## 4.5 Market Price of Bars

Most of domestic bars in Oman are actually supplied by the imports as shown in Chapter 4-4-1 and 4-4-2. The amount of domestic consumption of bars in Oman is very small. So, it is necessary to export a considerable amount of bars for the accomplishment of this steel project as shown in the next chapter.

Under these consideration, the current bar prices in the inside and outside of Oman are described on various data as follows.

The domestic market price in Oman refers to the import price by Customs Statistics of Oman. As for the overseas market prices, the export price of Antwerp which is the standard of an international price and the import price of UAE which is the largest imported country in Gulf countries are referred. Those results of 1991 – 1997 are shown in Table 4-5-1 and Figure 4-5-1.

Table 4-5-1 Bar Price in 1991 – 1997

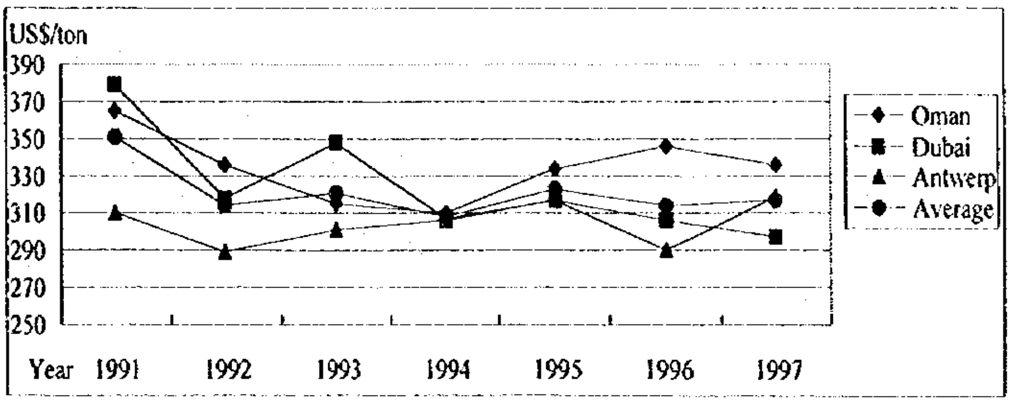
( US $ / ton )

| Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Average 91-97 | Average 95-97 | 91- 97 max | 91- 97 mini |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oman | 365 | 336 | 315 | 310 | 334 | 346 | 336 | 335 | 339 | 365 | 310 |
| Dubai | 379 | 318 | 348 | 307 | 317 | 306 | 297 | 325 | 307 | 379 | 297 |
| Antwerp* | 310 | 289 | 301 | 306 | 317 | 290 | 319 | 305 | 309 | 319 | 289 |
| Average* | 351 | 314 | 321 | 308 | 323 | 314 | 317 | 321 | 318 | 351 | 308 |

Source : Oman and Dubai are from these Custom Statistics. Antwerp is from "Metal Bulletin". Average* is among Oman, Dubai and Antwerp.

Note : Based on cif. Antwerp* is added freight. Bar is based on re-bar.

Figure 4-5-1 Trend of Bar Price in 1991 – 1997




According to these data, the import price of Oman and the overseas market prices changed respectively in the width of 310 –365 US$/ton and 289 –379 US$/ton.

## 4.6 Target Markets

The target market, both domestic and abroad, for Omani steel bars under this Project is discussed below.

### 4.6.1 Domestic target market

#### (1) Sector Market

The market for bars in Oman is almost all construction related. The overall construction sector comprises (i) building construction (housing, general building and factory), and (ii) civil works for infrastructure and utility structures including roads, port facilities, power stations, etc. The demand in the building construction sector is relatively small scale individually. In contrast, the more active civil works sector is characterized by both large-scale and long-term demand for bars. Accordingly, focus in terms of the domestic market must be given to the infrastructure and utility sector centering on national projects.

#### (2) Market by region

A regional development program is being pursued under the Fifth Five Year Plan. Region-wise investment and capital formation under the program are collated in Table 4-6-1. From this, the following conclusion can be drawn:

In addition to national projects, regions targeted under the said Five Year Plan for large investment of which a sizable percentage is marked for infrastructure are Muscat, Al Batinah, Ahd Dhaira, Ad Dakhliyay and Ash Sharqiyah. Data on region-wise investment after the present five year plan is not available; however, it is assumed highly probable that major investment will continue to be directed in the above regions.

Accordingly, it is concluded that these regions in all probability will comprise the major domestic markets for bars.

Table 4-6-1 Total Investments and Gross Capital Formation in the Fifth Five-Year Plan by Major Sectors and Regional Share

(Unit : million O. R.; %)

| Governorate/ Region | Investments | | Investments | | Gross Capital Formation | |
|---|---|---|---|---|---|---|
| | Infrastructure | % | Total | % | Total | % |
| Muscat | 26 | 10.8 | 98 | 10.3 | 229 | 3.1 |
| Al Batinah | 15 | 6.2 | 89 | 9.5 | 777 | 10.6 |
| Musandam | 4 | 1.6 | 14 | 1.5 | 14 | 0.2 |
| Ad Dhaira | 26 | 10.8 | 71 | 7.5 | 111 | 1.5 |
| Ad Dakhliyah | 19 | 7.9 | 113 | 11.9 | 187 | 2.6 |
| Ash Sharqiyah | 11 | 4.6 | 73 | 7.7 | 2489 | 34.0 |
| Al-Wusta | 5 | 2.1 | 21 | 2.3 | 27 | 0.4 |
| Dhofar | 14 | 5.8 | 52 | 5.4 | 147 | 2.0 |
| National Projects | 121 | 50.2 | 416 | 43.9 | 3340 | 45.6 |
| Total | 241 | 100.0 | 947 | 100.0 | 7321 | 100.0 |

Source : The Fifth Five Year Plan

4.6.2 Export target market

Assuming that production under this Project is 1.16 million tons per year, breakdown for domestic and export markets is shown in Table 4-6-2. Production for the domestic market is in accordance with Table 4-3-7, with production exports comprising the difference between the foregoing and total production, i.e. 760,000 tons in 2005 and 590,000 tons in 2010.

Table 4-6-2 Delivery of Bars for Domestic and Export Markets under this Project

(Unit : 1000 tons)

| Year | 2005 | 2010 |
|---|---|---|
| Domestic | 400 | 570 |
| Export | 764 | 594 |
| Total production | 1,164 | 1,164 |

The export target market was studied with reference to market data contained in Table 4-4-1 to Table 4-4-12, and with particular attention to volume of imported steel products around Oman and transport distance from Oman, etc. of the potential export market.

Based on the above, the target export market for Omani bars is summarized as follows:

- The export market will center on the GCC countries and Yemen. In particular, adjacent UAE will comprise a central market among the GCC counties.
- The remaining export market will include other parts of the Middle East, and the countries of East Africa, South Asia and ASEAN 5.

Assuming the above export target market, imports of bars (both recent actual and future forecast) in the target countries, and future forecast for Omani bar export to these countries are collated in Table 4-6-3.

Table 4-6-3 Imports of Steel Bar and Wire Rod in Countries around Oman and Exports of Steel Bar from Oman

(Unit : 1000 tons)

| Country/Year | 1995** | 1996** | 2005 | 2005* | 2010 | 2010* |
|---|---|---|---|---|---|---|
| UAE | 970 | 1,026 | 2,060 | 470(30%) | 2,630 | 395(15%) |
| Kuwait | 323 | 442 | 680 | 34(5%) | 790 | 40(5%) |
| Bahrain | 81 | 86 | 90 | 10(10%) | 90 | 5(5%) |
| Saudi Arabia | 246 | 314 | 310 | 30(10%) | 310 | 10(3%) |
| Yemen | 207 | - | 420 | 130(30%) | 540 | 105(20%) |
| Jordan | 117 | - | 120 | 5(5%) | 120 | 4(3%) |
| Syria | 204 | - | 200 | 10(5%) | 200 | 6(3%) |
| Kenya | 18 | - | 20 | 1(5%) | 20 | 1(5%) |
| Tanzania | 9 | - | 10 | 1(5%) | 10 | 1(5%) |
| Pakistan | 33 | - | 50 | 3(5%) | 50 | 2(3%) |
| ASEAN 5 | 3,515 | 3,603 | 3,600 | 70(2%) | 4,000 | 25(0.6%) |
| Total | 5,723 | - | 7,560 | 764 | 9,600 | 594 |

Source : ** IISI, GOIC Data Bank.

Note : * Exports from Oman. ( ) is share of Oman. Share in 2005* and 2010* in UAE is in accordance with the figure minus the production of 500,000 tons indicated in Table 4-4-9.

The concept behind the forecast of steel bar import volume by major country in Table 4-5-3 is as follows:

- Imports of bars in UAE grew by an annual rate of 15.6% over the period 1991-1996. Annual growth rate for the subsequent period 1996-2005 is assumed at one-half, or 8%. The said rate for the period 2005-2010 is assumed at 5%.
- Imports of bars in Kuwait grew by an annual rate of 20.4% during the period 1993-1996. Annual growth rate for the subsequent period 1996-2005 is assumed at 5%. The said rate for the period 2005-2010 is assumed at 3%.
- Imports of bars in Bahrain showed flat growth during the period 1993-1996. Annual growth in the future is assumed at a flat rate of 90,000 tons per year.
- Saudi Arabia possesses domestic production capacity, and imports have shown an erratic trend up to now. Nevertheless, imports of bars in the future are assumed at a flat rate of 300,000 tons per year.
- Yemen exhibits a past trend of a sharp drop and a rise in bar imports. The population is 15 million, and the government is aggressively pursuing programs for effective utilization of recently discovered natural gas resources, and economic development. Also, up until twenty years ago, Yemen imported large quantities of steel products. After having experienced separation and reunification, political stability is finally returning to the country, and against this background it is assumed that volume of steel rod imports will double over the period 1995-2005 (annual growth rate of 7.2%). After that, average annual growth rate is seen at 5%.
- The bar import market in ASEAN 5 is very large as shown in Table 4-4-6. However, these imports in 1997 and 1998 are supposed to fall terribly due to the 1997 economic crisis. Under these considerations, it is assumed that these imports in 2005 will recover to the level of 1996 and that the annual growth rate of these imports in 2005 to 2010 will be about 2%.

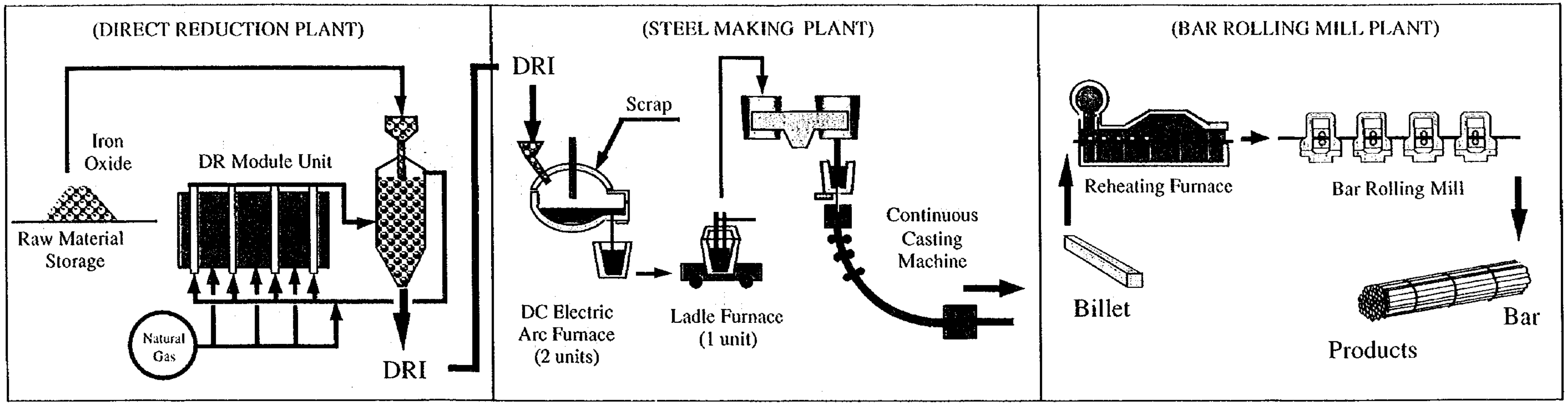
## Chapter 5. CONCEPTUAL STUDY FOR THE STEEL COMPLEX

### 5.1 Optimization of Production Capacity

In consideration of an internationally competitive and appropriate facility size, an annual production of about 1.2 million tons of concrete reinforcing steel bars has been suggested as the optimum capacity. This figure is based on the high utilization of the direct reduction plant, for the key production process of iron and steel making in the Steel Complex using natural gas.

The Steel Complex as studied consists of the following main production facilities as shown in Figure 5-1-1 "Process Flow of Steel Complex" attached herein.

| | | |
|---|---|---|
| - Iron making process | : | Direct Reduction Plant (DRP) |
| - Steel making and casting | : | Electric Arc Furnace (EAF) for steel making process and Continuous Casting Machine |
| - Rolling process | : | Bar Rolling Mill |




MIDREX MEGAMOD Module
Capacity : 1,300,000 tons/year

2- DC type Electric Arc Furnace
Capacity : 150 tons/heat each,
DRI charging system
1- Ladle Furnace
1- Continuous Casting Machine with 8 strands

1- High Speed Rolling Mill with Multi Slit Rolling
Capacity : 1,164,000 tons/year

Figure 5-1-1 Process Flow of the Steel Complex

## 5.2 Product Mix

(1) As mentioned in Chapter 5.1, the study has been conducted on the basis that the finished product to be produced by the Steel Complex is concrete reinforcing steel bars, and that the project is an export-oriented project where the bars will be more attractive than the flat products (see Chapter 4).

The major size range of the concrete reinforcing steel bars produced in the Steel Complex is expected to be 10 mm to 32 mm in diameter.

(2) Certain section products of similar size such as angles, channels, flat bars, etc. in addition to the concrete reinforcing steel bars could also be produced by a minor additional provision in the same bar rolling mill as planned to produce the concrete reinforcing steel bars.

However, productivity (i.e. rolling rate) of such section products becomes remarkably lower than that of the concrete reinforcing steel bars.

## 5.3 Material Flow

The preliminary material flow and balance for the major items starting from iron oxide to the finished concrete reinforcing steel bars is shown in Figure 5-3-1 "The Steel Complex Material Flow and Balance Sheet" attached herein.

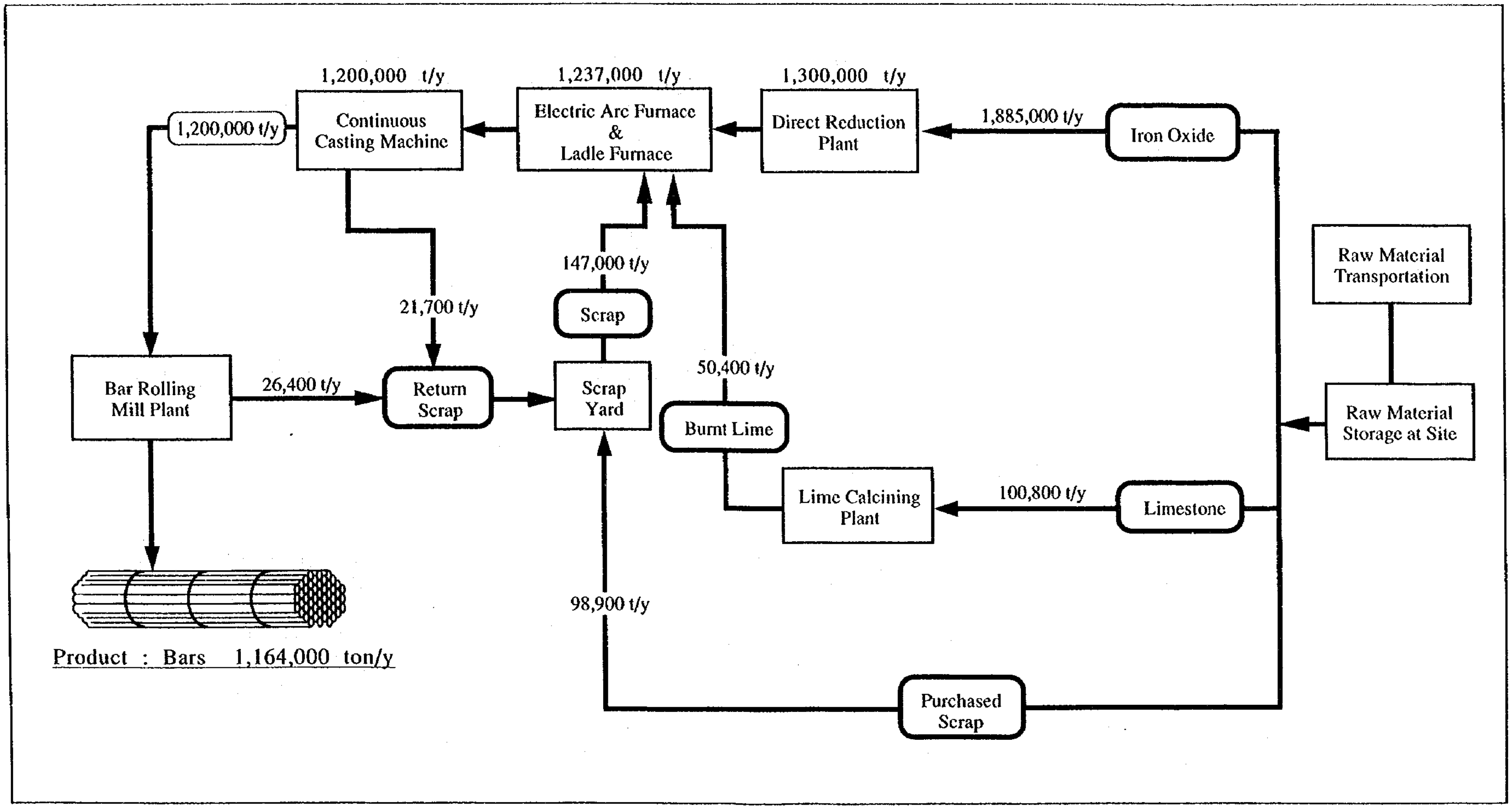



Figure 5-3-1 The Steel Complex Material Flow and Balance Sheet

## 5.4 Site and Infrastructure Requirements

The requirements for the selected plant site and the essential infrastructure for the implementation of the suggested Steel Complex Project are expected as follows;

(1) Area of the plant site

The total area of the plant site required for installation of the suggested Steel Complex is approx. 1,200,000 $m^2$ (800 m x 1,500 m).

