Integration of mini blast furnace with existing electric arc furnace for modernisation & expansion of Usha Martin Mini Steel Complex at Jamshedpur

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Introduction

Steel production through electric arc furnace has achieved substantial growth in the last decade. The advent of UHP electric arc furnaces, eccentric bottom tapping, secondary refining, continuous casting machine etc., has increased the flexibility of operating practices for manufacturing of various grades of steel with consistent quality and reduced cost.

Scrap constitutes the basic raw material input other than the electric power in the EAF. Scrap in India is not only scarce but the quality has been uniformly poor. The shortage and poor quality of scrap is a perennial problem in India and its fluctuating quality has wide ranging adverse effects in the EAF economy. Sponge iron has been a good substitute for scrap as far as tramp elements are concerned and many steel plants in India are using it upto 60-70% in the charge mix under compulsion due to non-availability of good scrap.

The latest trend in EAF steelmaking is use of cold pig iron upto 30% in the charge due to availability of pig iron from plants in the country. In order to use pig iron in the charge and utilise the enthalpy of hot metal Tata Korf has developed KORFARC process of steel making which is being implemented at Usha Martin with installation of a 215 cu.m. mini blast furnace along with necessaryt modifications in the EAF.

The mini steel plant of Usha Alloys & Steels Division (a Division of Usha Martin Industries Ltd.) at Jamshedpur with 30t Electric Arc furnace, ladle furnace, Billet Caster and Wire Rod Mill produces wire rods from 5.5 to 22.0 mm. High carbon wire rod grade constitutes approx. 60-70% of the total wire rod production. Cold Heading quality, Semi Freee Cutting and Free Cutting including Leaded Steel, electrode quality and ball bearing Steel etc. completes the rest 30% of the product mix.

Situation at Usha Martin before modernisation and expansion

The actual production results of liquid steel from May, 1991 to May '92 excluding July, 1991 (plant down due to transformer upgradation) and April '93 to March '94 were as follows :

	May'91 - May'92	Apr'93 - Mar'94
Days	366	365
Days lost due to no power	43	10
Days for maintenance	35	42
Operating days	288	313
Heats made	2204	2694
Tonnes made	66660	60674
Tonnes per heat	30.3	29.94
Heats per day	7.6	8.6

During the period May'91 to May'92 - under standard operation, tap to tap was 149 minutes which means that the plant should have produced 9.7 heats per day. The actual results represent an operating efficiency of 79.1% which could have arisen from a number of causes such as EAF operation under reduced power, poor scrap mix etc.

During the period 1991-92 the EAF operation consisted on a 2-bucket charge containing 33-34 T of metallics of which approx. 50% was charged in buckets and balance 50% DRI was fed continuously to the furnace from an overhead system.

In a typical heat, about 1.05 t of carbon was placed in the second bucket and 150 kg of carbon was being injected through a hand held pipe when the charge is melted. The melt in carbon was about 0.8% which was reduced to about 0.4% by hand held oxygen lance for tapping. Typical heat data was as follows :

Item	Unit	May'91-May'92	Apr'93-Mar'94
Liquid steel	t	29.94	29.94
Tap to tap time	min	149	149
Transformer	MVA	16	16
Power factor		0.82	0.82
Power	kWh/t	720	670
Electrode	kg/t	4.75	4.66

Metallic Charge (Typical) in EAF

Skull	%	5.07	4.56
Heavy melting	%	9.85	9.50
Shredded	%	31.35	9.46
DRI	%	53.73	48.50
Pig Iron	%	-	23.10
Others	%	-	4.88
Buckets/Charge		2	2
Tapping Temp.	Deg. C	1650	1650
Tapping Carbon	%	0-15-0.40	0.15-0.40

Data for year 1991-92 is given since the decision to install a mini blast furnace to produce hot metal and use the same in Electric Arc Furnace was taken in that particular year.

