LAYOUT OF MODERN CONVERTER STEEL PLANT FOR THE PRODUCTION OF 1.5 MILLION TONNES PER YEAR OF CONTINUOUSLY CAST BILLETS

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TASK

In the framework of an international tender a converter steel plant has been proposed which will produce 1.5 million tons of liquid steel and will be suitable for expansion to 3.0 m.t.p.a. of liquid steel. The product of the steel plant is supposed to be cast to billets of max. 130 mm square.

The proposed steel works complex has been designed with two top-blown basic oxygen converters and three six-strand billet casting machines.

In the projecting stage special attention has been paid to the continuous casting plant sector. As a matter of principle the layout of a continuous casting plant is determined by the heat size and the tap-to-tap time in the melting shop as well as by the required billet dimensions. Optimum conditions may only be achieved by adopting continuous sequence casting instead of batch casting. The former is always possible where the casting time is equal to or is a multiple of the tap-to-tap time of the converter.

Further, investigation has been made in consideration of the production of 1.5 million tons of liquid steel with the converter size selected, under the following aspects:

Investment and Operating Cost

The selected converter size contributes to keeping the investment and operating cost in the following sectors within optimum limits:

- Hot metal ladle transport car and ladles
- Flux and ferro alloys charging system

- Steel structures
- Civil works
- Equipment (detachable bottom)
- Other accessories (cranes, hoists, elevators, etc.)
- Maintenance
- Number of skilled personnel

Lining Life

Higher lining life will be gained due to selected vessel design and also adopting combined lining (dolomite and magnesite) process. Furthermore, the lining life can be increased by adopting well performed patching, gunning and process computer control led blowing techniques.

Interference between Material Supply, Material Transport and Production Unit.

Scrap will be transported by rail; it will enter the melting shop at the end opposite to the metal entry end. The additives are delivered to the converter bay by means of belt conveyor installations entering the bay at the face ends crossing free, that means no interference of material transport system takes place.

Possibility of Further Expansion

Further expansion is possible in all areas and sectors, as for example by installing an additional vessel in the same melting shop, increase of the total production would cause no problems. Provisions have also been made for further expansion of the bin plant of the flux and ferro alloy handling system to feed one more vessel.

Process Technological Advantages

With this selected converter size, higher productivity will be achieved. At the same time the amount of consumables required for the melt shop will be reduced; this particularly applied to refractory materials. Furthermore, a higher yield (96%) will be achieved by adopting continuous sequence casting instead of single casts. The heat loss will be less than with converters of smaller size. In addition to a reduced consumption of service media, the electrical, measuring and control equipment for the vessel size selected is less extensive.

By considering the above mentioned influences and after evaluation of the investigation results two converters have been chosen each of a heat size of 150 t. These will be capable of achieving the target production of 1.5 million tonnes of liquid steel by adopting the normal mode of operation.

BASIC DESIGN ASPECTS AND DATA

Taking into account the local conditions and the availability of the raw material, a high proportion of hot metal in the charge has been considered for the specific heat.

Hot Metal and Charge Analysis

The charge calculation is based on the following data:

C approx. 4.2%
Si max. 1.2%
Mn approx. 0.7%
P approx. 0.2%
S approx. 0.05%
Hot metal temperature approx. 1250°C

Lime

CaO > 85%
SiO_2 approx.4%
MgO approx.7.2%

Reactivity of lime > 350 ml 4 n Hcl/10 min

Scrap Analysis

C approx. 0.15%
Si approx. 0.15%
Mn approx. 0.50%
P approx. 0.02%
S approx. 0.02%
Fe approx. 98%

Availability

The converter availability, tap-to-tap time and other major technical data to match the required production according to the tender enquiry are given in a tabular form (see Table 1).

TABLE 1 **Technical data for BOF plant**

Working days per year	333
Working hours per year	7992
Average tap- to tap-time	approx 48 mins
Blowing time	approx 18 mins
Number of heats per day	30
Heat size	2 x 150 t
Converter drive power	4 x 73,5 kW/230 V (D.C.)
	515 r.p.m.
Production of liquid steel	1.500.000 t/year
Production per day	4.500 t
Oxygen blowing rate min/max	350/600 Nm^3/h
Wastegas cleaning system	OG or similar type
Fan suction capacity	approx 88.500 Nm^3/h
Drive power rating	1.800 kW
Speed	1.450 rpm
Availability of C.C.P	approx 300 days
Number of billet machine	3
Casting time	approx 90 mins
Casting speed	approx 2,1 m/min

CONSUMPTION FIGURES

The consumption figures per 150-t heat are calculated as follows:

Heat Balance

Heat input:

$Q_{chem.}$ = 260,586 kcal/t

$Q_{sensible}$ = 255, 110 kcal/t

Total heat input = 515, 696 kcal/t

Total heat output = 474, 386 kcal/t

ΔQ = 41,310 kcal/t

The following consumption figures per 150-t heat, based on the above fundamental calculation, are indicated in Table 2, according to the hot metal and charge analysis as specified in chapter 2.1.

LAYOUT AND MAIN FEATURES OF THE PLANT EQUIPMENT

The determination of an optimum layout is the prime factor for designing the steel plant (Fig.1). The steel plant has

TABLE 2 **Consumption data for BOF production**

Heat size	150 t
Metallic input	Average consumption per heat (t)
Hotmetal	approx. 148,5 t
Scrap	approx. 18,8 t
Iron ore	approx. 4,5 t
Ferroalloys	approx. 2,4 t
Flux and additives	
Burntlime	approx. 14,3 t
Limestone	approx. 0,3 t
Calcined dolomite	approx. 5,3 t
Fluorspar	approx. 0,8 t
Desulphurising agent	approx. 0,8 t
Service media	
Oxygen	approx. 9.000 Nm^3
Nitrogen	approx. 600 Nm^3
Compressed air	approx. 900 Nm^3
Argon	approx. 15 Nm^3
Cooling water lance and Cooling hood	approx. 1.000 Nm^3

been projected under modern aspects and takes into account the latest findings and knowledge particularly in the following steel plant bays:

- Scrap bay (Row C-E)
- Mixer bay (Row D-E)
- Charging bay (Row E-F)
- Converter bay (Row F-G)
- Ladle transfer bay (Row J-K)
- Ladle bay (Row G-H)
- Continuous casting bay (Row K-L,
- Cutting bay (L-M)
- Discharge bay (M-N)
- Storage bay (N-O)