(2) Natural gas

The requirement for natural gas is estimated as follows;

- Annual consumption : Approx. 396,000,000 $Nm^3/y$ (14,700,000 MMBTU/y)
- Hourly peak consumption rate : Approx. 66,000 $Nm^3/h$ (2,500 MMBTU/h)

Natural gas will be received with a pressure of approx. 4 $kg/cm^2G$ at the natural gas receiving station in the Steel Complex and it will be distributed to DRP, EAF, Continuous Casting Machine, Bar Rolling Mill, etc..

(3) Electricity

The requirement for electric power is estimated as follows;

- Average power demand : Approx. 170 MW
- Peak power demand : Approx. 200 MW

The plant, and especially the EAF, will be entirely dependent on the electric power supply to the plant site. As the EAF is a fluctuating power consumer, flicker problems will arise.

In order to prevent such phenomenon, a static type reactive power compensator should be provided. Also, a high harmonic filter should be provided against harmonic wave problems.
The electric power supplied to the plant site is expected to be 132 kV. The short circuit capacity of the incoming power at 132 kV to the receiving point shall be at least 1,500 MVA.

(4) Industrial (fresh) water and sea water

The requirement for industrial (fresh) water is estimated as follows;

- Average consumption : Approx. 1,200,000 $m^3$/y
- Peak consumption rate : Approx. 200 $m^3$/h

Fresh water is made at the desalination plant installed in the Steel Complex and it will be distributed to the following;

| | |
|---|---|
| - DRP | : Make-up water for circulated water cooling system |
| - EAF | : Make-up water for circulated water cooling system |
| - Continuous casing machine | : Make-up water for circulated water cooling system |
| - Bar rolling mill | : Make-up water for circulated water cooling system |
| - Buildings | : Potable water / Laboratory |
| - Others | : Fire water, etc. |

In order to minimize the consumption of fresh water in the Steel Complex, sea water will cool the circulated cooling water by means of a sea water cooled heat exchanger instead of the evaporate cooling tower method.

The requirement for sea water is estimated as follows;

- Average consumption : Approx. 184,000,000 $m^3$/y
- Peak required quantity : Approx. 25,000 $m^3$/h

(5) Port/Port facilities

The specification of the planned port/port facilities should be decided in regard to the size of the ocean vessels. In the international trade, vessels of 70,000 DWT to 100,000 DWT are commonly used to transport iron oxide so that freight costs can be reduced. Therefore, it is recommended that the port/port facilities should be planned to give access to vessels of 100,000 DWT.

The port/port facilities for exporting the final concrete reinforcing steel bars, need to construct a berth of about 700 m in length. Dredging the seabed to make to 16 m depth, and an approach channel of more than 16 m will be necessary.
The recommendable specifications for the port/port facilities are mentioned below;

1) Port approach channel : More than 16 m in depth

2) Berth

- Length : Approx. 700 m for one ore carrier and two general cargo vessels
- Depth : 16 m for ore carrier and 12 m for general cargo vessel

3) Unloading : Two x 1,000-t/h unloaders

4) Loading : Two x 20-ton gantry cranes with magnet

(a) Quantity of handling materials

| | | |
|---|---|---|
| a) | Iron oxide | : 2,000,000 t/y (approx.) of unloading |
| b) | Steel scrap | : 100,000 t/y (approx.) of unloading |
| c) | Auxiliary materials, etc. | : 80,000 t/y (approx.) of unloading |
| d) | Bar products | : 340,000 t/y (approx.) of loading |

(b) Capacity of vessel

| | | |
|---|---|---|
| a) | For iron oxide | : 100,000 DWT ore carrier with 250 m long |
| b) | For steel scrap, bars and others | : 10,000 - 20,000 DWT general cargo vessel with 140 - 165 m long |

The preliminary port layout is shown in Figure 5-4-1 "General Layout of Port Facilities" and the recommended location of the site for the Steel Complex is shown in Figure 5-4-2 "Sohar New Port Plan and Steel Complex Site" attached herein.

(6) Disposal area for waste

During operations of the planned Steel Complex, large amounts of waste will be generated from each process in the steel works. The waste must be disposed somewhere outside the plant but close at hand. Table 5-4-1 shows the types of waste to be disposed outside the works.

Table 5-4-1 Waste Disposed Outside the Steel Complex

| Waste | Amount (t/y) |
|---|---|
| Slag | 200,000 (approx.) |
| Fine, Dust and Sludge | 76,000 (approx.) |
| Scale | 16,000 (approx.) |
| Waste bricks | 1,600 (approx.) |

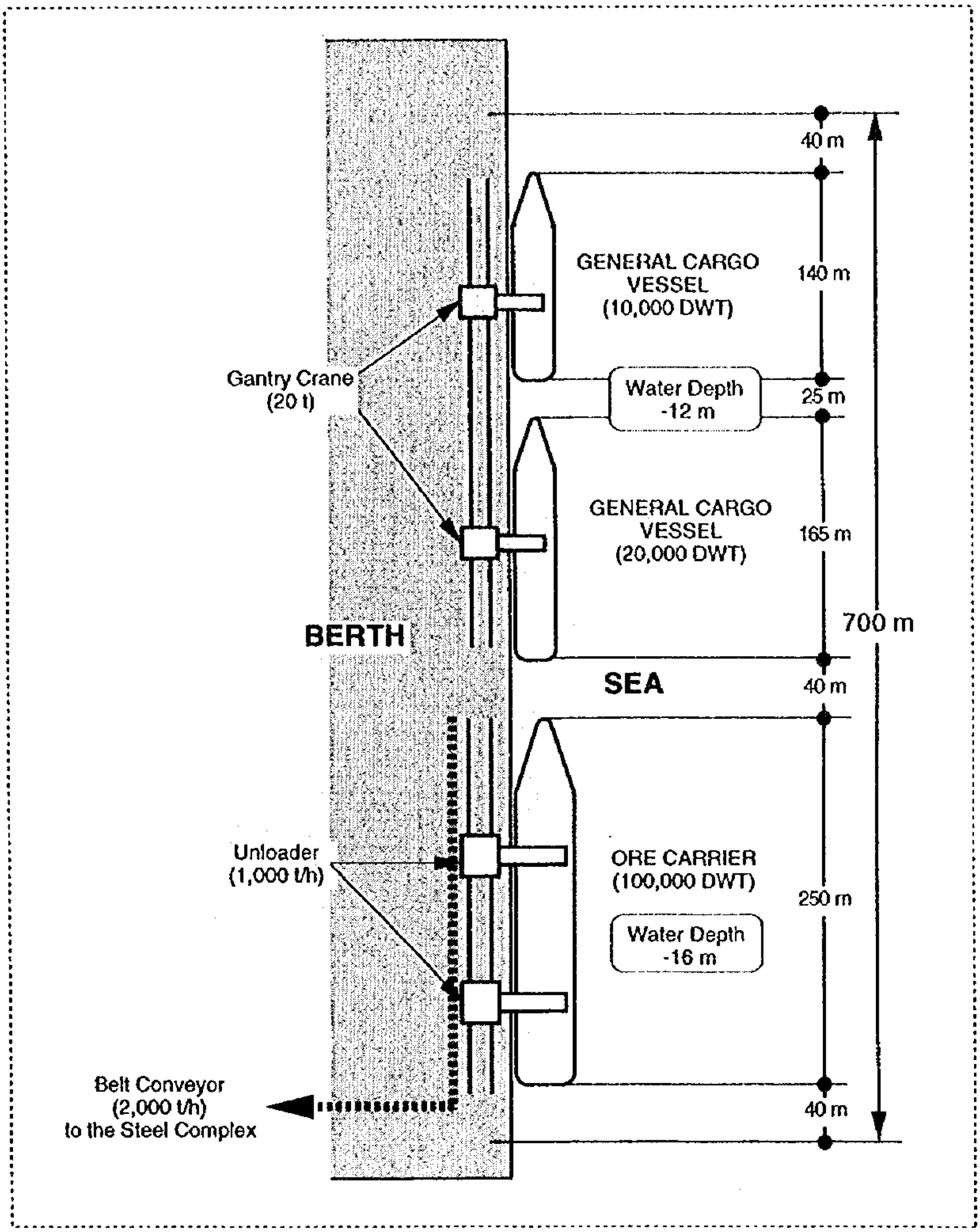



Figure 5-4-1 General Layout of Port Facilities

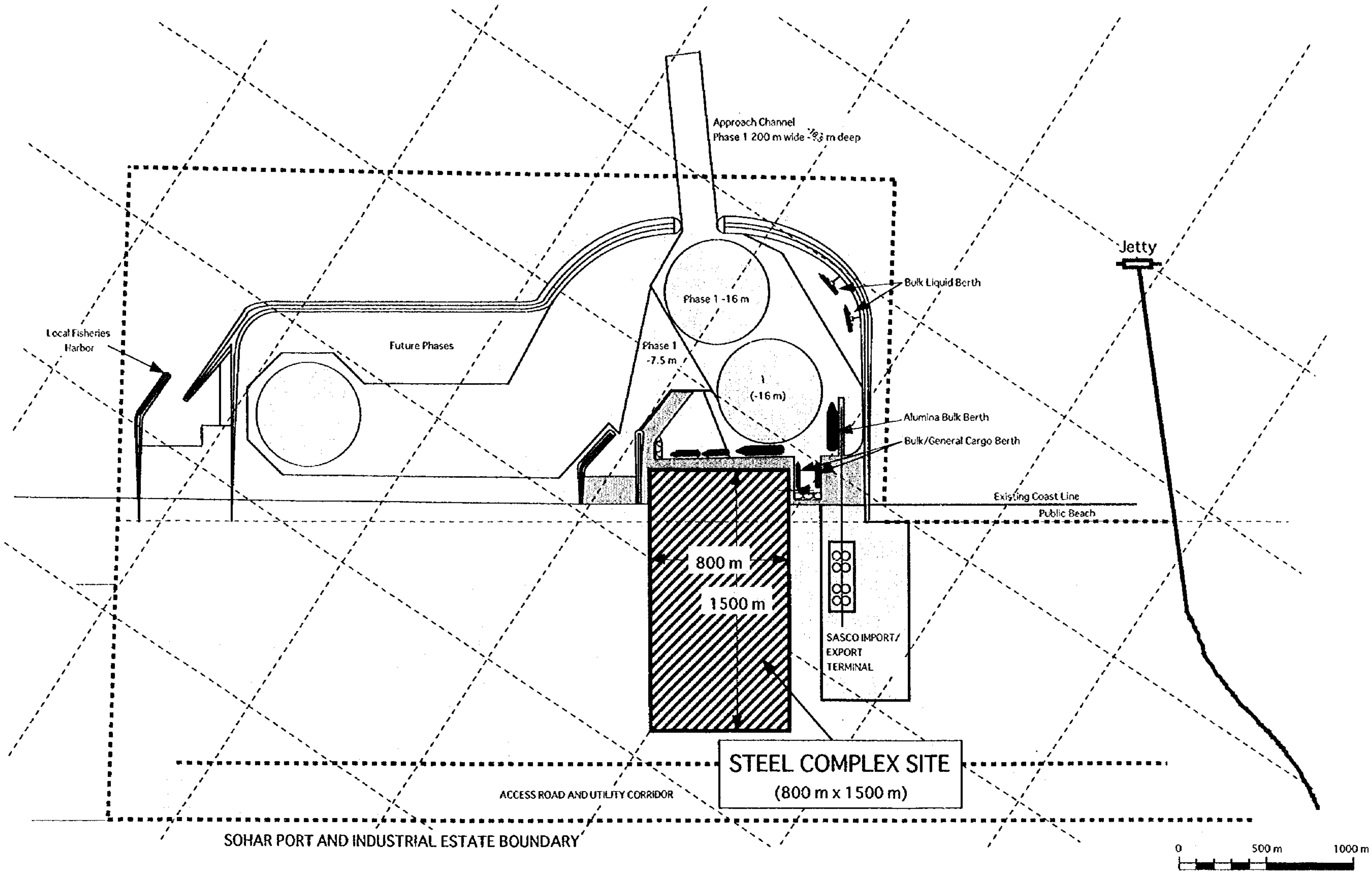



Figure 5-4-2 Sohar New Port Plan and the Steel Complex Site

## 5.5 General Layout

The preliminary layout of the Steel Complex is shown in Figure 5-5-1 "General Layout of Steel Complex" attached herein.

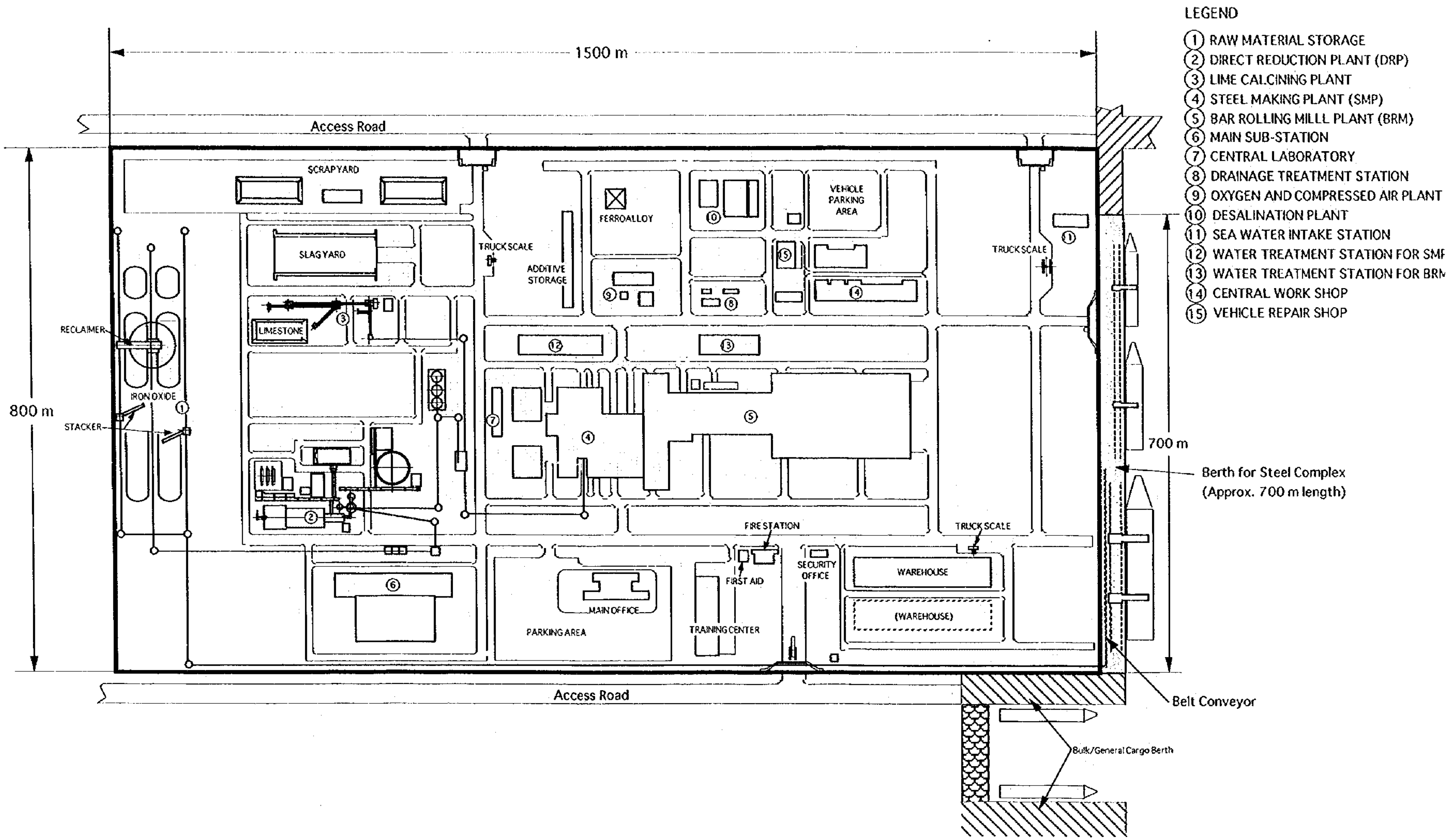



Figure 5-5-1 General Layout of the Steel Complex

## 5.6 Energy and Utility Consumption

The energy consumption for the major plants and facilities will be estimated as shown in Table 5-6-1 "Electric Power Energy Consumption of Major Plants/Facilities" and Table 5-6-2 "Natural Gas Energy Consumption of Major Plants/Facilities", respectively.