Expansion and modernisation

The situation at Usha Martin was not a comfortable one in the year 1991-92. Usha Martin decided to expand the steel producion and reduce the cost by Tata Korf Technologies. It is a well known fact that hot metal is the cheapest source of iron for steelmaking. Usha Martin decided to set up a mini blast furnace and integrate the same with the existing electric arc furnace with suitable modifications in the hardware of the EAF for accepting hot metal as charge instead of purchased scrap.

The application of the KORFARC process at the Usha Martin, Jamshedpur plant has been cosidered in combination with supply of hot metal to the modified EAF. The hot metal supply will be about 109,000 tonnes per year. All the hot imbalances and therefore, approximately 8000 tons of hot metal will be converted into pig iron for sale or subsequent use in the EAF.

The use of hot metal provides a very high proportion of the energy required in the process which reduces the electrical energy consumption and results in a significant increase in production. The production change is expected to be from about 80,000 tonnes of steel per year to about 150,000 tonnes per year. The proposed flow sheet of the plant is shown in Figure-1.

Potential steel production using hot metal and oxygen

As stated earlier the production from the MBF will be 109,000 tpa with 8000 tpa available as could pig iron and 101,000 as liquid iron for steel making.

The operating days for MBF will be 340 i.e., a daily production of about 320t. The production of steel in the EAF is possible without power also, however, this means a very high consumption of hot metal in the charge with an equivalent oxygen requirement.

Calculations show that the tap-to-tap time can vary between as low as 50 minutes up to 80 minutes depending on conditions in the shop and whether sequence casts are required.

The low furnace efficiency of 79% found before expansion can be overcome when applying hot metal and oxygen to the furnace. Production of liquid steel is expected to be as follows :

Item	Unit	
Heat weight	t	30.3
Heats	Per day	16
Maintenance	Days	40
Power on	Days	315
Power off	Days	10
Hot Metal	kg/t	617
Hot Metal	t/Day	320
Production	t	152,000

Besides the above, it is possible to produce steel from EAF by use of hot metal upto 80% in the charge even during non-availability of power. It is possible to make about 11 heats in a day with no power situation i.e., about 330 t/day.

Plant layout

The mini blast furnace has been constructed in the existing mini steel complex adjacent to the steel melting shop in order to facilitate easy hot metal handling by transfer cars as shown in Figure-2. Although the space available in the existing site was not adequate for storing large quantities of raw materials, the balst furnace along with its auxiliaries and a 3 MW captive power plant have been accommodated without any problem.

As far as the layout of steel melting shop was concerned, it was a good layout except arrangements for slag handling. A 17m wide bay has been accommodated in between the MBF and the SMS to facilitate slag handling and disposal by slag pots on transfer car and thereafter using payloaders and dumpers.

Hot metal handling

The MBF is located adjacent to the existing steel melting shop so that the hot metal from the furnace can cast into two ladles which are inline with the existing scrap track. The pig casting machine will cast surplus pig iron either for sale or for use in the furnace. The pig iron will be stored in the existing scrap bay.

The hot metal will be cast into two 20t ladles. These ladles will be placed on ladle cars and the ladle cars will be placed on wigh bridges in order to record the exact weight of iron in each ladle.

The casting arrangement in the MBF cast house includes a tilting launder so that iron can be diverted from the first ladle to the second when the desired quantity of iron is proured into the first ladle. The cast will be stopped when the iron in the second ladle has the desired quantity of iron. The ladles are having covers and can be kept hot for a long time by ladle preheaters.

The ladles will then be moved to the SMS where two heats will be made from one tap of about 40T from the MBF. No mixer has been provided and the concept of this layout is such that the iron has no intermediate transfers before the furnace, (saving in energy) and for any short delays the ladle heater will be used and in the case of long delays the iron will be cast into pigs.

Hot metal because of its chemistry will stay liquid for a considerable period (up to 8 hours) especially if the ladle is covered and heating is provided.

The maintenance of hot metal ladles will be done in the slag aisle using 15/5T crane.

Slag handling

The existing slag handling system from the furnace was cumbersome and presented a continuing threat to smooth operation of the furnace. The system utilised EOT crane for removal and placement of slag pot in the furnace pit.