The total building area is approx. 32,000 m^2. The B.O.F. melting shop is arranged in such a way that by

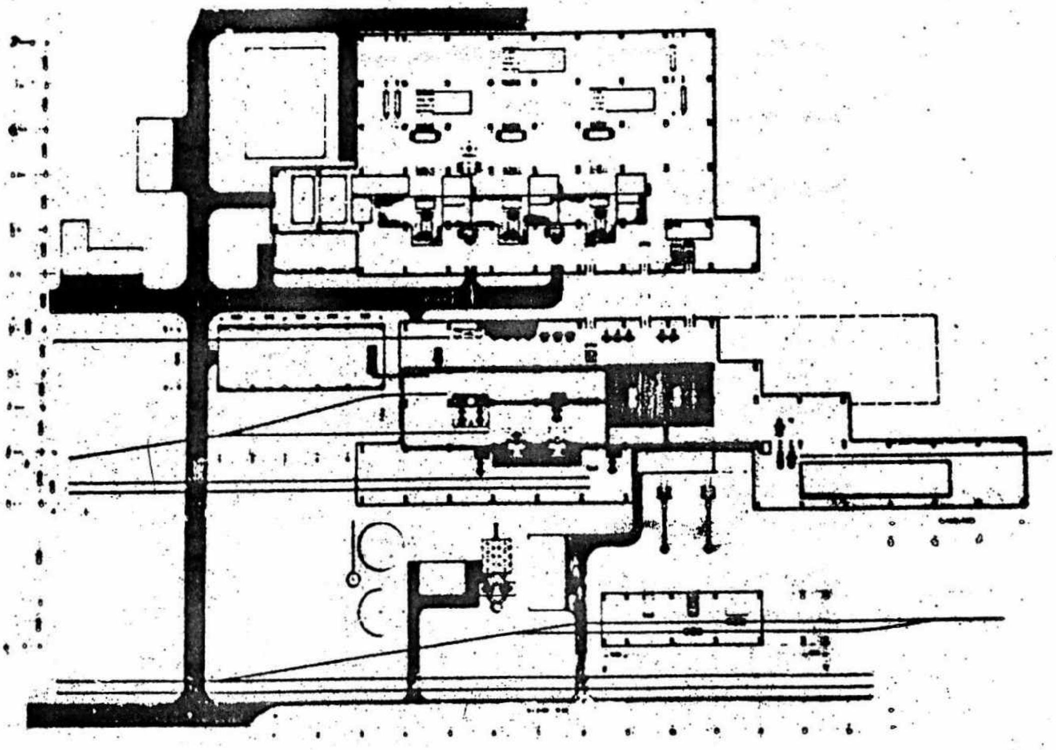


FIG 1 Layout of BOF steel plant

installing one more vessel (row F, axis 11-12), the total production can be easily increased. The converter is fitted with a removable bottom and will be relined from the bottom by using a relining tower.

The layout developed permits crossing-free transportation in all sectors, i.e. scrap will enter the converter bay from the northern side by rail and hot metal will enter from south (i.e. row D-E).

The main control station (row E, axis 9-11) is situated ahead of the charging bay i.e. centrally in front of the converters, to control and supervise the converter operation, waste gas systems and to monitor the operation sequence control.

Burnt lime and other additive materials (row P-Q, axis 1-6) will be delivered by conveyor belt into the ground storage hoppers outside the steel plant. The additives will be delivered to the converter bay by means of belt conveyor that enters the bay at face end. For each converter, separate bin systems are provided permitting charging from both sides.

An argon purging station (row J-K, axis 5-6 and 7-8) is provided between the two ladle turrets. A RH-Circulation degassing plant is arranged in the continuous casting bay (row J-K, axis 10-11).

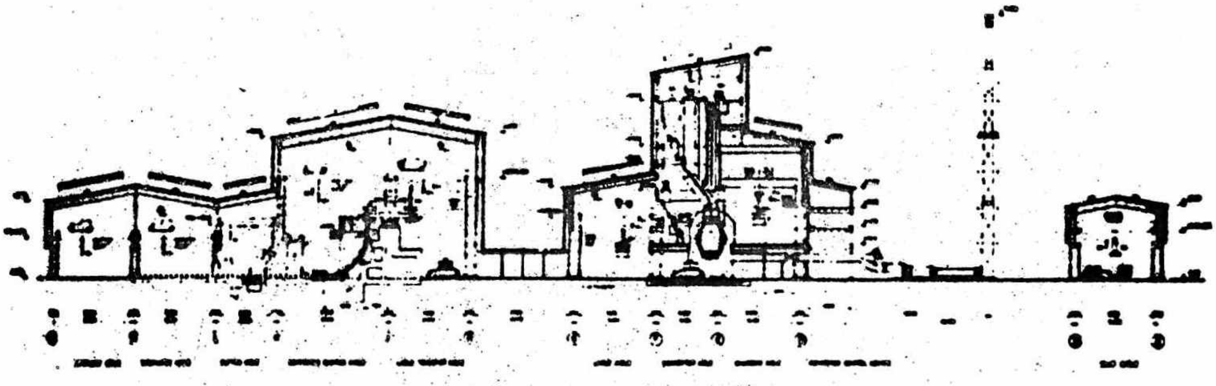


FIG 2 **Cross section of BOF steel plant**

Each converter will be connected to a separate complete cooling and cleaning system. Secondary ventilation is connected to a bag filter plant. It is also possible to collect the cleaned combustible gases in a gas holder for further energy utilization.

Adjacent to the converter shop, three six-strand billet casting machines (row K-O) are installed for the production of billets of maximum 130 mm square section. These billets will be transferred to the rolling mill for further processing.

The cross sectional drawing indicates the separation of the steel melting shop from the continuous casting plant (Fig.2).

This separation ensures natural ventilation of the plant areas, even under extreme climatic conditions as well as a smooth material flow in and out.

Flux Handling

The flux materials, such as iron ore, lime, limestone, dolomite and fluorspar required during the blowing process for temperature and metallurgical reasons can be added either continuously or discontinuously or before the blowing process, from the corresponding bins via down pipes.

The basic concept of the flux handling system is indicated in Fig.3.

The individual materials are reclaimed from the storage bunkers with a capacity ranging from 100 to 250 m^3, by vibro-feeders and are transported by belt conveyors into high level storage bins of the steel plant.