Table 5-6-1 Electric Power Energy Consumption of Major Plants/Facilities

| Plants/Facilities | Production (t/y) | Unit Consumption (kWh/t) | Annual Consumption (MWh/year) |
|---|---|---|---|
| Direct Reduction Plant | 1,300,000 | 100 | 130,000 |
| Lime Calcining Plant | 50,400 | 50 | 2,520 |
| Steel Making Plant | 1,200,000 | 695 | 834,000 |
| Bar Rolling Mill Plant | 1,164,000 | 90 | 104,760 |

Table 5-6-2 Natural Gas Energy Consumption of Major Plants/Facilities

| Plants/Facilities | Production (t/y) | Unit Consumption (kcal/t) | Annual Consumption (Gcal/year) |
|---|---|---|---|
| Direct Reduction Plant | 1,300,000 | 2,500,000 | 3,250,000 |
| Lime Calcining Plant | 50,400 | 926,500 | 46,700 |
| Steel Making Plant | 1,200,000 | 30,600 | 36,720 |
| Bar Rolling Mill Plant | 1,164,000 | 280,000 | 325,920 |

In the above tables, the production and unit consumption are based on the following;

(1) The product for the direct reduction plant is DRI and its unit consumption shows the DRI product-ton base.

(2) The product for the lime calcining plant is burnt lime and its unit consumption shows the burnt lime-ton base.

(3) The product for the steel making plant is the cast billet and its unit consumption shows the cast billet product-ton base.

(4) The product for the bar rolling mill plant is the rolled bar and its unit consumption shows the rolled bar product-ton base.

Water consumption will be estimated as shown in Table 5-6-3 "Water Consumption".

Table 5-6-3 Water Consumption

| Kind of Water | Unit Consumption | Consumption |
|---|---|---|
| Industrial (Fresh) Water | 1.0 ($m^3$/t-bar) | 1,200,000 ($m^3$/y) |
| Sea Water | 165 ($m^3$/t-bar) | 192,000,000 ($m^3$/y) |
| Potable Water | 200 (liters/person-day) | 200 ($m^3$/d) |

In the above table, the mentioned unit consumption and annual/daily consumption are based on the following;

(1) For industrial water and sea water, the unit consumption shows the rolled bar product-ton base and the annual consumption is based on the annual production of rolled bars (approx. 1,200,000 tons).

(2) The unit consumption of potable water shows a person per day base and the daily consumption is based on the total number of persons (approx. 1,000).

## Chapter 6. APPLICABLE TECHNOLOGY FOR THE STEEL COMPLEX

### 6.1 Raw Material Handling Facilities

As imported iron ore (oxide pellets and/or lump ore) will be unloaded at Sohar port, which will be located near the Steel Complex, a system to handle raw material shall be provided to transport the iron ore from the berth to the Steel Complex.

The system will consist of belt conveyors (2,000 t/h, each) running from the unloaders at the berth to the storage yard in the Steel Complex, two stackers (2,000 t/h, each) and one reclaimer (500 t/h) for the storage yard and belt conveyors running from the reclaimer up to the top of the storage day-bins in the direct reduction plant.

The area of the open storage yard will be 2 x 35 m wide by 400 m long. The storage capacity will be approx. 270,000 tons in total, which is equivalent to about 50 days storage capacity for normal operation.

A schematic flow sheet for the raw material handling system is shown in Figure 6-1-1 on the next page.

Appendix A6-1-1 attached hereto shows Major Equipment List of Raw material Handling Facilities.

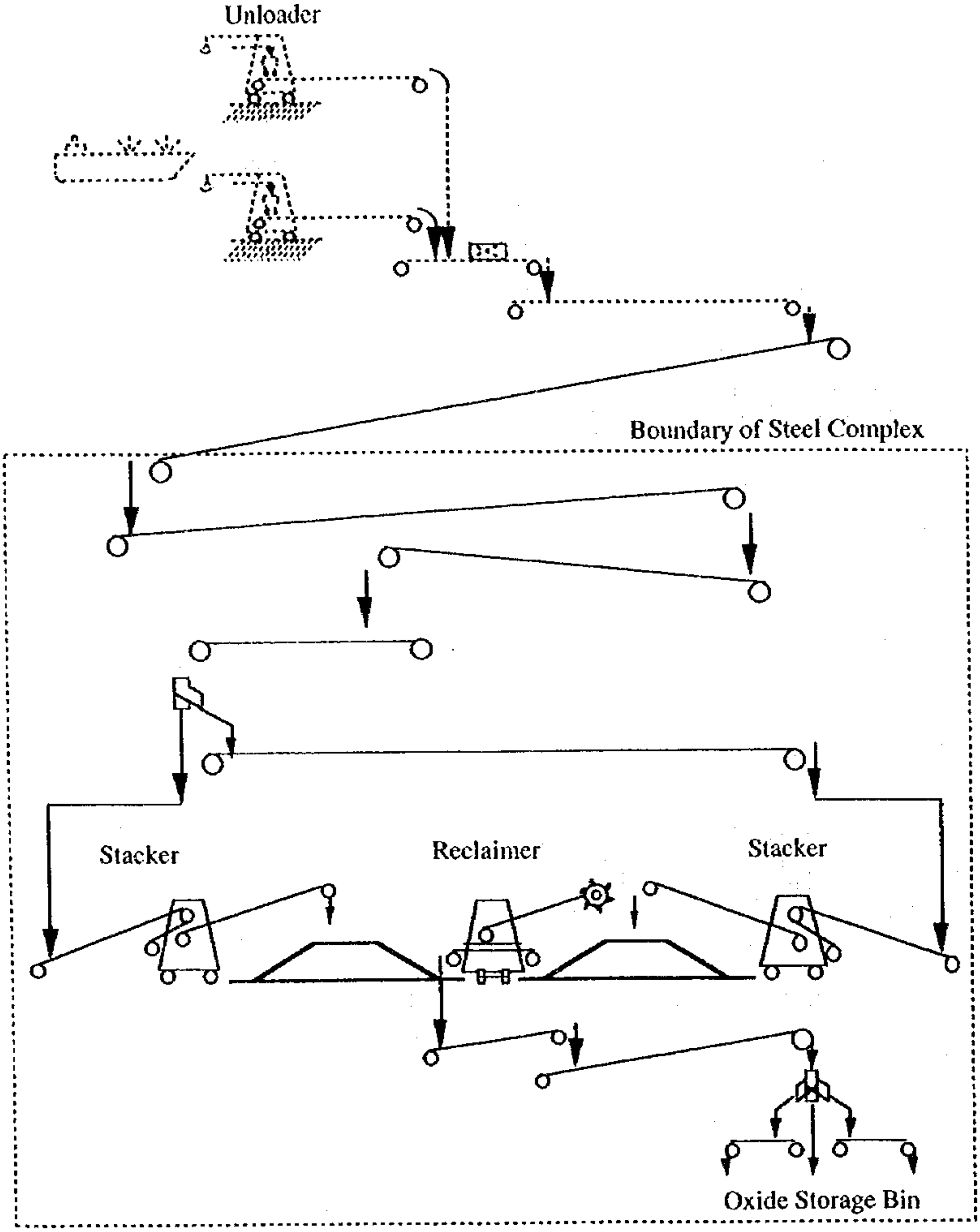



Figure 6-1-1 Schematic Flow Sheet for Raw Material Handling System

## 6.2 Direct Reduction Plant

### 6.2.1 Applicable process for direct reduction plant

Of the steel making processes, a combination of gaseous direct reduction and EAF presently occupies the second largest share of steel making operations in the world.

- MIDREX Process
- HYL-III Process
- FINMET (former FIOR) Process
- IRON CARBIDE Process

A comparison of the main features of the representative processes for gaseous direct reduction is given in Table 6-2-1.

Table 6-2-1 Comparison of the Representative Process

| | MIDREX | HyL-III | FINMET (former FIOR) | IRON CARBIDE |
|---|---|---|---|---|
| Status | Industrial | Industrial | Industrial | Industrial |
| Iron source | Pellets Lump | Pellets Lump | Fines (Size: sinter feed) | Fines (Size: 0.1-1mm) |
| Pressure (kg/cm$^2$) | Atmospheric | 5 | 11 - 12 | 0.8 |
| Maximum plant capacity per one module (x 1,000 tons/y) | 1,360 * | 1,100 * | FINMET: 625 * (FIOR: 400) | 330 * |
| Plant installed (modules) ** | 43 | 13 | 1 | 1 |
| Total capacity installed (x 1,000 tons/y) ** | 23,190 | 6,970 | 400 | 300 |
| Evaluation | Most widely used | Less plants than MIDREX | Only one industrial plant | Only one industrial plant |
| Commercial operation in Arabic countries | Yes | No | No | No |

* Plant under construction as of 12/31/1997

** Status as of 12 / 31 / 1997

As shown in Table 6-2-1, plants using FINMET (former FIOR) or IRON CARBIDE processes with capacity in excess of 400,000 tons/year by single module have not been constructed or proven viable yet. Therefore, those processes are not suitable for study at this stage. Even if those processes are adopted for study, it would result in higher initial costs and higher operation/maintenance costs because of the necessity for plural modules of the plant. (A FINMET plant of 2,500,000 tons/year capacity using four modules has not been operated yet.)

Both MIDREX and HyL-III processes are suitable for the direct reduction plant in the Steel Complex. However, the MIDREX process has been chosen in this feasibility study because of the following reasons:

1) The MIDREX process has the largest number of commercial plants installed world wide.
2) The MIDREX process has the largest total production of direct reduced iron world wide.
3) The MIDREX process installed in IMEXSA, Mexico consistently operating at 180-200 tons per hour of DRI is the only single module, direct reduction process in operation.
4) A HyL-III plant with a capacity of 1,000,000 tons per year or more, using a single module has not been put into operation yet.

For reference, the MIDREX and HyL-III processes are briefly described as below.

(1) The MIDREX Process

The first MIDREX plant was built in Portland, Oregon, United States of America in 1969 by the Midrex Division of the Surface Combustion Company which had been purchased by the Midland Ross Corporation, USA. In 1974, the Korf Group purchased the division and formed Midrex Corporation. In the early 1980s, the Korf Group experienced financial difficulties and in 1983 sold Midrex to Kobe Steel.

The MIDREX Process (Figure 6-2-1) converts iron oxide pellets or lump ore into high purity direct reduced iron (DRI) or hot briquetted iron (HBI). The direct reduction of iron oxide proceeds on a continuous basis: the iron oxide is fed into the top of the shaft furnace, flows downward by gravity and is then discharged from the bottom of the shaft furnace in the form of DRI.

Reducing gas is generated in a stoichiometric $CO_2$ reformer which reforms a mixture of fresh natural gas and recycled top gas from the shaft furnace at approximately 920°C. As the reducing gas leaves the reformer in near equilibrium conditions, containing 90 to 92 percent hydrogen plus carbon monoxide, the gas does not require quenching; it is fed directly to the shaft furnace where reduction takes place at about 850°C.

Part of the shaft furnace off-gas is used to fire the reformer burners; the remainder is recirculated to the reformer. Thermal efficiency of the reformer is greatly enhanced by a comprehensive heat recuperation system. The heat exchangers recover the sensible heat from the reformer flue gas to preheat combustion air (used in the reformer burners) up to 650°C and to preheat the process gas (mixture of top gas and natural gas) fed to the reformer up to 540°C.

The DRI produced can be discharged at an ambient temperature or hot briquetted. The briquettes are cooled in a quench tank or with water sprays. The shaft furnace is operated at low pressure and has a number of internal mechanical devices and flow aid devices to facilitate solid/gas contact.

A major feature of the MIDREX Process is its stable product quality. The uniform gas distribution in the shaft furnace ensures uniform product metallization even when the ore supplies change.

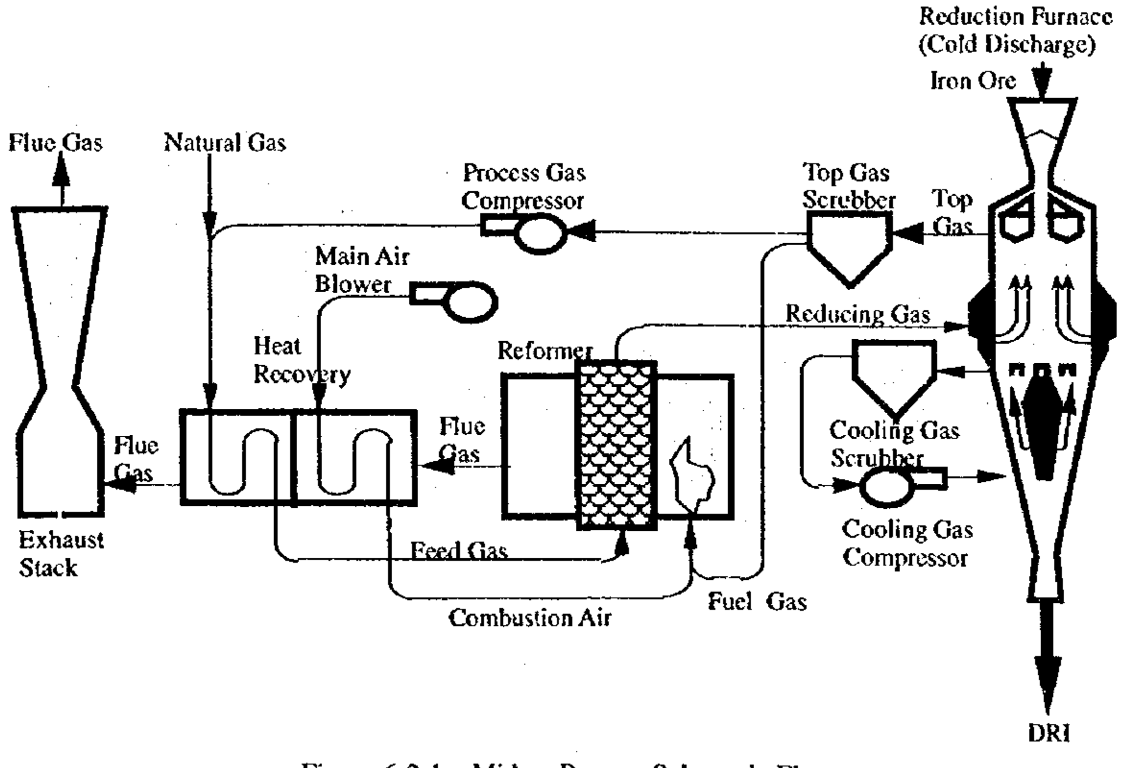



Figure 6-2-1 Midrex Process Schematic Flow

(2) The HYL-III Process

The first HyL plant was built in 1957 in Puebla, Mexico. This technology, known as HYL-I, uses four fixed bed reactors, operated in a batch mode. Development of HYL-II, an improved batch process, started in 1969. Simultaneously, HyL began working on HYL-III, a continuous process using a shaft furnace. The first commercial HYL-III plant, 2m5, began operation in 1979.

The HYL-III Process (Figure 6-2-2) reduces iron oxide pellets or lump ore in a shaft reactor. Reducing gas is generated in a steam reformer to produce the hydrogen plus carbon monoxide required as make-up gases for the reduction process. The reformed gas is quenched to remove excess steam, then reheated.

Reducing gases are made up of a mixture of make-up and recycling gases. The basic components of the reduction circuit, aside from the reactor, are (1) a gas heater to increase the reducing gas temperature up to 925°C, (2) a scrubbing unit for deducting, cooling and $H_2O$ elimination from the top gas, (3) the recycle gas compressor and (4) the $CO_2$ removal unit. Here $CO_2$ is selectively eliminated from the system for a more efficient reuse of the recycle gas.

The zero kWh option uses steam turbines to produce electricity; steam for the turbines is generated using heat from the reformed gas quenching step. The shaft furnace is operated at high pressure; it has no internal mechanical devices or flow aids except for a "cluster breaker" at the furnace outlet.

After $CO_2$ is removed, reactor off-gas is circulated to the reactor. The DRI produced can be discharged at an ambient temperature or hot briquetted. The briquettes are cooled in a quench tank.