A new concept has been provided in which the pot will be moved on a car to a new bay adjacent to the scrap bay from where pot changes can be effected and slag disposed from the building after cooling.

The mini blast furnace

The mini blast furnace of Tata Korf design is not a miniature version of the conventional large blast furnaces but has several features which are known for their simplicity and therefore, economy and which have been well tried and tested.

Mini blast furnace of size 215 cu.m working volume has been selected to produce 109,000 tpa of basic iron with 100% lump ore and imported coke of 12% ash content.

As far as the product quality is concerned, the silicon content in the iron can be controlled between 0.5 to 1.0% with lump ore, the sulphur content will be about 0.04% and the phosphorous, which depends on inputs, can be maintained below 0.1% with imported coke and most Indian iron ores.

The cold balst at the rate of 26,000 Nm^3/h will be generated at 1.3 kg/cm^2 sq. pressure through a set of six centrifugal fans coupled in series. The blast will be heated to a temperature of 850°C by metallic recuperators, coils of which have been imported from Spain and Brazil. These recuperators are inexpensive and simple to operate and maintain. The combustion system of the preheaters have been supplied by M/s. Thermax and will normally operate on blast furnace gas. Provision for LDO firing with all necessary interlocks in the instrumentation system (burner management system) has been provided.

Upto 250 cu. m mini blast furnaces, extensive operating data obtained in Brazil with Brazilian lump-ores and in several Indian plants employing imported coke and iron ores from Bailadilla, Goa, Bellary, Hospet, Daitari and Keonjhar have confirmed two fundamental process parameters (a) blast pressure in excess of 1.0 bar is never encountered and (b) the hot blast accepted by the mini blast furnace in the absence of any blast additive does not exceed 750°C. Hence, the above system of blast generation and heating is the most cost effective mehtod.

The cooling of MBF shell will be done by water spraying. High grade 62% Al_2O_3 refractories for the hearth, bosh and lower stack and 45% alumina bricks in the stack from M/s. TRL have been employed to assure a campaign of 4-5 years. The blast furnace is equipped with a modern raw material system supplied by M/s. TRF and computerised weighing, batching and conveyor charging facilities supplied by M/s. Philips.

The MBF has a top pressure of about 0.3 kg/cm^2, just enough to ensure a thorough gas cleaning by a double venturi scrubber system supplied by M/s. Rathi which will ensure a solid content of 5 Kg/Nm^3 in the clean gas with low sulphur content.

The çast house facilities include hydraulically operated mudgun and pneumatically operated taphole drilling machine of KORF design supplied by M/s. Sesa Goa to enable a high frequency of casts, upto 12 per day, ladle heating system from M/s. Incorporated Engineers, pig casting machine and a slag granulation sytem. The pig casting machine is of caroussel type with 27m diameter and 188 moulds to cast pigs of 5 kg. in weight.

The MBF is environment friendly unit with very efficient gas cleaning, effluent treatment and pollution control facilities. The system includes gas cleaning by dust catcher, saturator and a double venturi system. The clean gas will be used in the plant for heating the air for blowing into the MBF and for power generation in the 3 MW captive power plant. This in-plant usage of gas has completely eliminated the source of air pollution.

Water for the entire mini steel complex is brought from a river from Jamshedpur. This water is being treated and supplied to the MBF complex for shell and tuyere cooling of MBF, gas cleaning plant and slag granulation system.

Compressed air for the plant will be generated by three compressors supplied by M/s. Kirloskar Pneumatics. Emergency power will be provided by three 1 MW diesel generating sets.

All the raw materials will be brought to the plant by road and unloaded in the raw material storage yard or directly into the ground hopper by Hydraulic Truck Unloaders supplied by M/s. Usha Atlas. The raw materials will be stored in day bunkers having about 20 hours storage capacity and will be charged in the MBF after screening, batching and weighing by a PLC system.

Coke of size +15 - 60mm will be normally used in the MBF. However, in order to use the intermediate size of +8 - 15mm, a separate screening station with steep inclined conveyor (due to space constraint) has been provided. Iron ore of size +12 - 30mm will be used in the MBF after screening below the day bunkers.