This high-level storage bin plant comprises the following bins:

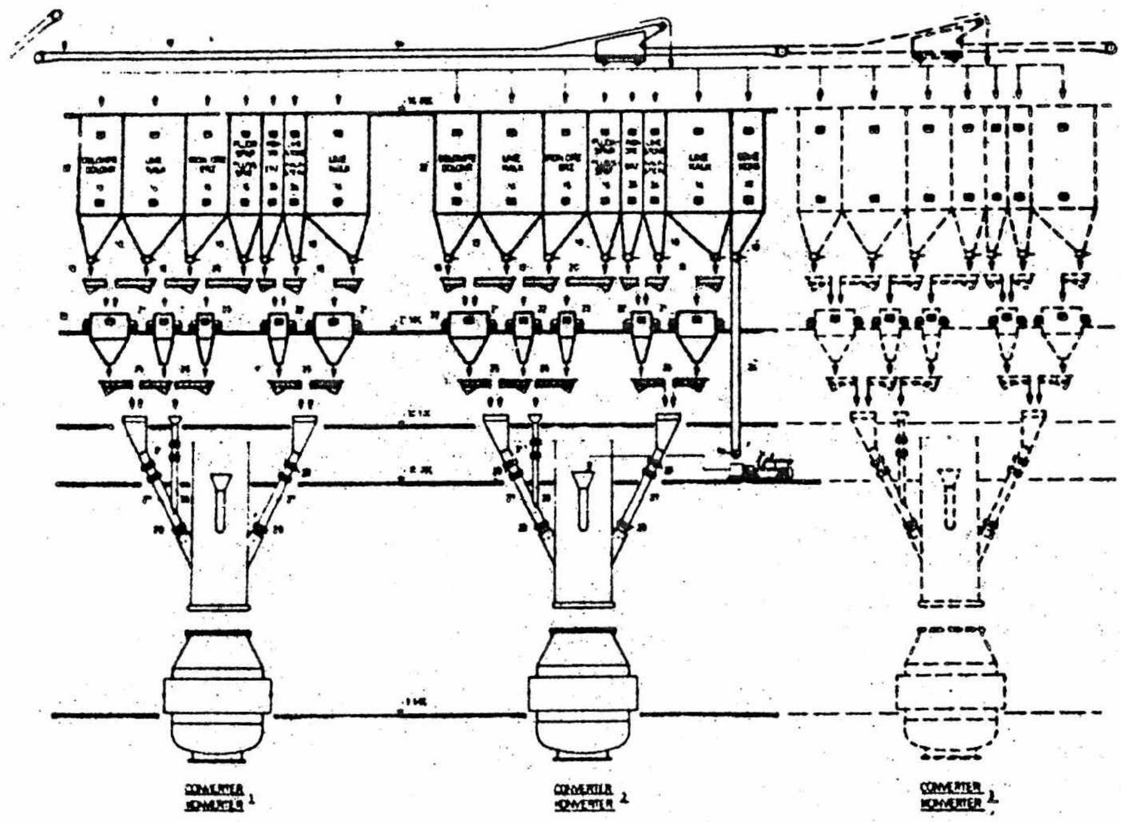


FIG 3 **Flux handling system**

4 bins for burnt time	effective volume	120 m^3 each
2 bins for limestone	effective volume	40 m^3 each
2 bins for iron ore	effective volume	80 m^3 each
2 bins for iron ore	effective volume	40 m^3 each
2 bins for fluorspar	effective volume	40 m^3 each
2 bins for dolomite	effective volume	80 m^3 each
1 bin for coke	effective volume	40 m^3

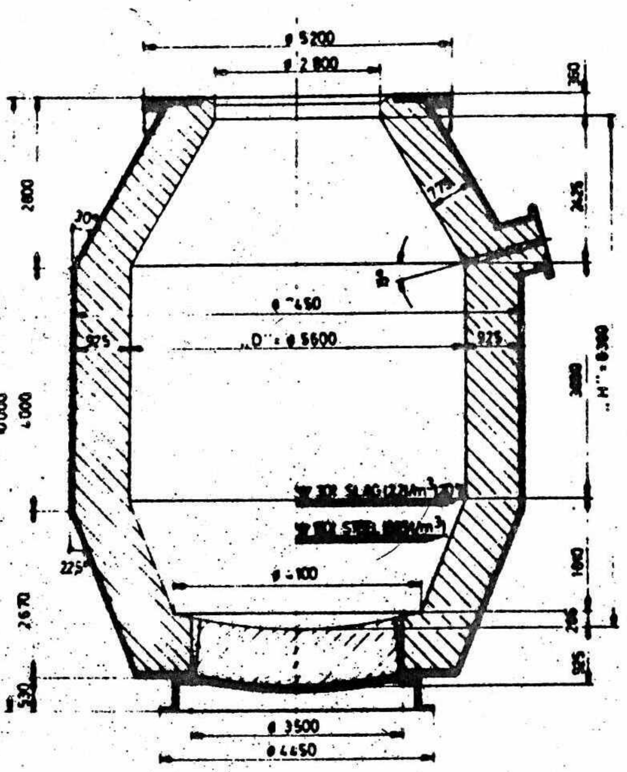
From these bins the material is fed, via vibro-feeders arranged under the bins, into weight hoppers and from there, via another vibro-feeder, to the down pipes.

The down pipes are fitted with N_2 seals to prevent CO-containing gases from entering the flux supply system.

The operation of the flux handling system is controlled from a control panel installed in the converter control room.

Basic Oxygen Converter

The new basic oxygen steel plant is designed for two 150-metric tonne converters. Fig.4 indicates the converter



HEAT	150 t
VOLUME INSIDE LINING	165 m^3
BATH VOLUME	21,9 m^3
BATH DIAMETER	5100 mm
BATH SURFACE AREA	20,42 m^2
BATH HEIGHT	1470 mm
VOLUME INSIDE PLATE	334 m^3
WEIGHT OF LINING	490 t

$$\frac{\text{VOLUME INSIDE LINING}}{\text{HEAT}} = \frac{165}{150} = 1{,}1\ m^3/t$$

$$\frac{\text{„H" INNER HEIGHT}}{\text{„D" INNER DIA}} = \frac{8350}{5600} = 1{,}49$$

FIG 4 Characteristic features of converter with new lining

geometry for 150-t-heat size and the main characteristic features. Fig.5 shows the relation between the converter specific volume and the heat size of converters previously planned, designed and supplied by M.A.N.-GHH STERKRADE.