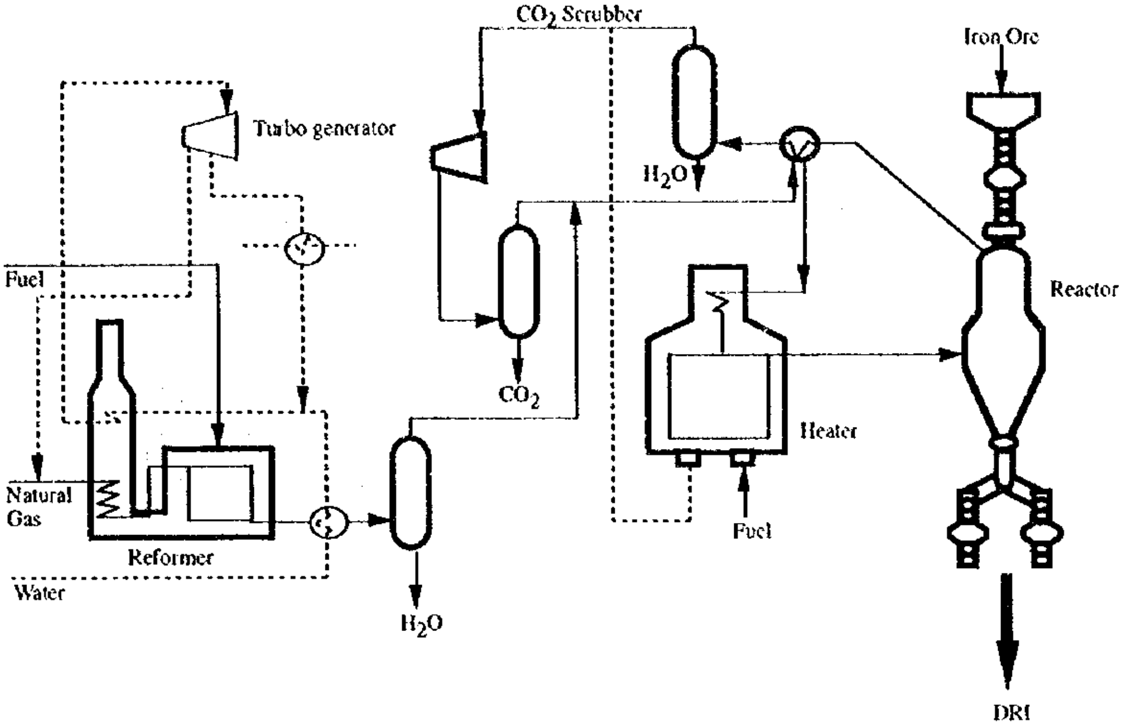



Figure 6-2-2 HyL-III Process Schematic Flow

6.2.2 Plant capacity

(1) Basic plan of the DRP

Basically, the direct reduction plant (DRP) for the Steel Complex is to adopt the MIDREX Megamod® gas based direct reduction plant.

(2) Production plan

1) Rated production plan

Rated annual production plan is 1,300,000 tons of direct reduced iron per 8,000 hours.

2) Start-up production plan

At the initial stage of plant start-up, the equipment will be checked during production operation. As the operators may not yet be familiar with operation and maintenance of the plant, production capacity will be gradually increased from the initial start-up over a period of two years.

Production schedule:

- 1st year : 70 % of the annual rated capacity
- 2nd year : 90 % of the annual rated capacity
- After the 2nd year : 100 % of the annual rated capacity

(3) Production and products

1) Production capacity

Production capacity of the DRP is 1,300,000 ton of direct reduced iron per year.

2) Product specification

The expected main specifications of the direct reduced iron are as follows;

(a) Fe Total : 90 - 94 wt %
(b) Fe Metallic : 83 - 89 wt %
(c) Metallization : 92 - 95 wt %
(d) Carbon content : 1.0 - 2.5 wt %

(4) Scope of facilities

The Direct Reduction Plant includes the following:

1) A reduction system
2) A reforming system
3) A process gas system
4) A heat recovery system
5) A seal gas and purge gas system
6) An emergency inert gas system
7) A material handling system
8) A water system
9) A fire fighting system
10) A dust collection system

(5) Operation

1) Operation shifts

Daily operation involves three shifts by four crews.

2) Operation hours

Annual operation time is 8,000 hours, which is determined based on the consideration of the annual production schedule of the Steel Complex.

6.2.3 Iron oxide feed

The design base of the raw materials for the DRP is 1,885,000 ton per year of iron oxide feed, a mixture of oxide pellets and lump ore.

The typical standard mixing ratio of the raw materials is as follows;

1) Oxide pellets : 100 - 70 wt %
2) Lump ore : 0 - 30 wt %

6.2.4 Process description

Detailed explanations about the plant and process of the main systems of DRP is described hereinafter.

(1) Reduction system

The reduction furnace is the patented MIDREX Shaft Furnace with a 6.65 meter diameter. Iron ore is fed into the Shaft Furnace through the upper dynamic seal leg and then uniformly distributed on the stock line by means of a plurality of symmetrical feed pipes.

The iron ore is reduced to metallic iron in the reduction zone (upper portion of the furnace) by contact with hot gases containing hydrogen and carbon monoxide, which flow counter current to the descending iron oxide. Uniform reducing gas flow is assured by special designed inlet ports (tuyeres).

Below the reduction zone, the furnace contains burden feeders which ensure a uniform velocity of material flow through the furnace.

In the lower portion of the MIDREX Shaft Furnace, the direct reduced iron (DRI) is cooled by re-circulated cooling gas to near ambient temperature.

The DRI leaves the shaft furnace through the bottom gas seal leg which operates in the same manner as the upper seal leg. The vibrating discharge feeder is used to control the rate of product discharge from the shaft furnace. Product is discharged onto the product discharge conveyor. The product discharge system conveys the DRI from the discharge feeder to the DRI product silos.

(2) Reforming system

The MIDREX Reformer is a refractory-lined, gas-tight steel structure which contains vertically suspended heat resistant alloy tubes filled with catalyst and arranged in the fire box in six parallel rows. For ease of installation and future expansion, the reformer is constructed in modules called "bays".

The reformer tubes are supported at the roof and expand downward through the floor of the reformer. The bottom of each tube is sealed with a flexible expansion seal to prevent air infiltration into the combustion zone of the reformer.

A preheated mixture of scrubbed and compressed process gas and natural gas enters the bottom of each reformer tube and flows upward through the static catalyst bed. The natural gas is stoichiometrically reformed with carbon dioxide and water contained in the process gas stream to produce a hot gas containing hydrogen and carbon monoxide.

The reformed gas exiting from three headers (each tied into two rows of reformer tubes) is collected into a single refractory lined duct that supplies the reducing gas directly to the bustle of the reduction shaft furnace.

Heat for the reformer is supplied by the main burners which are located on the bottom of the reformer box between tube rows and between the outside tube rows and the reformer wall. The fuel for main burner combustion is a mixture of natural gas and excess spent reducing gas which has been cleaned and cooled in the top gas scrubber to produce top gas fuel.

The required air for combustion of the main burner fuel mixture is supplied by the main air blower. Natural gas fired auxiliary burners serve to maintain reformer box temperature when the Plant is in an idle mode of operation so as to minimize both restart time and thermal cycling of the reformer tubes.

Flue gas is withdrawn from the reformer box in two flue gas headers arranged along the upper parts of both longitudinal walls of the reformer. To ensure uniform heat distribution along the reformer length, each reformer bay has a separate flue gas port to each of the flue gas headers.

These flue gas ports are located in the side wall sections of every bay directly below the reformer roof. The flue gas headers are refractory lined and expansion joints are provided between the single sections of the headers to compensate for thermal expansion. Also, to permit thermal expansion, the reformer structure is anchored at its center and allowed to expand freely in either direction. A series of sliding plates allow the columns to move horizontally in an uninhibited fashion.

Finally via the flue gas header, the flue gas exiting the reformer box flows to the heat recovery system where the waste heat is recovered.

(3) Process gas system

The process gas system consists of a direct contact water scrubber and compressors necessary to clean, cool, and compress the spent reducing gas exiting the shaft furnace.

The spent reducing gas exits the shaft furnace and first enters the top gas scrubber. Inside the scrubber the gas passes through two distinct processing zones:

1) The gas first flows through the venturi portion of the scrubber where the hot gas is rapidly cooled and particulate matter is wetted and removed;
2) Warm gas is then split into two streams that pass through two parallel packed beds and two sets of spin vanes (for water droplet removal) within the scrubber. Additional gas cooling takes place within the packed beds and excess water vapor condenses.

After scrubbing and cooling, approximately two-thirds of the clean top gas (now process gas) flows to the inlets of the process gas compressors.

The process gas is subsequently mixed with preheated natural gas before entering the feed gas pre-heater. The preheated feed gas is then passed through the reformer tubes filled with catalyst where the reforming reactions take place with a sufficient supply of energy from the reformer's main burners, both to heat the gases to the temperature required for reduction and to supply the heat required by the reforming reactions.

The remaining one-third of the cleaned top gas (now top gas fuel) is mixed with a small amount of natural gas to become the fuel mixture for the reformer main burners. The fuel then passes through a mist eliminator to remove water droplets before entering in the top gas fuel pre-heater.

Reformed process gas exiting the reformer (now reformed gas) is usually too hot for direct injection to the reduction shaft furnace as bustle gas. Therefore, tempering or cooling of the hot reformed gas is required to obtain the proper temperature.

The reformed gas cooler performs the function of cooling a small slip stream of reformed gas which is then mixed with the remainder of hot reformed gas to obtain a bustle gas of proper temperature. This reformed gas cooler is a packed bed, direct contact cooler which uses a spray of process water as the coolant.

(4) Heat recovery system

The flue gas from the reformer is used to preheat the reformer main combustion air, the feed gas stream, the main burner fuel and the process natural gas. The total benefit of the heat recovery system is an increase in reformer capacity and a reduction in the net plant energy consumption by approximately 25 - 30 percent from the first generation MIDREX Plant designed in 1969. The system consists of combustion air recuperators, feed gas pre-heaters, top gas fuel pre-heaters, process natural gas pre-heaters, and a fan and an ejector stack.

The ejector stack is a forced draft (venturi type) flue gas stack that induces the hot flue gas to flow from the reformer through the heat recovery system. A fan is used to create the required suction to cause flow of the hot reformer flue gas by creating a venturi effect within the stack.

The combustion air recuperators are U-bundle type heat exchangers which are arranged within the refractory-lined reformer flue gas ducts. The recuperators are designed to preheat the combustion air to about 675 °C in two stages.

The natural gas is preheated to 370 °C, then mixed with the process gas (feed gas) heating it to over 100 °C. The feed gas pre-heaters finish heating the process gas and natural gas mixture to approximately 400 °C in the first pass and to a final temperature of 580 °C after the second pass. The feed gas pre-heaters are U-bundle type heat exchangers which are suspended in the refractory lined reformer flue gas ducts situated downstream from the combustion air recuperators.

The top gas fuel pre-heaters are also U-bundle type heat exchangers which are suspended in the refractory lined reformer flue gas ducts situated downstream from the natural gas pre-heaters. The top gas fuel pre-heaters are designed to preheat the main burner fuel to approximately 290 °C.

(5) Material handling system

1) Oxide handling system (Refer to Figure 6-2-3)

The oxide handling system of the DR plant begins with three 2,000 ton capacity oxide storage bins, each separated into 3 compartments. Beneath the oxide storage bins are weigh belt feeders which discharge the oxide proportionally from the bins. The weigh feeders place the oxide onto the storage bin discharge conveyor, which feeds the oxide to two oxide screens (one-operating, one stand-by) having double deck vibrating screens and removing the iron oxide fines (-3mm).

The screen oversize (+6mm) is conveyed by a transfer conveyor to a furnace feed conveyor. Along this transfer conveyor is located a bin and a weigh feeder for adding middle size oxide (-6 to +3 mm) from the oxide screen. Remet (materials to be re-metallized) is temporally piled near the shaft furnace area, reclaimed and fed to the oxide screens for furnace feed.

The furnace feed conveyor delivers material to the top of the shaft furnace and discharges it to the charge hopper. The charge hopper operates using a level controller which allows the operator to know the quantity of feed in the charge hopper. Through controllers, the oxide storage bin discharge feeder, the -6 to +3 mm fines feeder and the remet feeder are automatically stopped and started to control the level in the charge hopper.

2) Product handling system (refer to Figure 6-2-4)

The metallized product discharged from the shaft furnace is sent to the product storage bins and stored under inert atmosphere. These bins can store 21,000 tons, or enough to meet about 5 days steel making.

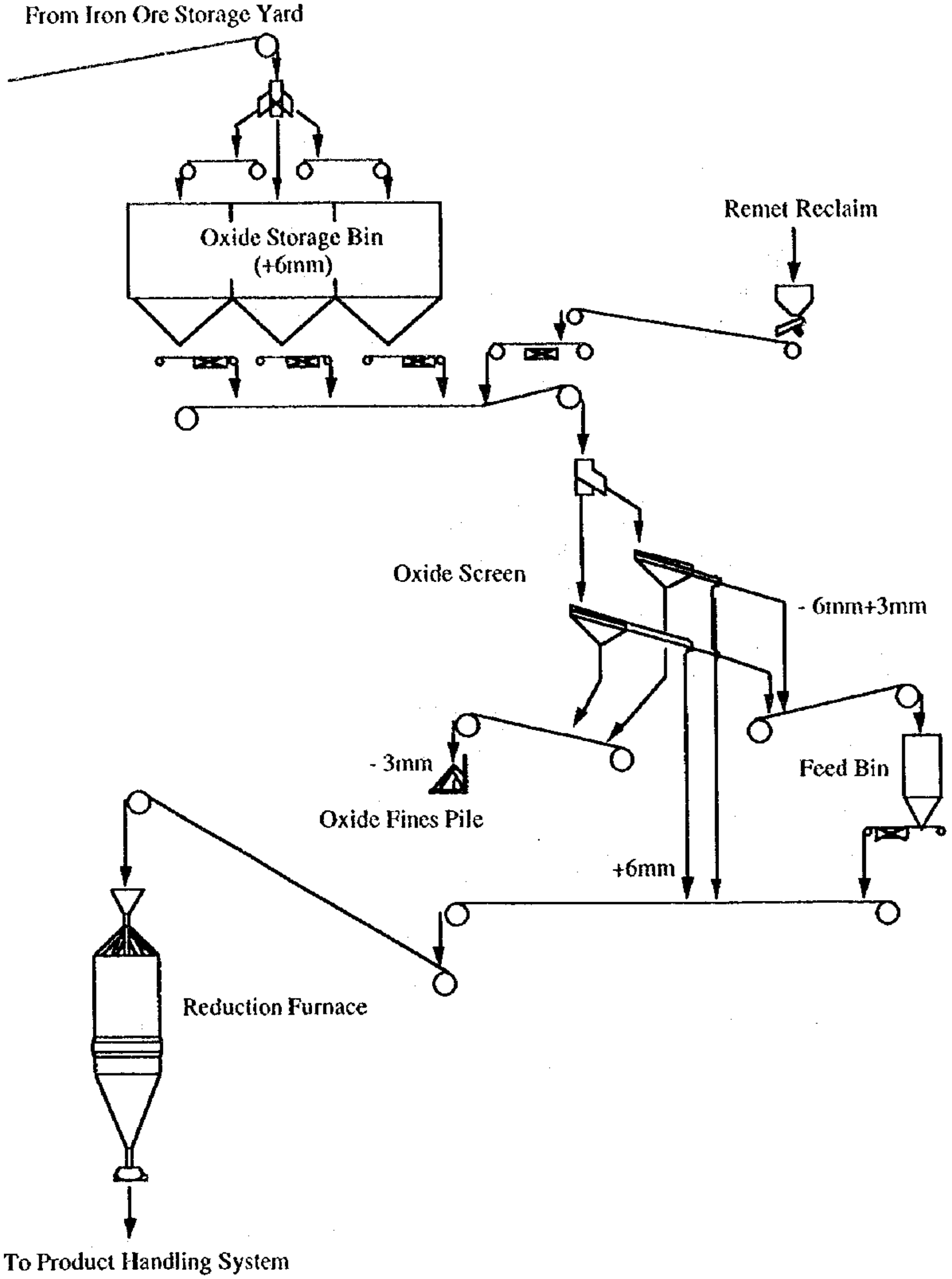



Figure 6-2-3 Schematic Flow Sheet for Oxide Handling System

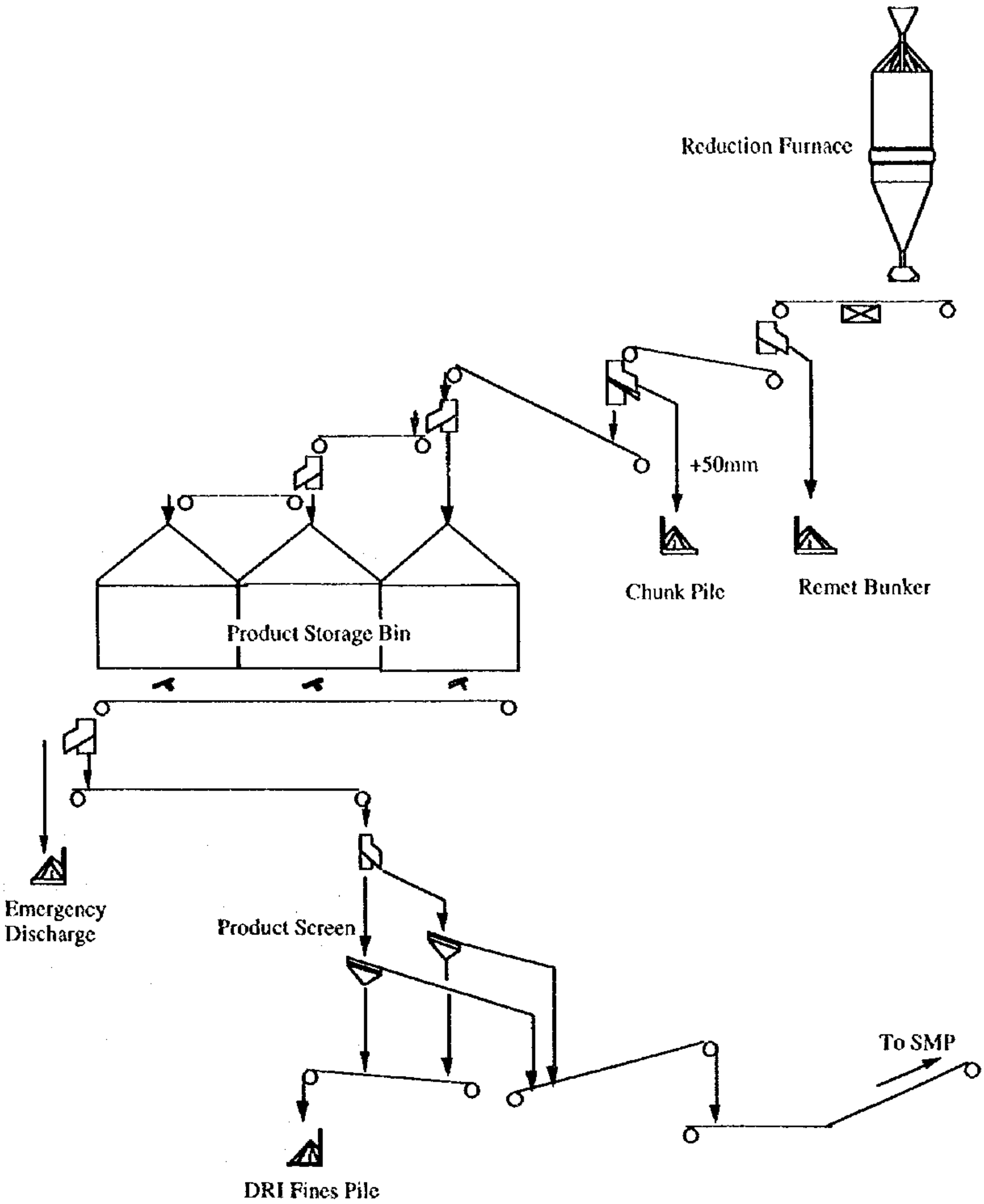



Figure 6-2-4 Schematic Flow Sheet for Product Handling System of DR Plant

### 6.2.5 General layout

Figure 6-2-5 shows a preliminary general layout of the Direct Reduction Plant.