Korfarc process

KORFARC process is an integrated system involving modifications to the hardware of the EAF (Electric Arc Furnace), minor changes in the furnace lining and changes to the operating methods and practices.

KORFARC is a process developed for the electric arc furnace in which electrical energy is partly replaced by oxygen, carbon or energy containing materials. The replacement of electrical energy provides a convenient means to increase energy input per unit time without large capital ivestment.

The process is based on the additon of exothermic materials to the scrap charge such as carbon added directly to the furnace before the first bucket of scrap is dropped into the furnace and then followed by carbon additions to subsequent buckets or injection depending on the desired results. These additions of carbon may be added loose and mixed with the scrap or may be added in steel containers or as carbon bearing materials such as liquid or solid pig iron or iron carbide etc.

In order to utilize the energy provided by carbon it is necessary to provide oxygen to the furnace at a flow rate sufficient to utilize the additional energy over the desired time period. The quantity of oxygen to be provided is maximum of about 50 Nm^3/min. The oxygen is introduced to the furnace from three sources, viz. submerged tuyeres, atmospheric injector and door lances. The modification to the furnace hardaware and refractories is not complex. The hearth modifications are the placement of the tuyere blocks in the hearth for the submerged tuyeres and fitting of atmospheric injector which would occupy a position on the side wall.

Steel production through EAF is a highly energy intensive operation. The cost of power along with that of electrodes constitute a major protion of conversion cost in the EAF. Under normal circumstances an EAF can take only solid charge in the form of scrap, DRI/HBI or pig iron. But with the modification of EAF to KORFARC, the furnace has the flexibility to use hot metal (pig iron) upto the extent of 80% in the charge. The expected benefits from the modification of EAF into KORFARC at Usha Martin as envisaged in the year 1991-92 are as follows :

Item	Unit	EAF	KORFARC	DIFF.
Power	kWh/t	720	230	- 490
Electrodes	kg/t	4.7	2	- 2.7
Oxygen	Nm^3/t	10	56	+ 46
Coke	kg/t	36.7	0	- 36.7
Tap to tap time	Min.	149	68	- 81

The difference in kWh/t is due to the hot metal charge (hot metal enthalpy), less power on time and oxygen replacement of electrical energy. Reduction in electrode consumption is related to the reduced power on time. The oxygen increase provides additional exothermic energy with resultant time decrease, and the carbon is replaced by carbon in the hot metal.

The energy required to produce 1 Nm^3 of oxygen is generally about 0.75 kWh, however, oxygen can replace electrical energy in the EAF (with liquid pig iron) at the rate of 3.7 kWh per Nm^3 of oxygen used. This gives an example of the tremendous saving in energy by the KORFARC process at Usha Martin.

Cappital cost

Mini blast furnace

The capital cost estimated to be incurred on the mini blast furnace is as given below : (Rs. lakhs)

1. Civil and structural 700

2.	Plant and machinery including MBF, MBP, Blowers, GCP, RMHS etc.	1475
3.	Electrical, instrumentation, controls DG sets, mobile equipment, weighbridge, etc.	700
4.	Erection	185
5.	Roads and drainage	155
6.	Captive power plant	1020
		4235

The above cost does not include fees for engineering and services, expenses on foreign technicians and capital related charges like interest during construction, preliminary expenses, contingency, etc. The above cost also does not include installations required for pumping water from river and associated facilities.

KORFARC

The capital cost for modification of EAF to KORFARC with consumables for 18 months operation is as follows : (Rs. lakhs)

1.	Imported capital items	350
2.	Imported consumables for 18 months opeation	230
3.	Fees, technical assistance, cost of modification including local supply etc.	160

The other costs incurred by Usha Martin was on a new split shell and tubular water cooled panels imported from Brazil for EAF. Split shell, however, is not a mandatory item for modification into a KORFARC.