The welded trunnion ring without water cooling, of box girder section, is provided with openings in the web plate to allow air cooling and observation of the shell.

Two slag skirts are attached to the upper part of the shell. They protect the upper conical section as well as the trunnion ring and the vessel suspension device. The tilt drive provided on one side only comprises the slide-on bullgear (spurgear), and either two or four sets of primary gear drives will be required.

The primary gear drives are connected with the bull gear in a detachable manner. The drive motors and magnetic brakes are mounted on brackets which are attached to the gearbox.

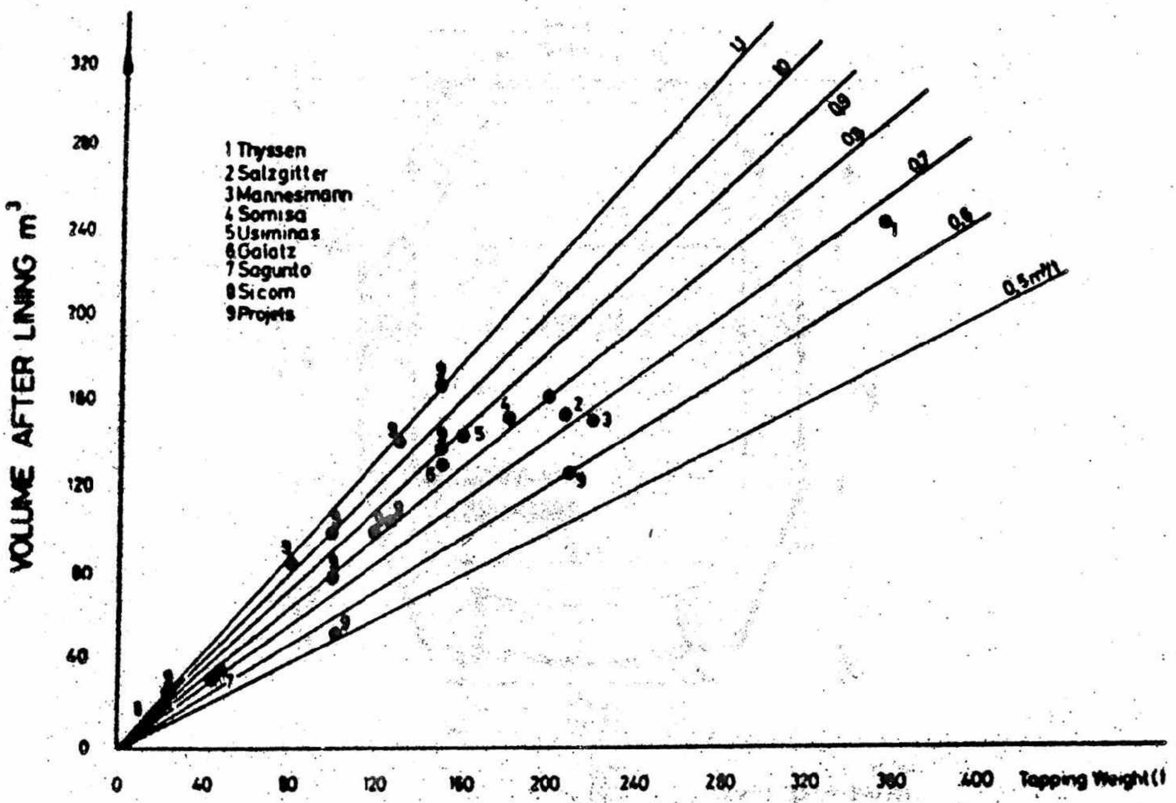


FIG 5 Relation between converter volume and tapping weight

The converter is furnished with a removable bottom(1), which offers the following advantages:

- the vessel cools down more quickly
- relining time is reduced
- transportation of lining material is much quicker and easier
- the bottom can be lined elsewhere
- shifting of the lower part of hood can be avoided, disconnection of water pipes and charging down is eliminated.

Lance System

The oxygen is blown into the converter through a water-cooled, multi-hole lance. Two lances are connected to the oxygen and cooling water circuits, ready for operation. One lance is in working position and the other one is in stand-by position. Moving of the stand-by lance to working position will be done by a translation car with its own travel drive. For lowering and lifting the oxygen lances, two lance hoists are mounted on the lance car. Hoist ropes are connected to lance carriages which carry the lances. A safety system comes into operation in case of slack rope or extremely differing elongation of he hoist ropes.

Guides for the two lance carriages are divided into a movable and a stationary part. The movable part consists of two guides which are fixed to the lance translation car. The other part below the translation car is fixed to the steel structure of the building and is situated above the furnace.

The lance design data are as follows:

Lance length	approx.	20.0 m
Lance outer dia	approx.	245 m
Lance translation car		
travel distance	approx.	3.5 m
travel speed	approx.	3 m/min
Lance hoist capacity	approx.	14,000 kg
height of life	approx.	16.3 m
Stationary guide system		
length	approx.	17 m

Sublance

The operation of the converter is facilitated by the use of a sublance for each converter. By application(2) of the sublance technique the current process data are directly determined and processed in a computer programme. The computer programme directly transmits the data established to the peripheral equipment of the control computer, such as the necessary adjustments to the oxygen volumes still to be blown and the necessary quantity of coolants to be added.

The following process data can be measured in the converter by means of the sublance:

- C content
- temperature
- oxygen content

Ferro-alloys and other Materials Handling System

Different types and quantities of ferro-alloys are necessary for the various grades of steel according to the wide range of product mix to be produced in the converter. Fig.6 shows the ferro alloy handling system.

The alloying materials are transported to the storage bins via a belt conveyor system.