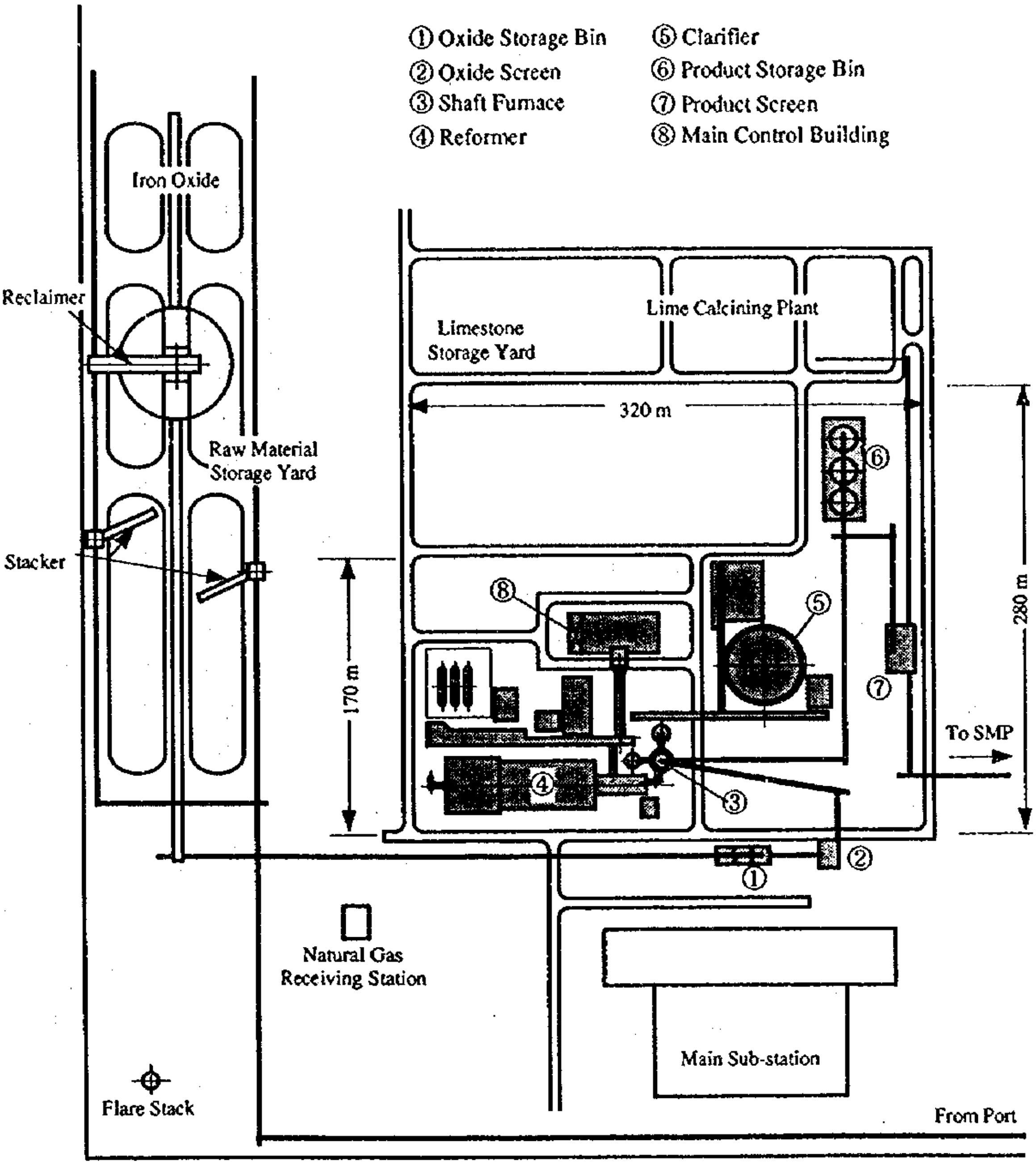



Figure 6-2-5 General Layout of the Direct Reduction Plant

### 6.2.6 Unit consumption

The following is the expected unit consumption (per one ton of DRI-product) based on the MIDREX Megamod® plant:

1) Iron oxide : 1.45 t
2) Natural gas : 2.50 Gcal (LHV)
3) Electricity : 100 kWh
4) Water : 0.3 $m^3$

### 6.2.7 Organization and personnel

Table 6-2-2 shows the standard organization and personnel of the DRP.

Table 6-2-2 Organization and Personnel for DR Plant

| Description | Per Day | Per Shift (*1) | Total |
|---|---|---|---|
| Section Manager | 1 | 0 | 1 |
| Assistant Section Manager | 1 | 0 | 1 |
| Process & Operations / Engineer | 2 | 0 | 2 |
| Water Treatment / Engineer | 1 | 0 | 1 |
| General Foreman | 1 | 0 | 1 |
| Shift Foreman | 0 | 1 | 4 |
| Control Room Operators | 0 | 3 | 12 |
| Field Operators | 0 | 7 | 28 |
| Process / Laboratory Technician | 0 | 1 | 4 |
| Total | 6 | 12 | 54 |

Note 1. (*1) : Three shifts by four crews per day.

### 6.2.8 Major equipment list

Appendix A6-2-1 attached hereto shows the Major Equipment list of the Direct Reduction Plant.

## 6.3 Steel Making Plant

### 6.3.1 Outline

(1) Basic concept

The steel making plant (SMP) will consist of two 150 t DC (direct current) electric arc furnace (EAF), one 150 t ladle furnace (LF), one billet continuous casting machine (BT-CCM) of eight strands (str), and auxiliary facilities to produce billets for reinforcing bar products. The main raw materials for the EAF are direct reduced iron (DRI) and scrap.

(2) Production and products

Production and products will be as follows;

1) Production

The amount of SMP production is shown in Table 6-3-1.

Table 6-3-1 SMP Production

Unit: t/y

| Item | SMP |
|---|---|
| Molten steel | 1,237,000 |
| Billet | 1,200,000 |

2) Products and steel grades

SMP products and steel grades are shown in Table 6-3-2.

Table 6-3-2 Products and Steel Grades

| Item | SMP |
|---|---|
| Products | Billet: 150 mm square x 16 m long |
| Steel grade | 36 kg class steel<br>52 kg class steel |

(3) Facilities

To produce the above, the following facilities are planned.

| | | |
|---|---|---|
| 1) | Handling facilities | : 1 lot |
| 2) | Electric arc furnace facilities | : DC type 150 t x 2 sets |
| 3) | Fume extraction system (FES) | : 1 set |
| 4) | Ladle furnace facilities | : 150 t x 1 set |
| 5) | Cranes and jib cranes facilities | : 1 lot |
| 6) | Electrical equipment, computer system and instrumentation | : 1 lot |
| 7) | Billet casting facilities | : 8 str x 1 set |

6.3.2 Basic design

(1) General

1) Main raw materials
Considering the 1,300,000 t/y DRI production of the direct reduction plant (DRP), the DRI/scrap ratio and consumption are as shown in Table 6-3-3.

Table 6-3-3 DRI/Scrap Ratio and Consumption

| Material | Ratio | Amount |
|---|---|---|
| DRI | 90 % | 1,300,000 t/y |
| Scrap | 10 % | 147,000 t/y |

2) Operating shifts
Operation is in three shifts by four crews.

3) Operation
Two 150 t EAFs will operate with a 108 min. tap-to-tap time along with one 150 t LF operation for four sequential casting operations with a 49 min./heat casting time of one BT-CCM of eight strands.
The operating sequence of the EAF, LF and CCM is outlined in Figure 6-3-1.

4) Annual operating days

Annual operating time will be 310 days.

5) Plant capacity

Plant capacity is determined based on total consideration of annual billet production, annual operating time, tap-to-tap time and casting time, transformer capacity, billet size, billet yield, etc.

| | | |
|---|---|---|
| Molten steel (MS) | : | 150 t/heat x 13.3 heat/d x 310 d/y x 2 furnace |
| | | = 1,237,000 t/y |
| Billet (BT) | : | 1,237,000 t/y x 97.0 % = 1,200,000 t/y |

(2) EAF equipment and operating factors

1) Furnace: DC arc furnace with eccentric bottom tapping system (EBT) x 2 sets
2) Heat capacity: 150 t/heat (excluding 30 t hot heel)
3) Transformer capacity: 88 MVA
4) DRI/scrap ratio: 90/10
5) Oxygen consumption: 30 $Nm^3$/t-MS
6) Electrical power consumption for melting: 610 kWh/t-MS
7) Heats/day: 13.3 heat/d
8) Tap-to-tap time: 108 min.

| | | |
|---|---|---|
| Tapping time | : | 3 min. |
| Fettling time | : | 6 min. |
| Charging time | : | 2 min. |
| Melting/refining | : | 97 min. (*1) |
| Tap-to-tap time | : | 108 min. |

Note *1: Each heat shall be subjected to LF treatment after EAF tapping.

(3) LF equipment and operating factors

1) Ladle capacity: 150 t/heat x 1 set
2) Transformer capacity: 22 MVA
3) Electrical power consumption: 50 kWh/t-MS
4) Heats/day: 13.3 heat/d
5) Operating time: Approx. 20 - 40 min./heat

(4) CCM equipment and operating factors

1) Machine: 8 strands billet casting machine x 1 set
2) Billet size: 150 mm square x 16 m long
3) Casting speed: 2.2 m/min., max. 3.0 m/min.
4) Casting time: 49 min./heat
5) Sequence casting: 4 heats

### 6.3.3 Process and equipment description

The SMP process flow is outlined in Figure 6-3-2.

(1) Scrap charging

After being loaded on dump trucks by scrap loaders at the open scrap yard and weighed at the weighing station, scrap is transported to the EAF aisle, and dumped directly into the scrap bucket placed in the pit.
Scrap in the scrap bucket is charged into the furnace by the scrap charging crane.

The scrap bucket is of the clam shell type.
Capacity of the scrap charging crane is 110/30 t. The main hoist is to lift the scrap bucket with scrap, and the auxiliary hoist is to be used for miscellaneous work.

(2) DRI and burnt lime charging

DRI produced in the DRP and burnt lime produced in the lime calcining plant (LCP) are transported by belt conveyor to their respective storage hoppers in the DRI aisle. This transfer is automatically and remotely controlled.
The DRI and burnt lime stored in the storage hoppers are continuously fed to the EAF by belt conveyor and chute. This operation is automatically and remotely controlled in accordance with the melting program.

The DRI/lime storage system has junction houses, conveyors and storage hoppers.
The DRI/lime charging system has such facilities as weighing feeders installed under the storage hoppers, and DRI/lime conveyor.

(3) Melting

In the EAF, scrap charged by the scrap bucket and continuously fed DRI are melted, in accordance with the melting process program, by electric power with the help of oxygen lancing and carbon injection to achieve rapid melting and generation of foamy slag. After melting at the target temperature and achieving the desired chemical composition, the molten steel is tapped through the EBT into the ladle lying on the ladle transfer car, leaving about a 30 t hot heel in the furnace.

During tapping, burnt lime and ferro-alloys are added to the ladle by means of an automatic additive charging system. Before tapping, ferro-alloys can be also added to the EAF, if necessary.

Before receiving molten steel from the EAF, ladles are heated by natural gas fired burner.

The EAF is of the 150 t/heat DC type with a 88 MVA transformer to produce each heat in 108 min.

The electric power transmission and distribution network in Oman can not always be considered sufficient as described in section 7.3. Considering this and the flicker problem caused by short circuit occurrence in EAF, the DC EAF, which has a more advantageous flicker level than the AC (alternating current) EAF, was adopted.

(4) Ladle furnace operation

After tapping is completed, the molten steel in the ladle is transferred to the LF station located in the ladle aisle by the ladle crane.
At the LF station, the molten steel is subjected to metallurgical treatment for adjustment of the temperature and composition by electric power, alloy addition and inert gas bubbling through porous plug on the bottom of the ladle.

The molten steel is then transferred by the ladle crane to BT-CCM and cast into billets.

In addition to adjustment of temperature and composition, the LF station is also utilized for adjustment of operating time between the EAF and BT-CCM.

The LF is of the 150 t/heat capacity with a 22 MVA transformer to treat each heat in approximately 40 min.

(5) Additives storage and charging

An additive storage system is installed in the DRI aisle. Additives are then transported from the additive warehouse by dump truck and stored in storage hoppers through a dumping hopper, conveyors and a shuttle conveyor. Additives thus stored are fed by means of an automatic additive charging system into the EAF before tapping, the ladle during tapping and LF treatment.

(6) Continuous casting operation

After LF treatment, the molten steel is transferred by the ladle crane to the BT-CCM turret. The molten steel in the ladle is cast into billets through the pre-heated tundish on the tundish car, and water cooled mold. For casting, a mold level control system and mold oscillation system are applied.

The cast billets are water-cooled in a cooling chamber, and withdrawn by withdrawal unit. Billets are discharged after cutting to the determined length by billet shear devices and are directly transferred to the bar rolling mill plant or are cooled at the cooling bed. Billets cooled at the cooling bed are transported to the bar rolling mill by the billet transfer car.

### 6.3.4 General layout

Figure 6-3-3 shows the SMP layout.

### 6.3.5 Unit consumption

Table 6-3-4 shows SMP unit consumption, by-products and waste.

### 6.3.6 Organization and personnel

Table 6-3-5 shows the SMP organization and personnel.

### 6.3.7 Major equipment List

Major equipment list is shown in A 6-3-1.