Besides the above, costs have also been incurred by Usha Martin for hot metal transfer from MBF to SMS, modified slag handling system, modifications on continuous casting machines including installation of ladle sequencing cars, new Turnover type cooling bed, modifications of EOT cranes and other balancing facilities required for increased productivity.

Usha Martin have also made arrangement for supply of liquid oxygen on long term basis for use in the KORFARC process. Other option which is installation of captive oxygen plant may be done in future.

Operating costs

The operating cost of hot metal is expected to be in the region of about Rs. 4200/t, before interest and depreciation charges. The hot metal will partly replace more expensive solid charge in EAF. Hot metal will also reduce energy and electrode consumptions in EAF thereby reduce the cost of the steel produced.

Project implementation

The site work on MBF project was started in May 1993. The major contractor for execution of civil and structural work and equipment erection is L&T - ECC. The total quantities of civil, structural and refractory items are as follows (excluding gas holder and power plant):

Civil work (concrete)	:	6300 cu.m
Roads	:	2500 cu. m
Building structures	:	700 t
Technological structures	:	525 t
Conveyor galleries & trestles (engineered by TRF)	:	300 t
Refractories, MBF	:	650 t
Refractories, others	:	1000 t

The MBF is expected to go on stream for regular production in November, 1994. The captive power plant is expected to be commissioned by February, 1995.

The split shell and water cooled panels in the EAF have already been installed and the furnace is operating with them since July, 1994. The present output, from the EAF is about 10-11 heats per day. It is planned to utilise the hot metal from the MBF in the EAF for about a month without the modification to KORFARC so that the operators get used to hot metal handling in the EAF. The modifications to the EAF for KORFARC will then be undertaken in January, 1995 and the first results of use of submerged oxygen blowing in the EAF will be expected soon after that.

Conclusion

The MBF-KORFARC combination at Usha Martin is expected to be a model plant for the electric furnace operators. It will motivate the entrepreneurs to go for backward integration of the EAF with a mini blast furnace and increase the output of the EAF at a much lower operating cost. The KORFARC can be the intermediate stage in implementation of an integrated steel plant in a phased manner, the ultimate aim being integration of MBF with oxygen steelmaking.

FIGURE-1

MINI BLAST FURNACE BASED EAF PLANT

[143,000 TPA BILLETS WITH 60% HOT METAL 40% SOLID CHARGE IN EAF (KORFARC)]

(All Figures in TPA)