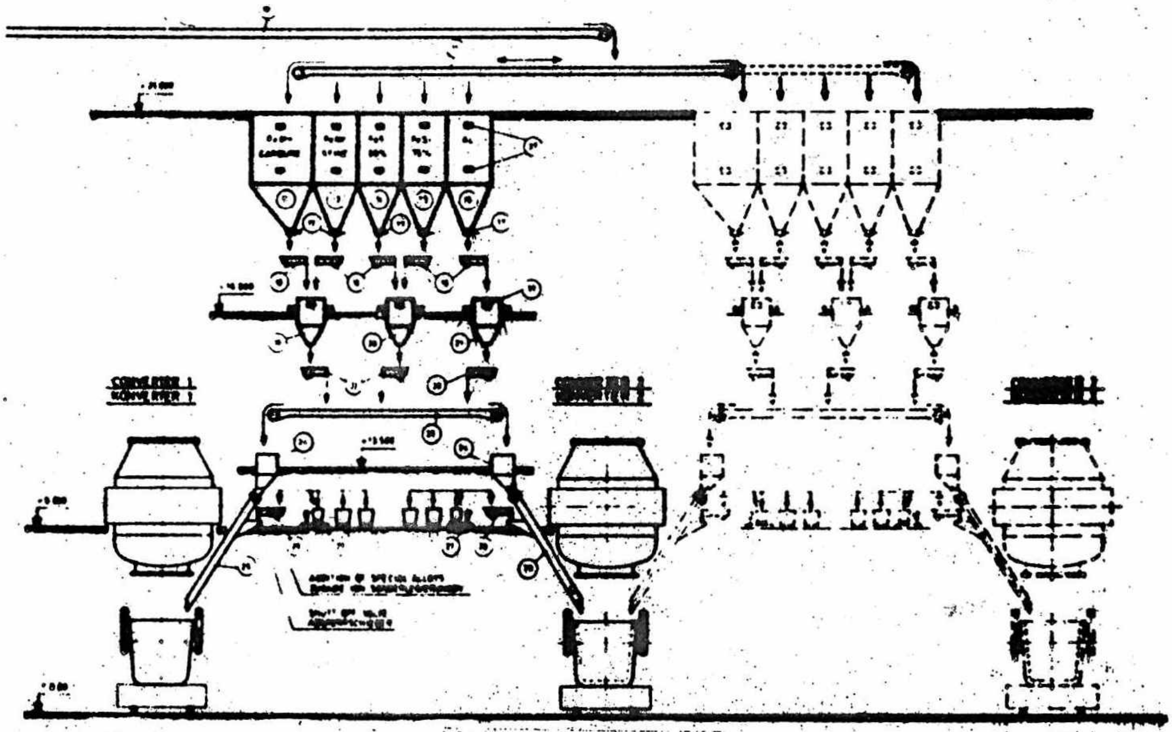


FIG 6 Ferro alloy system

The storage bins between the converters are as follows:

1 bin for high carbon FeMn effective volume 20 m^3

1 bin for medium carbon FeMn effective volume 10 m^3

1 bin for FeSi 90% effective volume 10 m^3

1 bin for FeSi 75% effective volume 10 m^3

1 bin for aluminium effective volume 10 m^3

Reclaiming of the individual materials from the bins and feeding them into the weight hoppers is achieved by means of vibro-feeders. After the desired quantity has been filled, the material is directed via vibro-feeders and a reversing belt conveyor, to the down pipes which are fitted with charge holding hoppers and clam-shell gates, and from there into the ladle.

Argon purging

Due to close tolerances of steel analysis, and steel temperature, post treatment in the ladle(3) is required Argon or nitrogen is blown into the liquid steel through a ceramic well block or a lance (Fig.7).

Ferro-alloys will be added from weighing hoppers for correction of the final analysis. Temperature homogenisation will be achieved by stirring. Higher temperature of

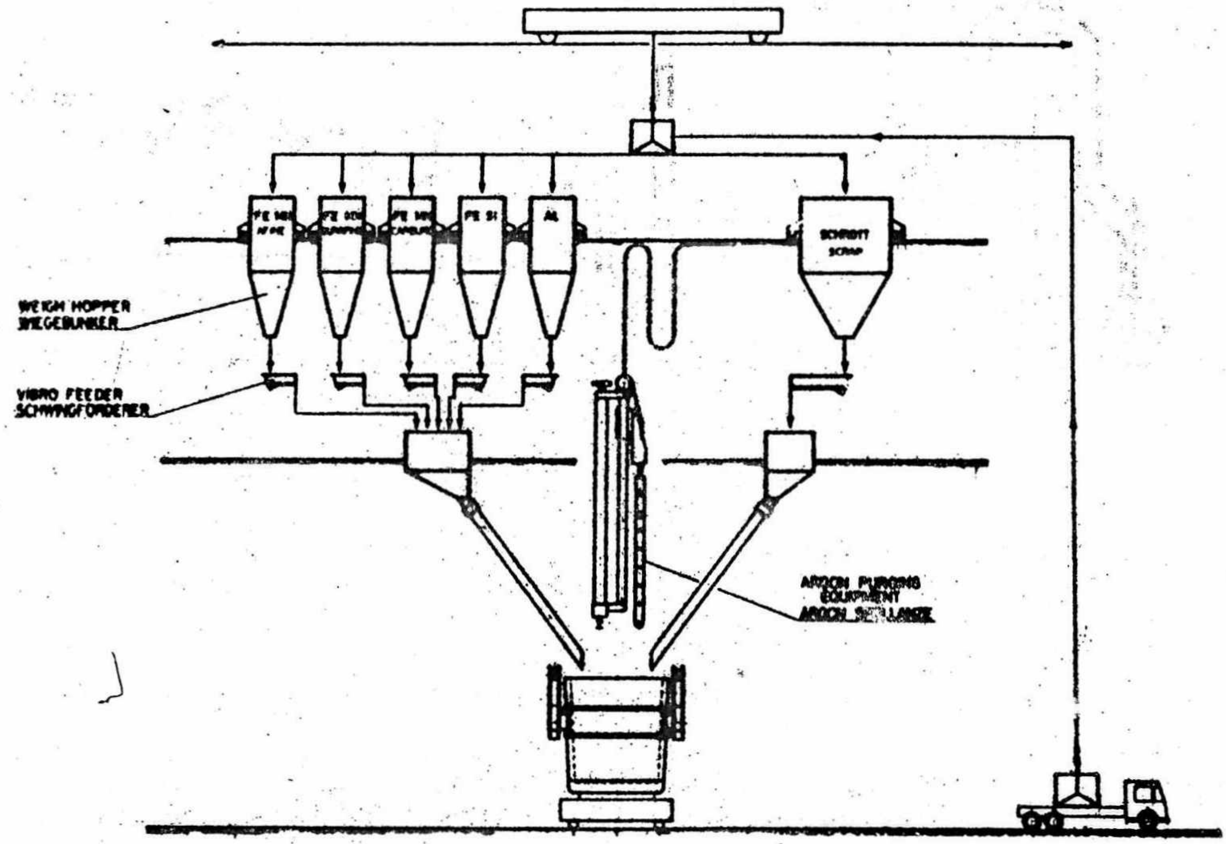


FIG 7 **Argon purging system**

few heats can be corrected by addition of cooling scrap from the scrap bin.