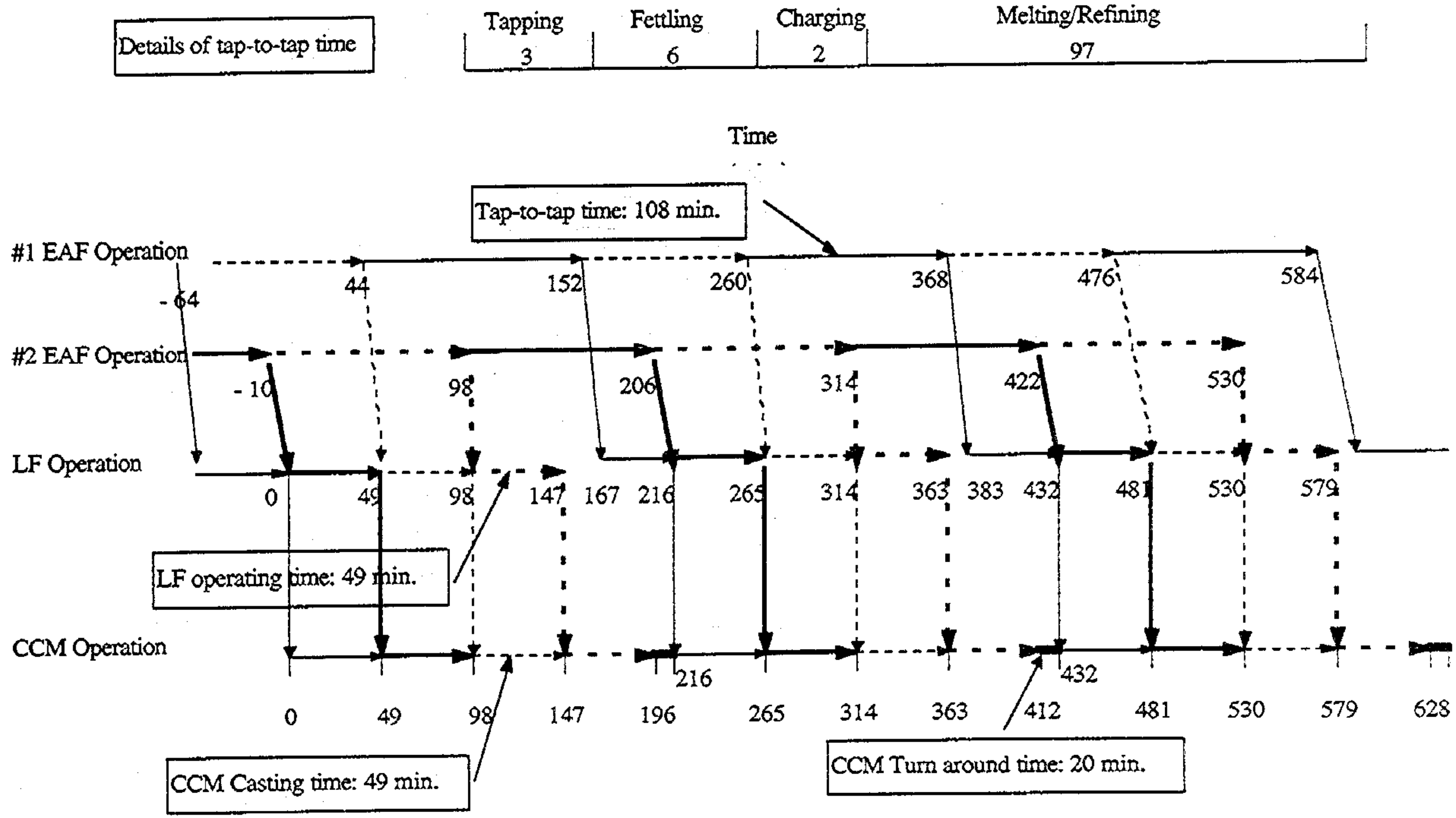



Figure 6-3-1 Operating Sequence of EAF, LF and CCM

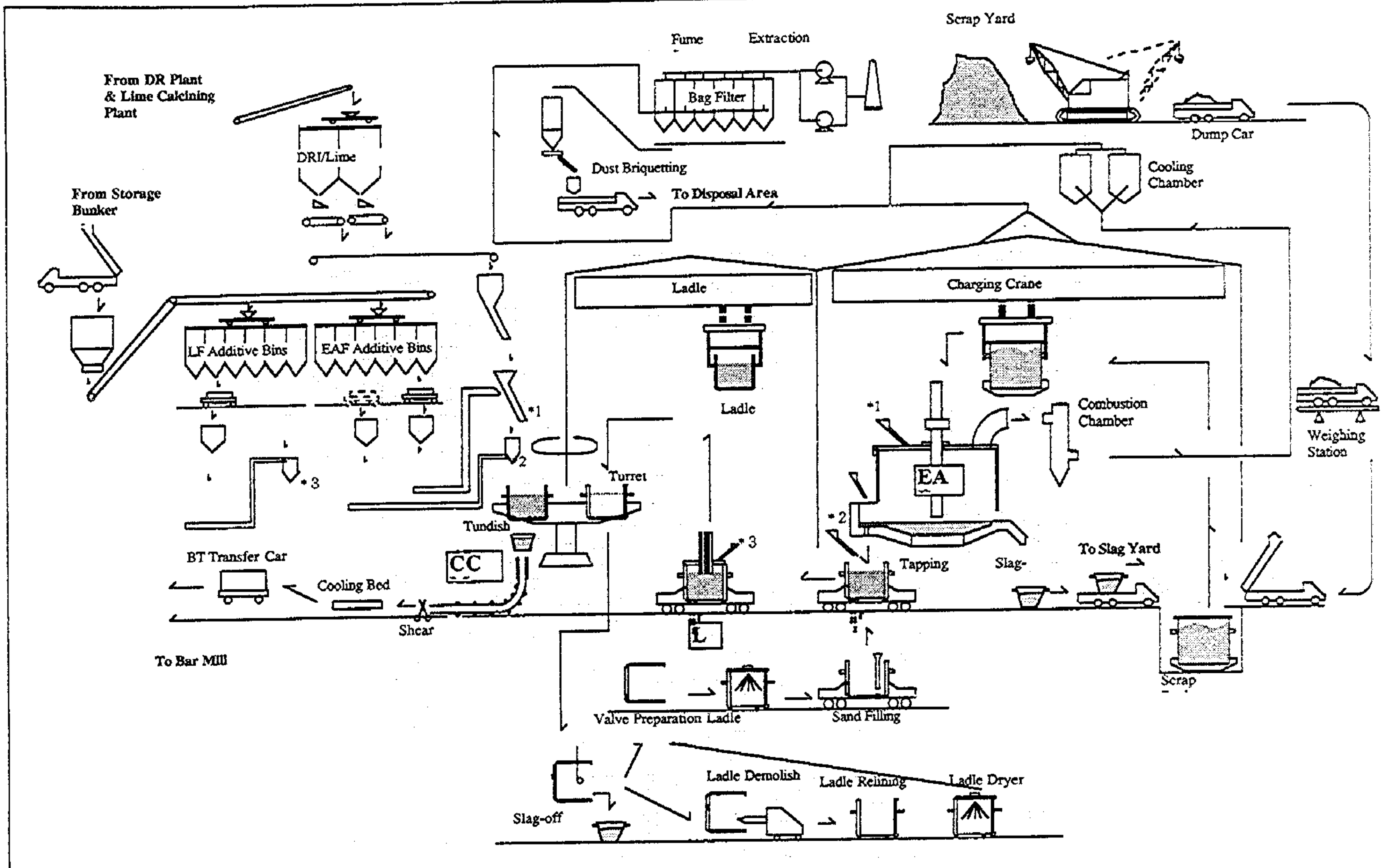
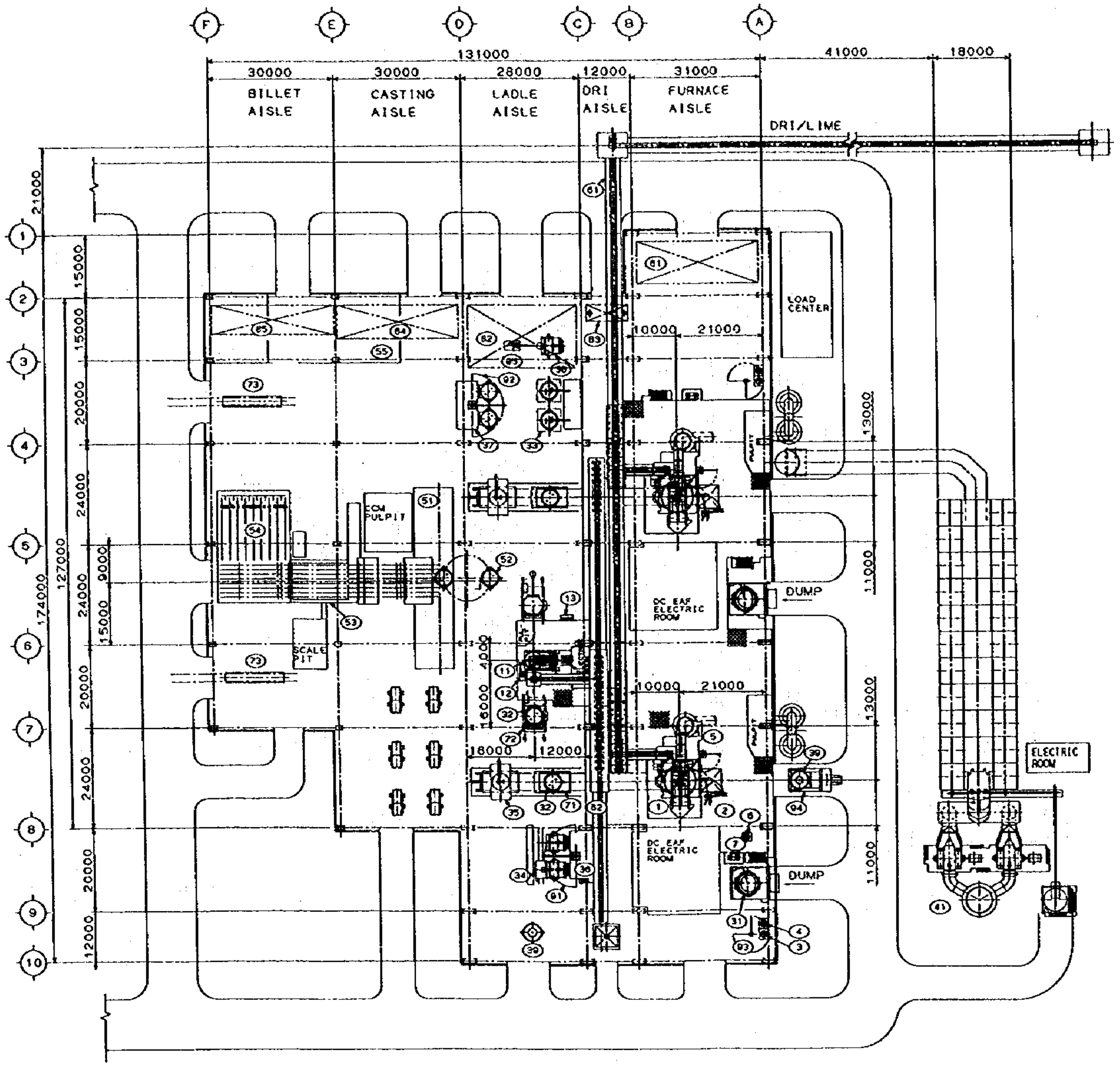



Figure 6-3-2 SMP Process Flow Sheet




| NO. | MAJOR EQUIPMENT | Q'TYS | REMARKS |
|---|---|---|---|
| 1 | ELECTRIC ARC FURNACE | 2 | |
| 2 | OXYGEN AND CARBON LANCE MANIPULATOR | 2 | |
| 3 | CARBON INJECTION SYSTEM -STORAGE HOPPER AND INJECTION VESSEL | 2 | |
| 4 | GUNNING SYSTEM -STORAGE HOPPER AND INJECTION VESSEL | 2 | |
| 5 | GUNNING SYSTEM -ROTATING GUN | 2 | |
| 6 | ELECTRODE NIPPLING DEVICE FOR EAF | 1 | |
| 7 | ELECTRODE STAND FOR EAF | 2 | |
| | | | |
| 11 | LADLE FURNACE | 1 | |
| 12 | TEMPERATURE, OXYGEN MEASURING AND SAMPLING DEVICE FOR LF | 1 | |
| 13 | ELECTRODE STAND FOR LF | 1 | |
| | | | |
| 31 | 110m³ SCRAP BUCKET | 2 | |
| 32 | 150t LADLE | 8 | |
| 33 | LADLE DRYER (VERTICAL) | 2 | |
| 34 | LADLE PREHEATER (HORIZONTAL) | 1 | |
| 35 | LADLE COVER WITH BURNER | 2 | |
| 36 | LADLE VALVE MAINTENANCE STATION | 1 | |
| 37 | LADLE RELINING STATION | 1 | |
| 38 | LADLE DISMANTLING STATION | 1 | |
| 39 | 16m³ SLAG POT | 8 | |
| | | | |
| 41 | DEDUSTING SYSTEM | 1 | |
| | | | |
| 51 | CONTINIOUS CASTING MACHINE | 1 | |
| 52 | LADLE TURRET | 1 | |
| 53 | RUNOUT TABLE | 1 | |
| 54 | COOLING BED | 1 | |
| 55 | MOLD REPAIRING AREA | 1 | |
| | | | |
| 61 | DRI/LIME HANDLING SYSTEM | 1 | |
| 62 | ADDITIVE HANDLING SYSTEM | 1 | |
| | | | |
| 71 | LADLE TRANSFER CAR FOR EAF | 2 | |
| 72 | LADLE TRANSFER CAR FOR LF | 2 | |
| 73 | BILLET TRANSFER CAR | 2 | |
| | | | |
| 81 | 110/30t SCRAP CHARGING CRANE | 1 | |
| 82 | 250/50t LADLE CRANE | 1 | |
| 83 | 10/5t MATERIAL HANDLING SERVICE CRANE | 1 | |
| 84 | 80/20t CCM CRANE | 1 | |
| 85 | 30t BILLET HANDLING CRANE | 1 | |
| | | | |
| 91 | 2t LADLE VALVE MAINTENANCE STATION JIB CRANE | 1 | |
| 92 | 2t LADLE RELINING STATION JIB CRANE | 1 | |
| 93 | 2t SUB-MATERIAL HANDLING JIB CRANE | 2 | |
| 94 | 85t SLAG POT CARRIER CAR (TO BE SUPPLIED BY OTHERS) | 2 | |
| 95 | DIG OUT MACHINE | 1 | |

REVISION

FIGURE 6-3-3

GENERAL LAYOUT OF STEEL MAKING PLANT (PLAN)

DESIGN SECTION: IRON & STEEL ENGINEERING DIV.

SCALE 1:600

NKK CORPORATION

AJ-0110-P80-01

Figure 6-3-3 General Layout of Steel Making Plant

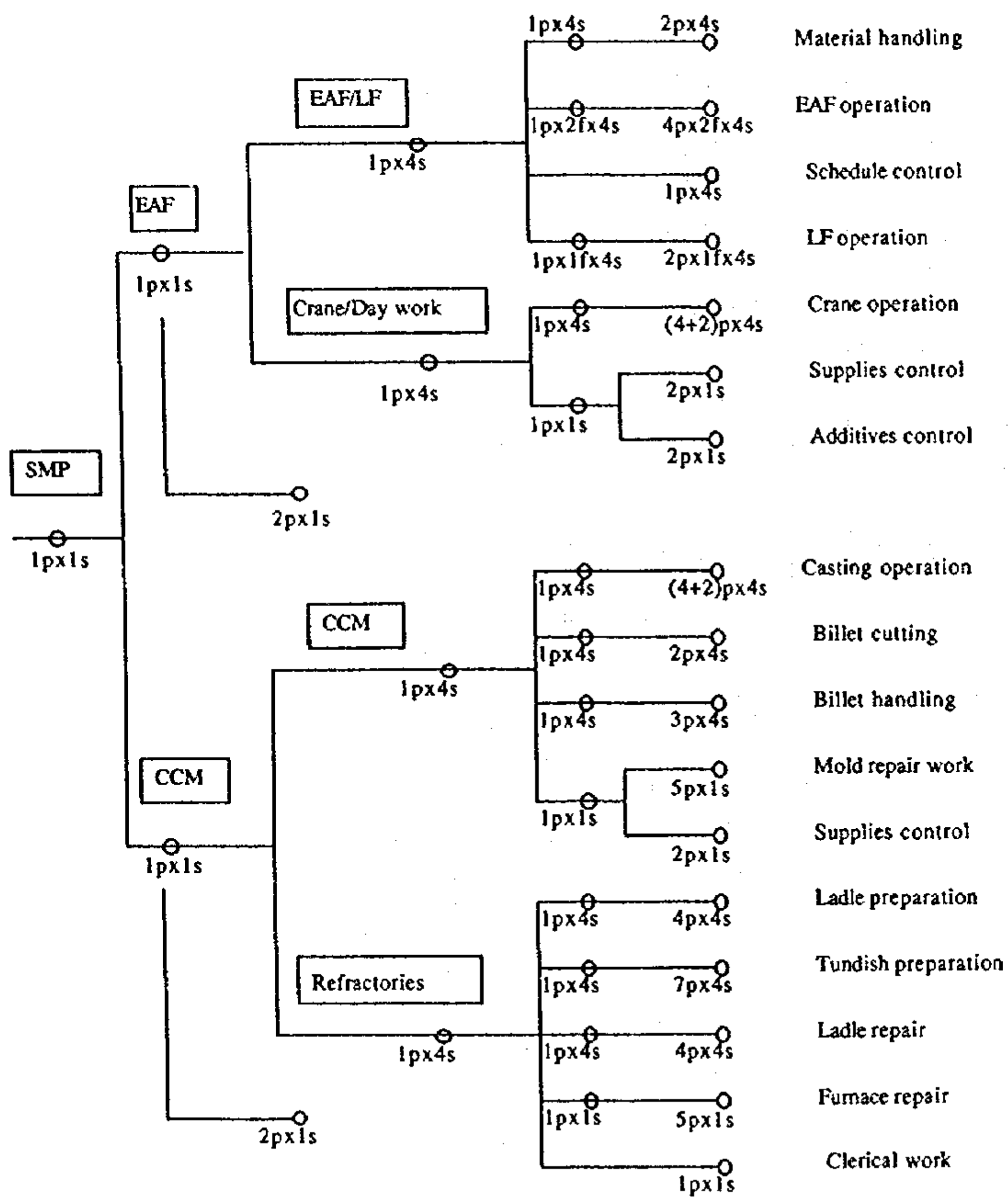
Table 6-3-4 SMP Unit Consumption, By-products and Waste