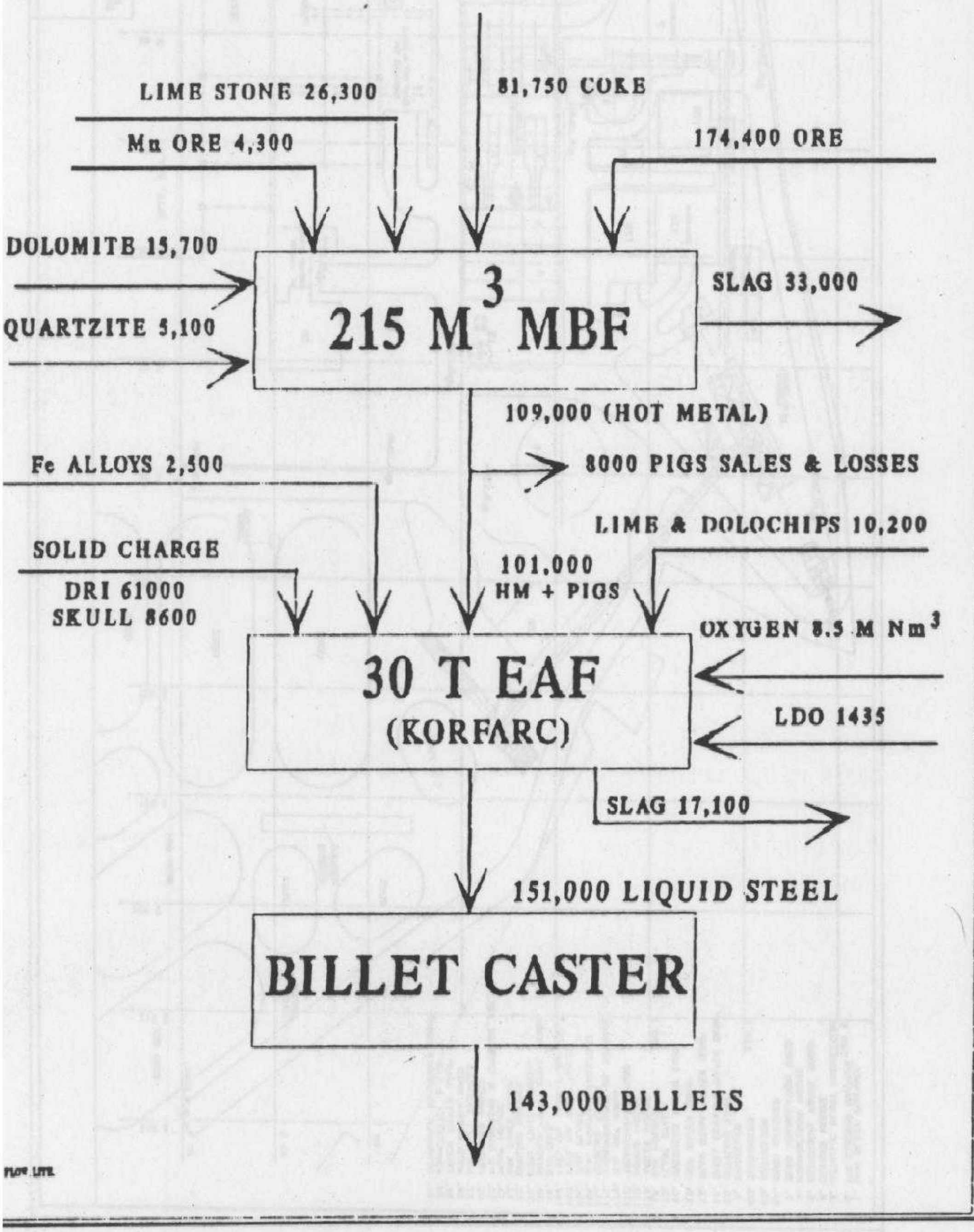
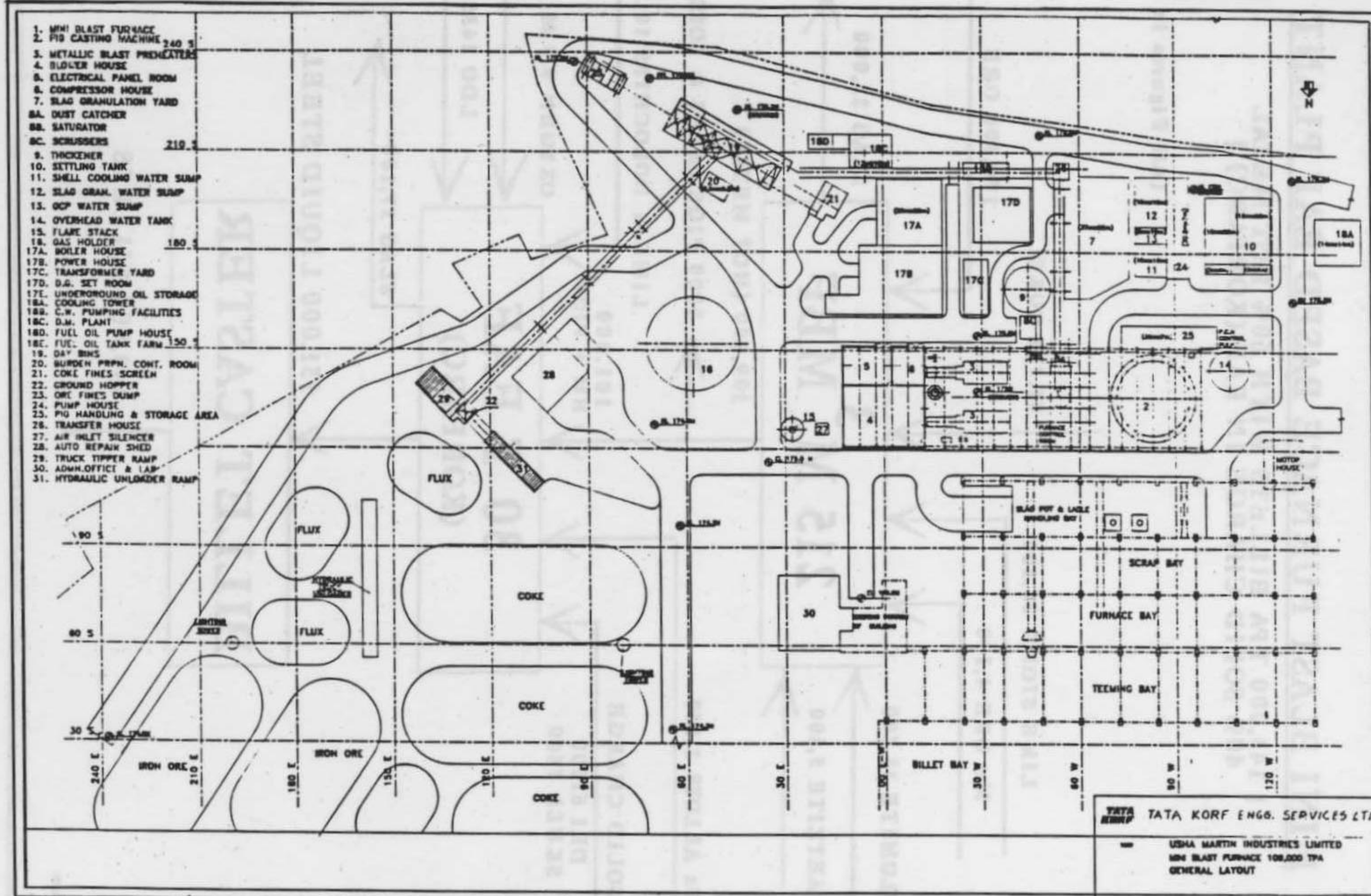