Vacuum degassing

For quality reasons a certain portion of the steel production (high carbon) will be degassed in a vacuum plant according to the RH process.

Gas cleaning

Primary gas cleaning system (OG or similar type)

The waste gas generated in the basic oxygen converter during oxygen blowing (Fig.8) will be cooled in a water or steam cooled hood and cleaned in a two-stage wet scrubber(3). Each converter will be provided with a complete cooling and cleaning system. This system is a suppressed combustion system designed to operate under normal oxygen blowing rates at a combustion factor of approximately 0.1. Table 3 indicates the major gas cleaning design data.

A water-cooled movable skirt will be installed at the bottom of the cooling hood. In the lowered position the skirt will close the gap between the converter and the hood bottom thereby minimizing the entrainment of combustion air

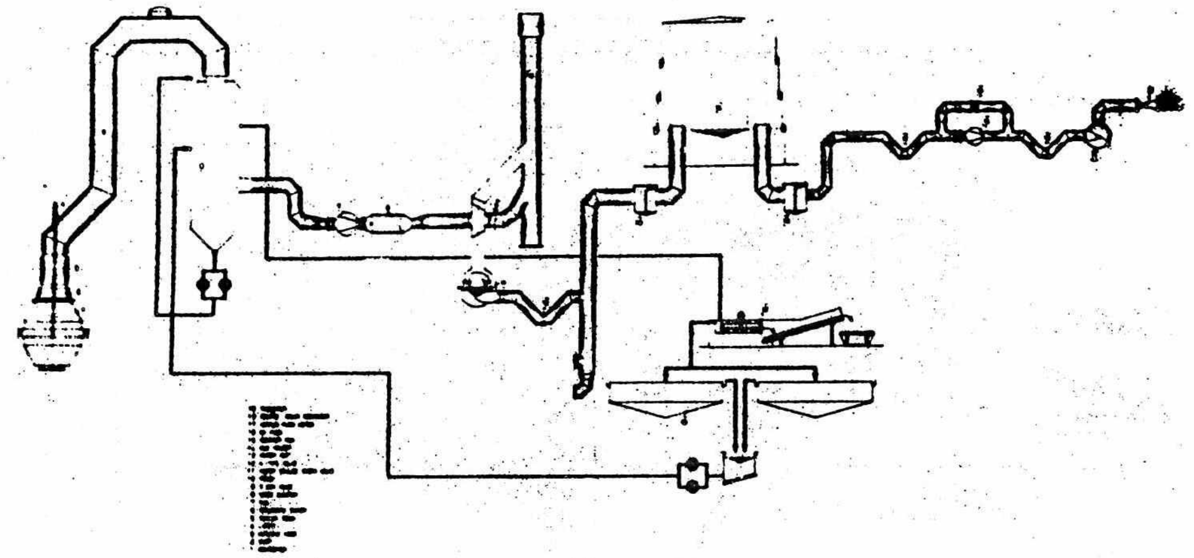


FIG 8 Flow sheet of waste gas cleaning

TABLE 3 Gas cleaning design data

Heat size	150 t
Oxygenblowing rate	max. 600 Nm³/min
Maximum iron ore addition rate	1 t/min
Combustion factor	0,1
Wastegas analysis during peak flow of oxygen	CO approx. 69 % by volume CO_2 approx 16% by volume N_2 approx. 15 % by volume
Heat content of wastegases after combustion	approx. 2 100 kcal/Nm³
Design temperatur at hood exist	approx. 1000°C
Dust loading at outlet from gas cleaning plant	100 mg/Nm³

during the oxygen blowing period. Hydraulic jacks will lift the skirt thus enabling the converter to rotate.

Waste gases will leave the upper fixed section of the cooling hood at approx. 1000°C and will be cleaned in a two-stage wet scrubbing system. The first stage will operate as a saturator. The second stage will operate on the principle of generating high gas velocities in a Venturi throat and using the kinetic energy of the gas to atomise water sprayed into the scrubber.

Furthermore, the system includes facilities for gas recovery in order to make best use of energy utilization.

Secondary gas cleaning

For reasons of air pollution control secondary gas cleaning has been increasingly gaining importance in all countries and has become a common practice. Therefore, reduction of losses and dust emission has become one of the main objectives in the industries concerned.

The main points of secondary fume emission are the places where molten iron, molten steel, slag or additives are handled, transferred or treated. Great efforts are being made to evacuate secondary fume emissions immediately at their sources.

Fig.9 shows the indicative curve of fan motor power for secondary ventilation at different sources in case a bag filter plant is installed.

Service media

Process gases, fuel gas, compressed air, cooling water as well as general-purpose water are required for operation of an LD steel melting shop.

Process-gases such as oxygen, nitrogen, argon, etc. are metered and regulated in valve stations and directly fed to the steelmaking process.

Part of the heat produced in steelmaking is removed in the waste gas cleaning plant and in the lance plant, by means of cooling water. Open and closed-loop systems are adopted. In closed-loop systems the water is recooled by air fans or by water/water heat exchangers, whereas in open systems the water is recooled in open cooling towers.

Instrumentation and control

The central control station will co-ordinate major operating functions in order to achieve an optimum control with the aid of instruments within the individual ranges.