| Item | Unit consumption | Materials Required | | |
|---|---|---|---|---|
| | | Per year | Per month | Per day |
| 1 DRI | 1,083.3 kg/t-BT | 1,300,000 t | 108,330 t | 4,194 t |
| 2 Scrap | 122.5 kg/t-BT | 147,000 t | 12,250 t | 474 t |
| 3 Burnt Lime | 42.0 kg/t-BT | 50,400 t | 4,200 t | 163 t |
| 4 Fluorspar | 0.1 kg/t-BT | 120 t | 10 t | 0.4 t |
| 5 Fe-Mn | 10.2 kg/t-BT | 12,200 t | 1,020 t | 39.4 t |
| 6 Fe-Si | 4.4 kg/t-BT | 5,300 t | 442 t | 17.1 t |
| 7 Al | 0.1 kg/t-BT | 120 t | 10 t | 0.4 t |
| 8 Coke Lump/Breeze | 35.0 kg/t-BT | 42,000 t | 3,500 t | 135 t |
| 9 Furnace Brick | 0.9 kg/t-BT | 1,100 t | 92 t | 3.5 t |
| 10 Fettling Materials | 9.1 kg/t-BT | 10,900 t | 910 t | 35 t |
| 11 Ladle Brick | 4.0 kg/t-BT | 4,800 t | 400 t | 15.5 t |
| 12 Electrode | 1.9 kg/t-BT | 2,300 t | 190 t | 7.4 t |
| 13 Tundish Brick | 1.3 kg/t-BT | 1,600 t | 130 t | 5.2 t |
| 14 Slag | 170 kg/t-BT | 204,000 t | 17,000 t | 658 t |
| 15 Dust | 17 kg/t-BT | 20,800 t | 1,730 t | 67 t |
| 16 Scrap | 18.1 kg/t-BT | 21,700 t | 1,810 t | 70 t |
| 17 Waste Brick | 1.3 kg/t-BT | 1,600 t | 130 t | 5 t |
| 18 Scale | 5.0 kg/t-BT | 6,000 t | 500 t | 19.4 t |
| 19 Electric power | 695 kWh/t-BT | 834,000 MWh | 69,500 MWh | 2,690 MWh |
| 20 Make-up Water | 0.4 m$^3$/t-BT | 504,000 m$^3$ | 42,000 m$^3$ | 1,626 m$^3$ |
| 21 Compressed Air | 3.1 Nm$^3$/t-BT | 3,720,000 Nm$^3$ | 310,000 Nm$^3$ | 12,000 Nm$^3$ |
| 22 Natural Gas | 3.3 Nm$^3$/t-BT | 3,960,000 Nm$^3$ | 330,000 Nm$^3$ | 12,774 Nm$^3$ |
| 23 Oxygen Gas | 32.9 Nm$^3$/t-BT | 39,480,000 Nm$^3$ | 3,290,000 Nm$^3$ | 127,355 Nm$^3$ |
| 24 Nitrogen Gas | 6.4 Nm$^3$/t-BT | 7,680,000 Nm$^3$ | 640,000 Nm$^3$ | 24,774 Nm$^3$ |

Table 6-3-5 SMP Organization and Personnel

| Section Manager | Asst. Section Manager | Engineer | Foreman | Asst. Foreman | Worker | Remarks |
|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 16 | 47 | 197 | Total 267 |

Note: (1) p: person (2) s: shift (3) f: furnace (4) Right hand figure in parenthesis: relief



## 6.4 Bar Rolling Mill Plant

### 6.4.1 Outline

(1) Basic plan

A Bar Rolling Mill Plant (BRM) will be constructed to produce concrete reinforcing steel bars with an annual production output of about 1.2 million tons from the cast billets to be produced by the continuous billet casting machine in the steel making plant.

Planning basis for the BRM shall be as follows;

| | | |
|---|---|---|
| a) Production capacity | : | About 1.2 million tons per year (i.e. 1,164,000 tons/year) |
| b) Products | : | Concrete reinforcing steel bars with a size range of 10 mm to 32 mm in diameter as the major products |
| c) Initial material | : | Cast billet (from the continuous billet casting machine) |
| d) Required rolling rate | : | Approx. 190 to 200 t/h (expected) |

The planned BRM will consist of the following major process equipment and facilities;

a) Billet receiving/storage
b) Billet reheating
c) Rolling and hot shearing
d) Bar cooling/cutting
e) Bar finishing, including bar bundling, weighing, etc.
f) Bar product storage

(2) Rolling process technology

The essential technology and arrangement concerning the rolling process which will be applied in the planned BRM are described below.

1) High speed and slit rolling process for small size bar products
In general, slit rolling is the current technology applied for raising the rolling rate (t/h) of concrete reinforcing steel bars of the smaller size, below around 16 mm to 20 mm in diameter, using the slit rolling process in the large production bar rolling mill.
A typical mechanism for the slit rolling process is shown in Figure 6-4-1 (attached on

the following page.)

Because the planned BRM requires not only the production of the small size bars (i.e. 10 mm in minimum) but also a high rolling rate (i.e. 190 to 200 t/h in average), application of the said slit technology combined with the high speed finish-rolling ("High Speed Slit Rolling") shall be considered essential for realization of the planned bar rolling mill with a production output more than one million tons per year.

In addition, by applying the said high speed slit rolling process, since the rolling rate (t/h) for the planned BRM will be almost the same for all sizes bars, a continued hot/warm-charge rolling of billets from the continuous billet caster with sequence casting can be fascilitated.

In contrast, in the case of a conventional rolling mill without a high speed slit rolling process, construction of two mills would be required to achieve the same production output.

2) Hot / Warm-charge rolling process

To save energy the hot/warm-charge rolling process from the continuous billet casing machine to BRM shall be considered, wherein the hot or warm cast billets are directly fed into the billet reheating furnace without cooling through billet transferring facilities such as roller table, conveyor, etc. in order to minimize heat loss of the billet.

3) Rolling section products

In the same BRM planned to produce the concrete reinforcing steel bars, section products of similar size such as angles, channels, flat bars, etc. can be also produced by additional provision mainly in the bar cutting and/or finishing process lines.

However, since it is impractical to apply the said high speed and/or slit rolling for such products, the productivity (t/h) of section products is significantly lower.

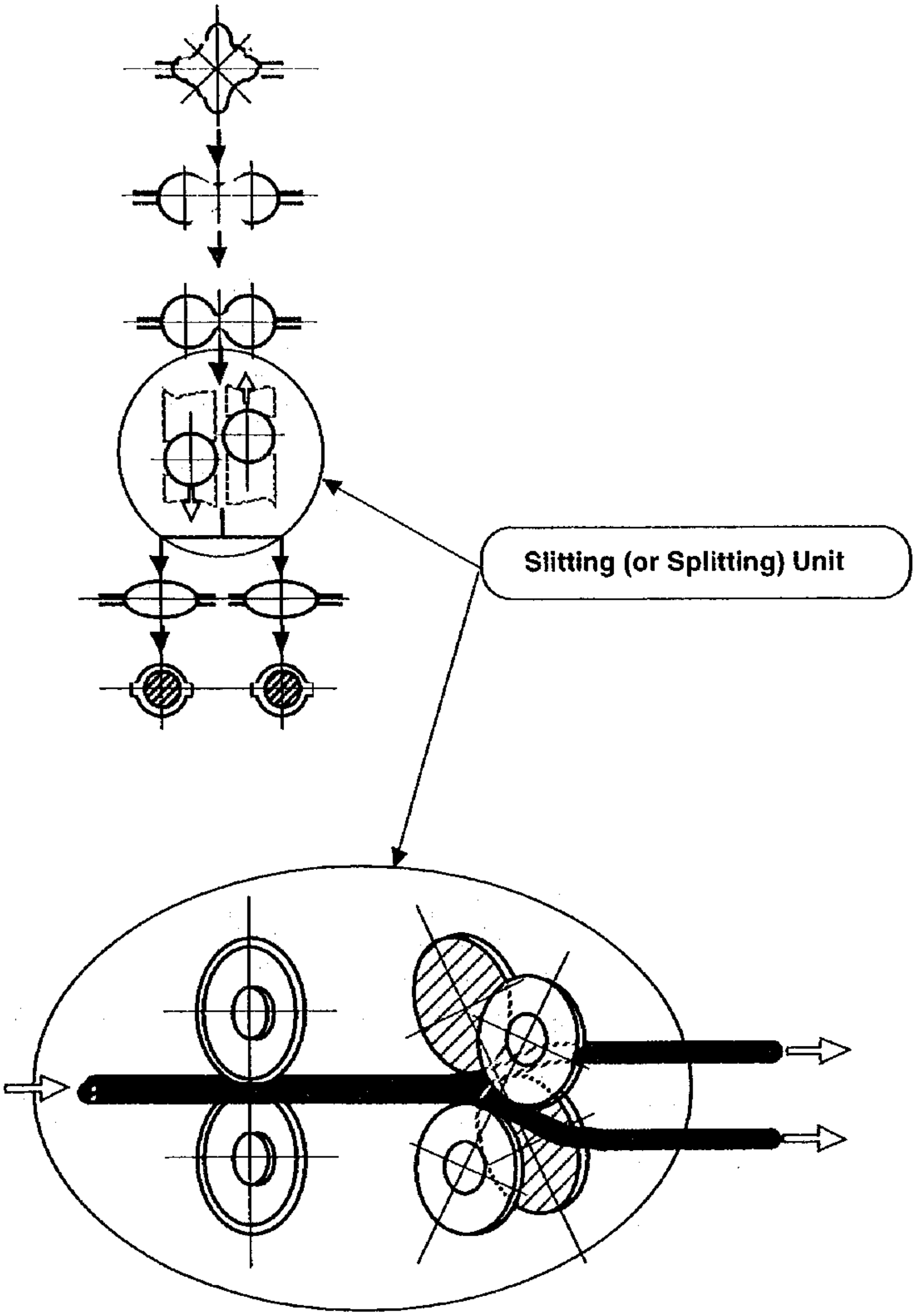



Figure 6-4-1 Typical Mechanism for Slit Rolling

6.4.2 Basic design

(1) Initial material

1) Initial material : Continuous cast billets

2) Kind of steel : Carbon steel for concrete reinforcing bars (and its similar kinds of steel)

3) Size of billet
   - Section : 150 mm sq.
   - Length : 16,000 mm (as standard)
   - Weight : Approx. 2,700 kg (as standard)

(2) Production plan

1) Steel grades and product sizes
   - Steel grades of products : Steel bars for concrete reinforcement
   - Size of products : D10 to D32 (as deformed bars in straight form)

2) Product length (i.e. final bar length)
   - Range of bar cut length : 3.5 m to 13 m
   - Normal bar cut length : 8 m (as engineering basis for production plan)

3) Product bundle (i.e. final bar bundle)
   Weight of large bundle
   - Maximum weight : Approx. 4,000 kg
   - Normal weight : Approx. 2,000 kg (as engineering basis for production plan)

4) Size-wise product mix for about 1.2 million tons per year
   The size-wise product mix for annual production of about 1.2 million tons (i.e. 1,164,000 tons) of the concrete reinforcing steel bars is estimated as follows, in consideration of the fact that the project is a exported-oriented project.

Table 6-4-1 Size-wise Product Mix of BRM

| Product size | Proportion ratio (%) | Annual production (t/y) | Kind of products |
|---|---|---|---|
| D10 | 13.0 | 151,320 | Deformed steel bars for concrete reinforcement |
| D12 | 23.0 | 267,720 | |
| D14 | 10.0 | 116,400 | |
| D16 | 25.0 | 291,000 | |
| D18 | 5.0 | 58,200 | |
| D20 | 10.0 | 116,400 | |
| D22 | 2.0 | 23,280 | |
| D25 | 7.0 | 81,480 | |
| D28 | 1.0 | 11,640 | |
| D30 | 1.0 | 11,640 | |
| D32 | 3.0 | 34,920 | |
| Total | 100.0 | 1,164,000 | |

For reference of the size-wise product mix, typical examples of the existing similar bar rolling mills are shown below;

Example for Size-wise Product Mix ("Case-A")

| Product size | Proportion ratio (%) | Annual production (t/y) | Kind of products |
|---|---|---|---|
| D10 | 13.0 | 72,800 | Deformed steel bars for concrete reinforcement |
| D12 | 23.0 | 128,800 | |
| D14 | 10.5 | 58,800 | |
| D16 | 25.2 | 141,120 | |
| D18 | 5.1 | 28,560 | |
| D20 | 9.7 | 54,320 | |
| D22 | 2.0 | 11,200 | |
| D25 | 7.1 | 39,760 | |
| D28 | 0.9 | 5,040 | |
| D30 | 0.6 | 3,360 | |
| D32 | 2.9 | 16,240 | |
| Total | 100.0 | 560,000 | |

Example for Size-wise Product Mix ("Case-B")

| Product size | Proportion ratio (%) | Annual production (t/y) | Kind of products |
|---|---|---|---|
| D10 | 12.0 | 81,600 | Deformed steel bars for concrete reinforcement |
| D12 | 24.0 | 163,200 | |
| D14 | 14.0 | 95,200 | |
| D16 | 25.0 | 170,000 | |
| D18 | 3.0 | 20,400 | |
| D20 | 8.2 | 55,760 | |
| D22 | 1.5 | 10,200 | |
| D25 | 7.0 | 47,600 | |
| D28 | 0.2 | 1,360 | |
| D30 | 0.1 | 680 | |
| D32 | 2.5 | 17,000 | |
| Others | 2.5 | 17,000 | |
| Total | 100.0 | 680,000 | |

Example for Size-wise Product Mix ("Case-C")

| Product size | Proportion ratio (%) | Annual production (t/y) | Kind of products |
|---|---|---|---|
| D10 | 45.0 | 450,000 | Deformed steel bars for concrete reinforcement |
| D13 | 30.0 | 300,000 | |
| D16 | 15.0 | 150,000 | |
| D19 | 0.0 | 0 | |
| [Sub-total] | (90.0) | (900,000) | |
| R10 - R16 | 10.0 | 100,000 | Bar-in Coil |
| Total | 100.0 | 1,000,000 | |

5) Start-up production plan

At the initial stage of plant start-up, the facility will be checked through the production operation but as operators may not be familiar with operation and maintenance of the plant. Production output will gradually be increased to reach full production from the initial start-up of the plant.

The start-up production schedule is estimated as follows, while being subject to the start-up production of cast billet in the steel making plant;

a) The 1st year : Approx. 70 % of the annual rated production
b) The 2nd year : Approx. 91 % of the annual rated production
c) After the 2nd year : Approx. 100 % of the annual rated production

(3) Production capacity

1) Available rolling hours

Refer to Figure 6-4-2 "Operational Time Balance" attached on the following page.

The available rolling hours mentioned in the attached Figure 6-4-2 "Operational Time Balance" are estimated, using the scheduled down hours and the estimated operational down ratio as follows;

- Operational shift system : 3 shift operation by 4 crews
- Calendar hours (Tc) : 8,760 h/y (= 24 h/d x 365 d/y)
- Scheduled down hours (Ts) : 480 h/y (as shown in Table 6-4-2)
- Actual operating hours (To) : 8,280 h/y
  (To = Tc - Ts) (= 8,760 h/y - 480 h/y)
- Operational down ratio (Tf) : 25% to 20% (estimated)
- Operational down hours (Td) : 2,070 h/y to 1,650 h/y (estimated)
  (Td = To x Tf) (= 8,280 h/y x 0.25 to 0.20)

- Available rolling hours (Tr) : 6,210 h/y to 6,624 h/y
  (Tr = To - Td) (= 8,280 h/y - 2,070 to 1,656 h/y)

Table 6-4-2 Maintenance Schedule

| Item | Scheduled Down Hours |
|---|---|
| Major Repairs | 10 days/year ( = 5 days/time x 2 times/year) |
| Monthly Repairs | 10 days/year (= 1 day/time x 10 times/year) |

2) Rolling process

The following rolling processes are applied, as shown in Figure 6-4-3 "Rolling Process" attached on the following page;

| | |
|---|---|
| - For bar sizes of D10 to D14 | : High speed/4-slit rolling process (as 4 strands' rolling after slitting) |
| - For bar sizes of D16 to D20 | : High speed/2-slit rolling process (as 2 strands' rolling after slitting) |
| - For bar sizes of more than D25 | : Conventional rolling process with single strand's rolling |

3) Rolling capacity

(a) Expected rolling rate and annual rolling time required

Refer to Table 6-4-3 "Calculation of Rolling Rate and Annual Rolling Time Required " attached on the following page.

The expected rolling rate of the product base ([M]:t/h as product basis in the said calculation table) for each size of deformed bar has been calculated as follows;

M (t/h as product basis) = K x L

where

| | | |
|---|---|---|
| - M (t/h as product basis) | : | Expected rolling rate as product basis |
| - K (t/h as billet basis) | : | Expected rolling rate as billet basis, based on 5 second billet gap and the capacity utilization (J = 95%) between the actual and theoretical rolling rates |
| - L (= 97%) | : | Product yield |

The expected annual rolling time required for the annual production of about 1.2 million tons (i.e. 1,164,000 tons) in the said table has been calculated on the basis of the size-wise product mix mentioned in Table 6-4-1 hereinabove.

