9	2	3.8
grade B/C	0.60			2	1.2	4	2.4	5	3.0	6	3.6
Carbon steels											
grade A	1.80			1	1.8	2	3.6	3	5.4	4	7.2
grade B/C	0.40			4	1.6	6	2.4	8	3.2	7	2.8
Mild steel	0.20	25	4.0	20	4.0	9	1.8	7	1.4	6	1.2
Spec. foundry iron	0.30	20	6.0	22	6.6	20	6.0	13	3.9	8	2.4
Sum			30.0		56.2		72.7		85.8		96.5
Pig iron consumpiton		52		65		65		65		65	

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Development scheme for MEL steel operation

Alt.4

Year		1986/87		1987/88		1988/89		1989/90		1990/91	
Product	Contrib. Rs/kg	tonnage 1000 t	Contrib mill.Rs	Tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs	tonnage 1000 t	Contrib. mill.Rs
Stainless steel (Market shares.%)	2	8 (6)	16.0	14 (11)	28	18 (13)	36.0	21 (14)	42.0	24 (15)	48.0
Spring steel	0.50	2	1.0	5	2.5	6	3.0	8	4.0	8	4.0
Case hardening steels											
grade A	1.90			1	1.9	2	3.8	3	5.7	4	7.6
grade B/C	0.60	3	1.8	4	2.4	5	3.0	6	3.6	7	4.2
Carbon steels											
grade A	1.80			2	3.6	4	7.2	5	9.4	6	10.8
grade B/C	0.40	5	2.0	5	2.0	6	2.4	7	2.8	8	3.2
Mild steel	0.20	17	3.4	17	3.4	12	2.4	9	1.8	6	1.2
Spec. foundry iron	0.30	20	6.0	22	6.6	18	5.4	14	4.2	10	3.0
Sum			30.2		52.4		63.2		73.5		82.0
Pig iron consumpiton		52		65		65		65		65	

1811C54EV4

6

6. SUMMARY OF RECOMMENDATIONS

Recommendations regarding products and processes are given in each separate chapter of this report. A summary of the most important recommendations will be given in this chapter.

The recommendations are listed in order of priority.

The summary will also include products and/or processes suggested in UNIDO's Terms of Reference, which will not be recommended.

1. Improvements in the existing ferro manganese production

This is given the highest priority because of short-time effect on results and limited expenses and efforts to obtain the improvement.

a) The manganese ore mixture should, if possible, be lower in silica.

b) The manganese ore mixture in the furnace burden should have a more consistent composition.

c) The basicity of the slag should be lowered, and the MnO content should be between 25-30%.

d) Carbon balance should be better controlled to avoid overcoking of the furnace.

Efforts to be made:

a) Purchasing of more low-silica ore

b) Higher manganese ore inventory, bedding and blending procedures should be introduced.

c+d) Intensive sampling and analysing work has to be performed.

Results:

- Improved manganese recovery
- Reduced consumption of reductants and electrodes

- Better furnace performance, reduced dust loss
- Approximately 800 Rs per tonne reduction in production costs

With an improved ferro manganese operation standard ferromanganese is recommended as a part of the MEL product mix until the steel operation demands that the furnace is converted to pig iron.

2. Steel Operation

Our studies have convinced us that a steel operation, based on pig iron from the electric smelter and with stainless steel and premium priced special steels as the main products, is the best way to bring the MEL plant into a profitable enterprise.

To establish such an operation following recommendations are given:

a) Repair of partly damaged lining of the pig iron smelter.
Investment cost up to 2.5 mill. Rs

b) Restarting the pig iron furnace and establishing a well controlled smelting operation, taking into account the recommendations given in Chapter 5.3. Expert assistance is recommended.

c) Installing a pig casting machine to secure a market outlet for surplus pig iron as special low phosphorous foundry iron.
Investment costs - approx. 5 mill. Rs

d) Rebuilding one LD reactor to the CLU process for stainless steel.
Investment costs - approx. 10 mill. Rs

e) Installing sliding gate nozzles in the teeming ladles.
Investment costs - approx. 1 mill. Rs

f) Changes on tundishes for use of stopper rods and casting tubes.
Investment costs - approx. 0.3 mill. Rs

g) Powder burners for billet cutting.
Investment costs - approx. 0.2 mill. Rs

h) Know-how assistance and training assistance from Uddeholm.
Programme for recruiting, educating and training must be worked out and followed up.

All the listed activities are necessary to establish the stainless steel process and will have the first priority.