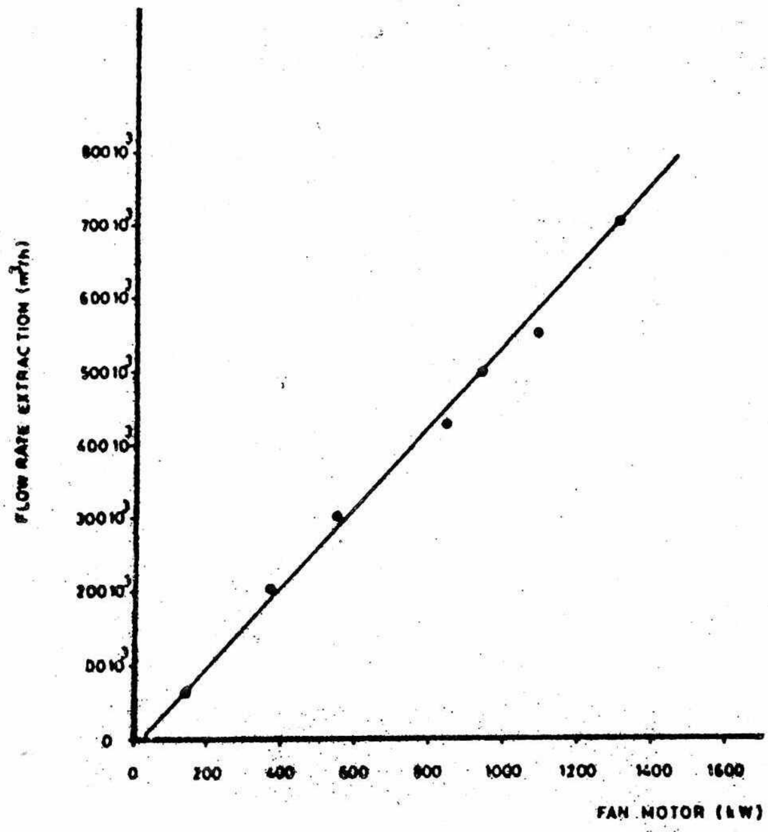


FIG 9 Relation between flow rate extraction and fan motor

The supervising, control and regulation equipment, not directly relating to the charging and blowing process, but rather to the process preparations, such as control of material and media flows, to energy supply systems, to making ancillary/auxiliary facilities available, etc., are mounted on supervising panels which are clearly arranged by graphic synoptic representations.

Process computer

The latest development shows that process control leads to high productivity, high quality and low production cost.

The advantageous features of employing the computer are as follows:

- Uniform run of the process in respect of refining reactions and slag work, resulting in improvement of the yield.

- Improvement of ability to achieve the specified analysis and temperature.

Fig. 10 indicates the block diagram of the computer system.

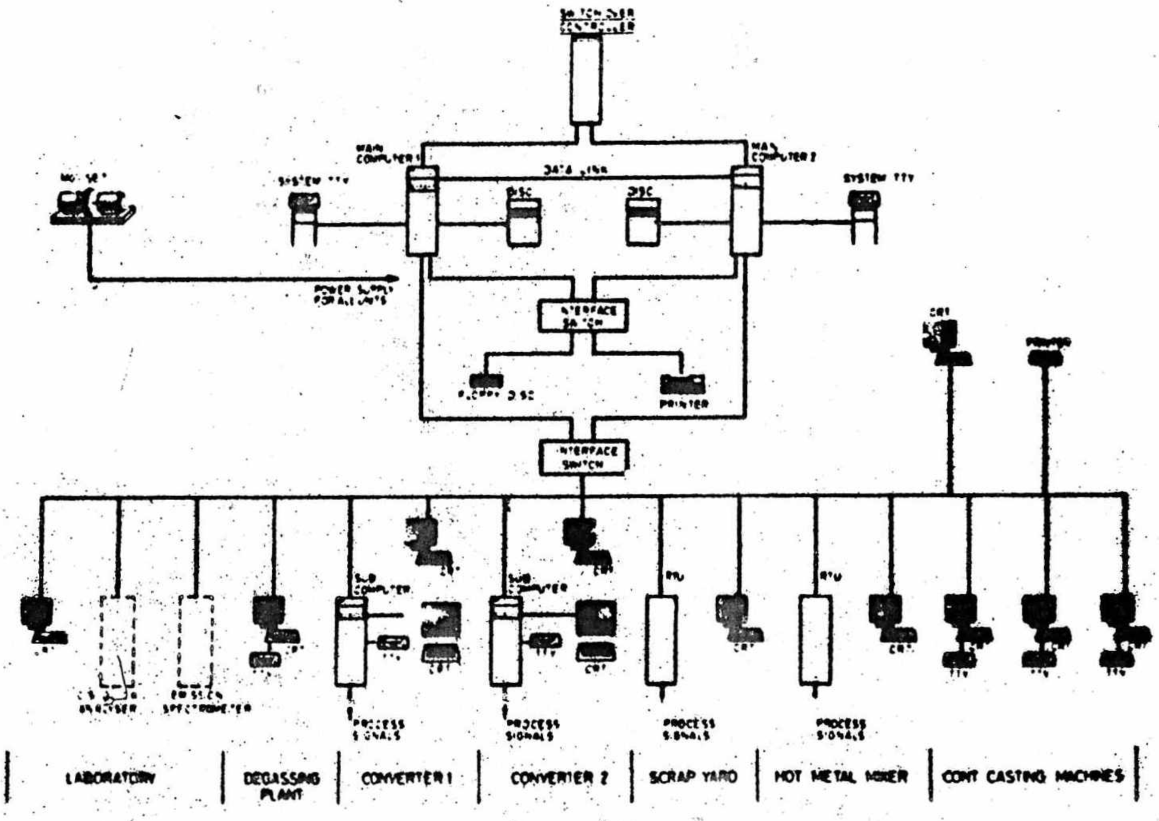


FIG 10 Block diagram of process computer system

The process control is effected with the aid of double main computers, sub-computers and remote terminal units, including a static model for charge calculations, a static model for automatic blowing process control and data logging.

Continuous casting plant

As a matter of principle the layout of a continuous casting plant is determined by the heat size and the tap-to-tap time in the melting shop as well as by the required billet dimensions (see Fig.11).

Further, the degree of utilization of the machines should be given special attention when projecting continuous casting plants(4). Accordingly, change of sections should be kept to a minimum, the number of different steel grades to be cast should be restricted, and the set-up and waiting times should be kept as short as possible. The tap-to-tap times of the steel converters should be programmed to a fixed cycle. Optimum conditions may only be achieved by adopting continuous sequence casting. This is always possible where the casting time is equal to or is a multiple of the tap-to-tap time of the converter.