FIGURE-2



1. MINI BLAST FURNACE
2. PIG CASTING MACHINE
3. METALLIC BLAST PREHEATERS
4. BLOWER HOUSE
5. ELECTRICAL PANEL ROOM
6. COMPRESSOR HOUSE
7. SLAG GRANULATION YARD
8A. DUST CATCHER
8B. SATURATOR
8C. SCRUBBERS
9. THICKENER
10. SETTLING TANK
11. SHELL COOLING WATER SUMP
12. SLAG GRAN. WATER SUMP
13. GCP WATER SUMP
14. OVERHEAD WATER TANK
15. FLARE STACK
16. GAS HOLDER
17A. BOILER HOUSE
17B. POWER HOUSE
17C. TRANSFORMER YARD
17D. D.G. SET ROOM
17E. UNDERGROUND OIL STORAGE
18A. COOLING TOWER
18B. C.W. PUMPING FACILITIES
18C. D.M. PLANT
18D. FUEL OIL PUMP HOUSE
18E. FUEL OIL TANK FARM
19. DAY BINS
20. BURDEN PRPN. CONT. ROOM
21. COKE FINES SCREEN
22. GROUND HOPPER
23. ORE FINES DUMP
24. PUMP HOUSE
25. PIG HANDLING & STORAGE AREA
26. TRANSFER HOUSE
27. AIR INLET SILENCER
28. AUTO REPAIR SHED
29. TRUCK TIPPER RAMP
30. ADMN.OFFICE & LAB
31. HYDRAULIC UNLOADER RAMP
FLUX
COKE
IRON ORE
SCRAP BAY
FURNACE BAY
TEEMING BAY
BILLET BAY
SLAG POT & LADLE HANDLING BAY
MOTOR HOUSE
N
240 S
210 S
180 S
150 S
90 S
60 S
30 S
240 E
210 E
180 E
150 E
120 E
90 E
60 E
30 E
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90 W
120 W
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