We will however strongly recommend that the further activities listed below are accomplished parallel to the activities listed above, to obtain a well controlled production of other steel grades and enable production of special steels.

i) Introduce bottom gas stirring in the second LD reactor.
Investment costs - approx. 1.5 mill. Rs

j) Installing porous plugs in the teeming ladles.

k) Installing ladle injection equipment.
Investment costs - approx. 2.5 mill. Rs

l) Recommended know-how assistance for bottom stirring: MEFOS, Sweden.
Training assistance bottom stirring: Norsk Jernverk, Norway.
Know-how and training special steel production: Ovako Oy, Finland.
Recruiting, educating and training activities must be incorporated in programme mentioned under point h).
Cooperation with SAIL, Research and Development Centre is recommended in these matters.

m) Negotiations with actual rolling mills for hirerolling should be taken up.

n) Marketing programme should be worked out and contacts established in the market.

Sum of investments in production facilities is in the range of 20-25 mill. Rs.

The costs of know-how assistance and training programmes have not been evaluated.

A production development programme is recommended where a strong concentration on stainless steel is foreseen in the first year of operation with simple mild steel and foundry iron as supplementary products.

In the second year the special steel grades are introduced and the production increased in a moderate rate avoiding a negative influence on the stainless steel development.

An example of this development strategy is showing an increasing contribution from 30 mill. Rs the first year to 96.5 mill. Rs the fifth year of operation.

3. Other product areas/process routes listed as possible in UNIDO's Terms of Reference

3.1 Pre-reduction of iron ore in a rotary kiln prior to smelting:

The project is interesting. An investment of approximately 180 mill. Rs would give a saving in production costs of approximately 800 Rs per tonne of pig iron.

The pig iron production would increase to approximately 100,000 tonnes per year.

It is recommended to study this project in more detail when an increased tonnage of pig iron is needed, but it seems to be the best way to supply the base material for an increased steel production.

3.2 Smelting of Khursipur ore with recovery of vanadium:

This process has interesting aspects. The ore deposit is however not sufficiently investigated to calculate landed costs for the ore concentrate and a new smelting technology had to be developed with pre-reduction of the ore.

The investment would be in the 250 mill. Rs range.

Even if a rough calculation shows around 50 mill. Rs per year as additional value compared with smelting of an ordinary iron ore, this process has too many uncertain aspects to be recommended for MEL. Other titaniferrous ores with higher vanadium content exist in India, and there is a question if the MEL plant in Chandrapur would be the right place for smelting any of these.

3.3 Medium or low carbon ferro manganese:

Medium carbon ferro manganese would be an interesting product if based on oxygen blowing of high carbon ferro manganese, but the process technology is not commercially available and independant deelopment would be costly and time consuming. It is not recommended to go into this product.

3.4 Ferro chrome or charge chrome:

is not recommended. There is no chrome ore nearby Chandrapur and a substantial part of the production would have to be exprted to loss-bringing prices, mainly due to high power cost.

3.5 Installation of a small blast furnace for pig iron production:

MEL has considered the possibility but abandoned the project after information from the Kalinga Iron Works.

We support this decision.

3.6 Conversion of existing cold blast cupola furnaces into hot blast:

Cupola melted hot metal will not have a cost benefit against pig iron from the electric smelter that will outweigh the quality supremacy of pig iron, even from hot blast cupolas.

Conversion to hot blast is not recommended.

Pig iron is recommended as the main raw material for the high quality steel production.

4. Long-term development recommendations

We have recommended to establish, as soon as possible, a steel operation based on stainless steel and premium priced special steel grades and to keep up an improved ferromanganese operation. We do not, however, recommend ferro manganese as a part of the MEL product mix in the long run.

The surplus production capacity of ferro manganese will most likely last for several years, the power price will exclude export and the supply of high quality manganese ores in India is limited.

The foreseen development in the steel operation during the 5 first years of operation is dependant on success in building up the stainless steel and special steel technology, a well organised production and a good market reputation.

This means that MEL would have a strong competitive position in these niches of the steel market, while it is hard to see any competitive advantages in the ferro manganese operation.

We will recommend that MEL should take advantage of their competitive strength in the steel sector, where the market growth is more than 10% per year, and develop the MEL plant into a pure iron and steel works.

A stepwise development is indicated in Chapter 5.4, page 33:

Step 1 Installing pre-reduction of iron ore prior to smelting in furnace no. 1.
A full 3-shift operation in steelmaking would give tonnages tentatively estimated to 95,000 tonnes of steel billets and 10,000 tonnes of special foundry iron.

Step 2 Converting furnace no. 2 from ferro manganese to pig iron.
Investments in increased converter and casting capacity could bring tonnages up to 140-160,000 tonnes of steel billets and 10-15,000 tonnes of special foundry iron.

Step 3. Installing pre-reduction on furnace no. 2.
Investments in further increased converter and casting capacity could bring tonnages up to 180-200,000 tonnes of steel billets together with 10-20,000 tonnes of special foundry iron.

Installment of rolling facilities may become actual somewhere in this development scheme.