For example the casting time should correspond to the heat cycle of LD converters, i.e. where the tap-to-tap time

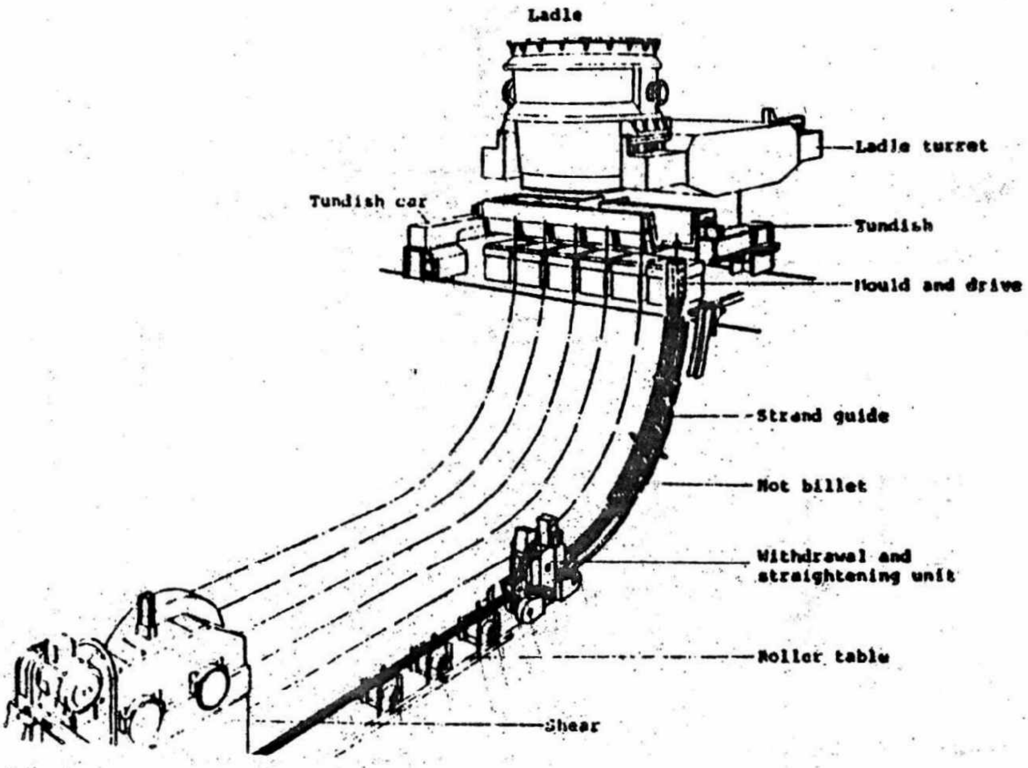


FIG 11 Six strand continuous casting machine

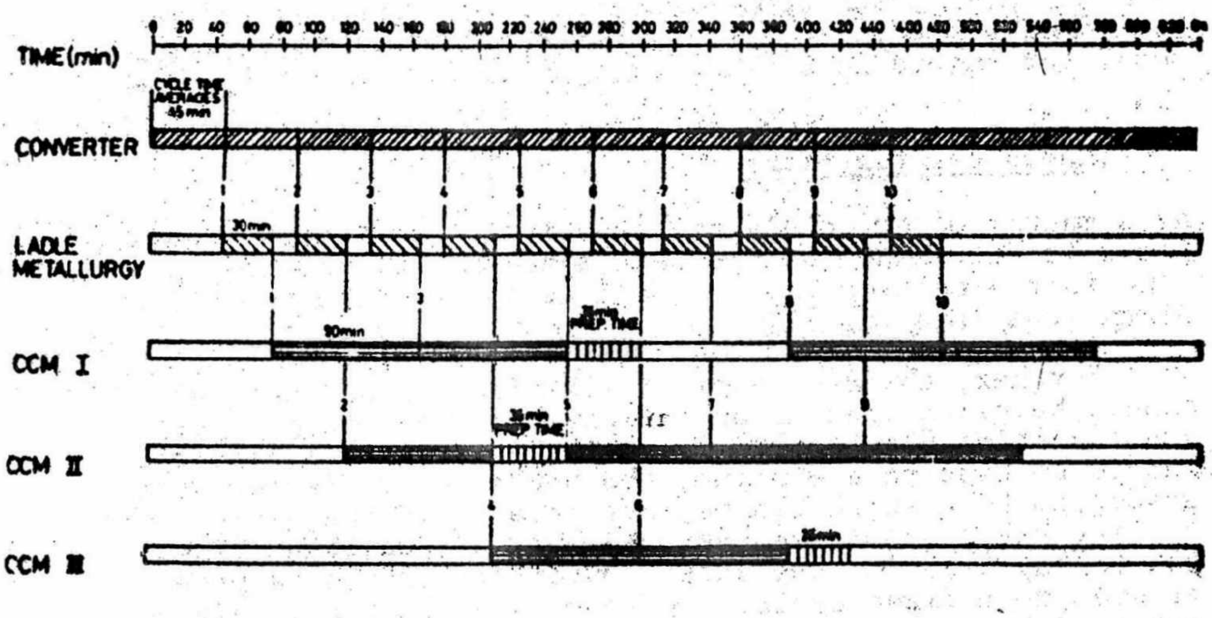


FIG 12 Bar chart sequence casting

of a 150-t LD-converter is on average 45 min., the casting time of the continuous casting machine should be adapted accordingly (see Fig.12).

Adjacent to the converter area, three six-strand continuous casting machines are installed for the production of 1.45 mill. tons of billets per year.

A ladle crane lifts the ladle onto one of the three ladle turn-turrets which reach into the ladle transfer bay. The ladle turn-turret is then rotated by 180^{o} and moves the ladle into position for casting. The casting ladle is provided with slide gate ladle valve.

The casting speed for 130 mm square billets is approx. 2.0-2.5 m/min. depending upon quality and casting radius. This means that the ladle content of 150 tons liquid steel can be cast in approx. 90 minutes on average. The continuous casting machine, type CONCAST, has a casting radius of 5-6 m. The liquid steel solidifies primarily in the water cooled mould. Further solidification is provided by the following secondary cooling zone which sprays water directly onto the strand.

All six strands are independently withdrawn, straightened and supported by roller tables to the cutting unit. At this point a mechanical or hydraulic shear cuts the billets to lengths of approx. 12 meters.

The hot billets are transported by roller tables to cooling beds (cooling time 50-60 min, temp. $<$ 400°C) and are lifted so that they may be stored for further processing in the rolling mill.

CONCLUSION

The proposed process route - blast furnace, top blown oxygen converter and continuous casting plant - will be able to produce a wide range of product mix (light section and bar products etc.) to meet the actual demand for the steel to be produced.

In keeping with the modern trend, 100% continuous casting will be adopted in order to reduce capital investment and operating costs, at the same time achieving an increase in yield.

By considering the various influences which have been discussed in this study and after evaluation of the investigation results two converters have been chosen each of a heat size of 150 t. These will be capable of achieving the target production of 1.5 million tonnes of liquid steel to be cast to billets with max. of 130 mm of cross section for further processing in the rolling mill. Provisions have been made in all sectors and areas for further expansion of the steel plant.

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