(b) Rolling capacity

The expected annual rolling capacity is calculated as follows;

Annual production [P (t/y)] = Pe x Tr

= 191.7 (t/h) x {6,210 to 6,624 (h/y)]

= 1,190,000 to 1,270,000 (t/y)

where

- Pe (= 191.7 t/h) : Average expected rolling rate as product basis, based on the size-wise product mix (Refer to Table 6-4-3 "Calculation of Rolling Rate and Annual Rolling Time Required" attached.)
- Tr (= 6,210 to 6,624 h/y) : Annual available rolling hours (Refer to Figure 6-4-2 "Operational Time Balance" attached.)

For calculation of the above rolling capacity, the required capacity of the reheating furnace is 210 t/h in maximum.

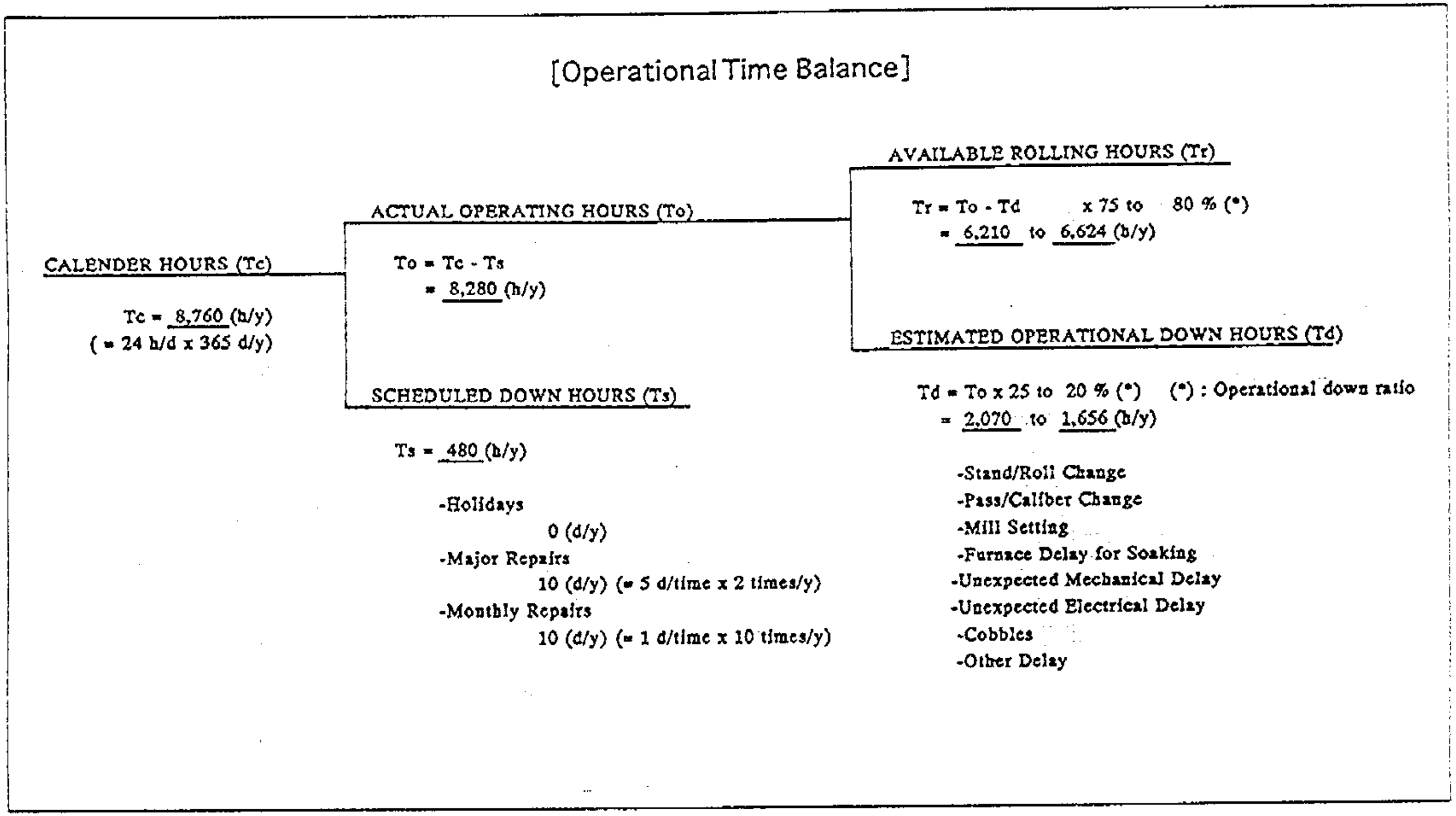



Figure 6-4-2 Operational Time Balance

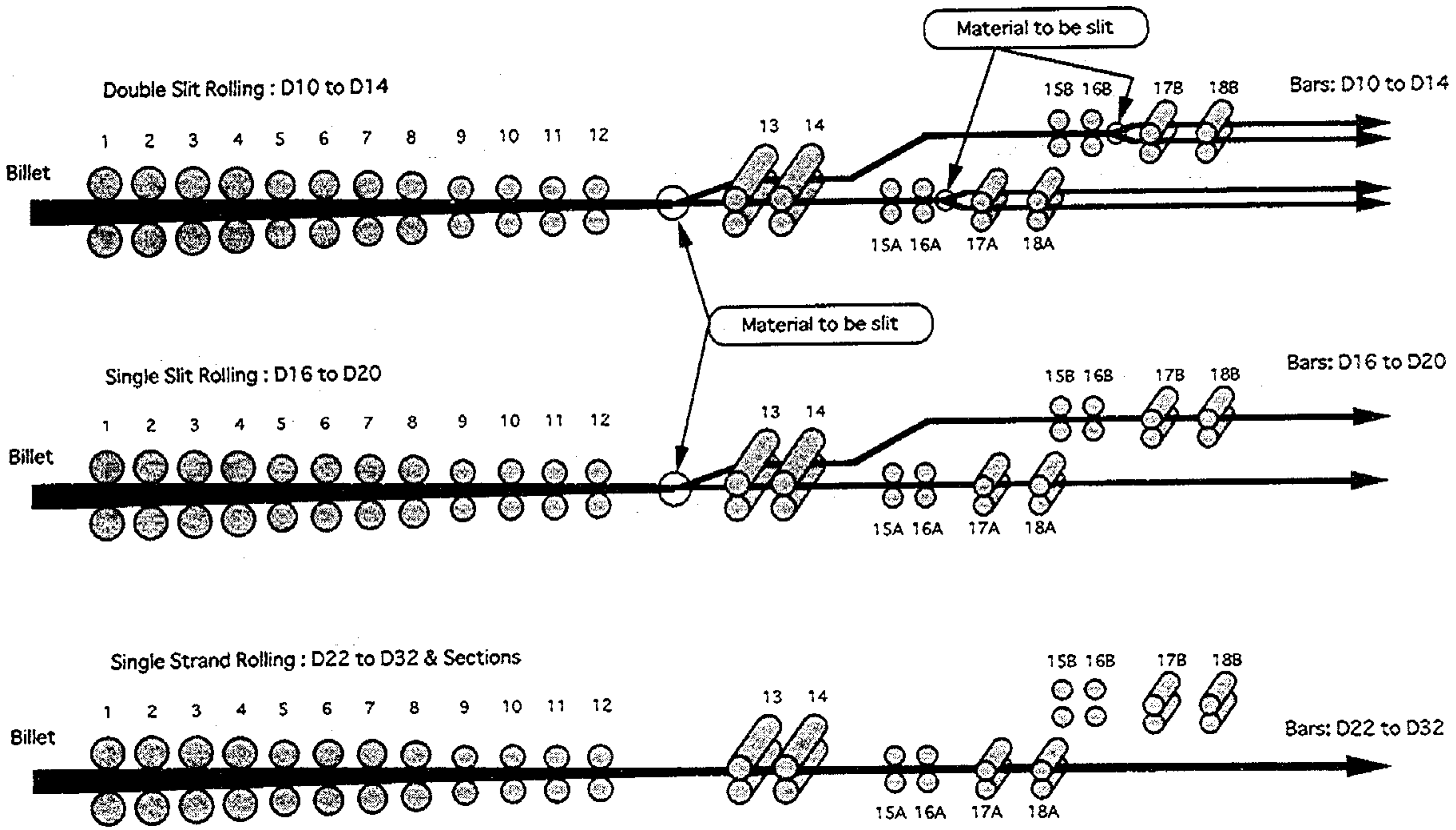



Figure 6-4-3 Rolling Process

## Table 6-4-3 Calculation of Rolling Rate and Annual Time Required

Billet : 150 mm sq. x 16 m ( 2,700 kg)

| Product Shape | Product Size | | Product Unit weight (kg /m) [A] | Billet Size (mm sq. x m) | Billet Weight (kg) [B] | Number of Slit Strands [C] | As-rolled Length (m) [D] = (B/A/C) | Finish-Rolling Speed (m/sec.) [E] | Rolling Time (sec.) [F]=(D/E) | Pause (sec.) [G] | Rolling Cycle Time (sec.) [H]=(F+G) | Theoretical Rolling Rate (Billet Basis) (t/hr.) [I]=[3600xB/(Hx1000)] | Capacity Utiliztation (%) [J] | Expect Rolling Rate (Billet Basis) (t/hr.) [K]=(IxJ/100) | Yield (Expected) (%) [L] | Expected Rolling Rate (Product Basis) (t/hr.) [M]=(KxL/100) | Annual Production Amount (t/y) [N] | Annual Production Amount (%) | Expected Rolling Time (hr./y) [O]=(N/M) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deformed Bars | D | 10 | 0.617 | 150 x 16 | 2700 | 4 | 1094.0 x 4 | 25.0 | 43.8 | 5 | 48.8 | 199 | 95 | 189 | 97.0 | 183 | 151,320 | 13.0 | 827 |
| | D | 12 | 0.888 | 150 x 16 | 2700 | 4 | 760.1 x 4 | 18.4 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 267,720 | 23.0 | 1,380 |
| | D | 14 | 1.21 | 150 x 16 | 2700 | 4 | 557.9 x 4 | 13.5 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 116,400 | 10.0 | 600 |
| | D | 16 | 1.58 | 150 x 16 | 2700 | 2 | 854.4 x 2 | 20.7 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 291,000 | 25.0 | 1,500 |
| | D | 18 | 2.00 | 150 x 16 | 2700 | 2 | 675.0 x 2 | 16.4 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 58,200 | 5.0 | 300 |
| | D | 20 | 2.47 | 150 x 16 | 2700 | 2 | 546.6 x 2 | 13.2 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 116,400 | 10.0 | 600 |
| | D | 22 | 2.98 | 150 x 16 | 2700 | 1 | 906.0 | 18.0 | 50.3 | 5 | 55.3 | 176 | 95 | 167 | 97.0 | 162 | 23,280 | 2.0 | 144 |
| | D | 25 | 3.85 | 150 x 16 | 2700 | 1 | 701.3 | 17.0 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 81,480 | 7.0 | 420 |
| | D | 28 | 4.83 | 150 x 16 | 2700 | 1 | 559.0 | 13.6 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 11,640 | 1.0 | 60 |
| | D | 30 | 5.55 | 150 x 16 | 2700 | 1 | 486.5 | 11.8 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 11,640 | 1.0 | 60 |
| | D | 32 | 6.31 | 150 x 16 | 2700 | 1 | 427.9 | 10.4 | 41.3 | 5 | 46.3 | 210 | 95 | 200 | 97.0 | 194 | 34,920 | 3.0 | 180 |
| TOTAL | | | | | | | | | | | | | | | | | ΣP = 1,164,000 | 100 | ΣQ = 6,071 |
| Average Expected Rolling Rate (t/hr.) (Product Basis) | | | | | | | | | | | | | | | | | Pe = ΣP/ΣQ = 1,164,000/6,071 = 191.7 t/hr. | | |

Note :

1) Symbols of products
   D : Deformed bars
2) Rolling process :
   D10 to D14 : 4-slit rolling
   D16 to D20 : 2-slit rolling
   Others : Single strand rolling

Average Expected Rolling Rate (product base) [Pe] 191.7 (t/h)

Furnace Capacity (max.) = 210 (t/h)

Average Expected Rolling Rate (product base) [Pe] : 191.7 (t/h)
Annual Available Rolling Hours [Tr] : 6,210 (hrs/y) to 6,624 (hrs/y)
(Refer to "Operational Time Balance")

Excepted Annual Production [P] : 1,190,000 (t/y) to 1,270,000 (t/y)

| | | | | |
|---|---|---|---|---|
| Calender Hours | [ 8,760 (hrs/y)] | = 365 (days/y) x | 24 (hrs/day) | |
| Scheduled Down Hours | [ 480 (hrs/y)] | = 20 (days/y) | | |
| (Holidays) | [ 0 (d/y)] | | | |
| (Major Repairs) | [ 10 (d/y)] | 2 (times/y) x | 5 (days/time) | |
| (Monthly Repairs) | [ 10 (d/y)] | 1 (days/time) x | 1 (times/m) x | 10 (m/y) |
| Actual Operating Hours | [ 8,280 (hrs/y)] | = 345 (days/y) | | |
| Operational Down Hours | [ 2,070 (hrs/y) to 1,656 (hrs/y)] | (Ratio = 25% to 20% ) | | |
| Annual Available Rolling Hours | [ 6,210 (hrs/y) to 6,624 (hrs/y)] | (Ratio = 75% to 80% ) | | |

(4) Rolling of section products

Certain section products can be rolled by the same high productivity BRM planned to produce the concrete reinforcing steel bars.

However, since it is impractical to apply the high speed and/or slit rolling for the section products, the productivity (t/h) for the possible section products would become remarkably lower (about less than half rolling rate) than for concrete reinforcing steel bars, as shown in Table 6-4-4 "Calculation of Rolling Rate for Typical Section Products" on the following page.

In addition, producing section products requires the following additional facilities in the bar cutting and/or finishing process lines;

a) Straightening machines
b) Stacking machines
c) Bundling machines for sections
d) Product shipping facilities for sections, etc.

## Table 6-4-4 Calculation of Rolling Rate for Typical Section Products

Billet : 150 mm sq. x 16 m ( 2,700 kg)

| Product | | | | Billet | | Number of Slit Strands | As-rolled Length | Finish-Rolling Speed | Rolling Time | Pause | Rolling Cycle Time | Theoretical Rolling Rate (Billet Basis) | Capacity Utiliztation | Expect Rolling Rate (Billet Basis) | Yield (Expected) | Expected Rolling Rate (Product Basis) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shape | Size | | Unit weight | Size | Weight | | | | | | | | | | | |
| | | | (kg /m) [A] | (mm sq. x m) | (kg) [B] | [C] | (m) [D] = (B/A/C) | (m/sec.) [E] | (sec.) [F]=(D/E) | (sec.) [G] | (sec.) [H]=(F+G) | (t/hr.) [I]=[3600xB/(Hx1000)] | (%) [J] | (t/hr.) [K]=(IxJ/100) | (%) [L] | (t/hr.) [M]=(KxL/100) |
| Section Bars | A | 40 x 3 | 1.83 | 150 x 16 | 2700 | 1 | 1,475.4 | 10.0 | 147.5 | 5 | 152.5 | 64 | 95 | 61 | 95.0 | 58 |
| | A | 40 x 5 | 2.95 | 150 x 16 | 2700 | 1 | 915.3 | 10.0 | 91.5 | 5 | 96.5 | 101 | 95 | 96 | 95.0 | 91 |
| | A | 50 x 5 | 3.77 | 150 x 16 | 2700 | 1 | 716.2 | 8.0 | 89.5 | 5 | 94.5 | 103 | 95 | 98 | 95.0 | 93 |
| | C | 40 x 35 | 4.87 | 150 x 16 | 2700 | 1 | 554.4 | 6.0 | 92.4 | 5 | 97.4 | 100 | 95 | 95 | 95.0 | 90 |
| | F | 32 x 4.5 | 1.13 | 150 x 16 | 2700 | 1 | 2,389.4 | 10.0 | 238.9 | 5 | 243.9 | 40 | 95 | 38 | 95.0 | 36 |
| | F | 32 x 9 | 2.26 | 150 x 16 | 2700 | 1 | 1,194.7 | 10.0 | 119.5 | 5 | 124.5 | 78 | 95 | 74 | 95.0 | 70 |
| | F | 38 x 4.5 | 1.34 | 150 x 16 | 2700 | 1 | 2,014.9 | 10.0 | 201.5 | 5 | 206.5 | 47 | 95 | 45 | 95.0 | 43 |
| | F | 38 x 9 | 2.68 | 150 x 16 | 2700 | 1 | 1,007.5 | 10.0 | 100.7 | 5 | 105.7 | 92 | 95 | 87 | 95.0 | 83 |
| | F | 44 x 4.5 | 1.55 | 150 x 16 | 2700 | 1 | 1,741.9 | 10.0 | 174.2 | 5 | 179.2 | 54 | 95 | 51 | 95.0 | 48 |
| | F | 44 x 9 | 3.11 | 150 x 16 | 2700 | 1 | 868.2 | 9.5 | 91.4 | 5 | 96.4 | 101 | 95 | 96 | 95.0 | 91 |
| | F | 50 x 4.5 | 1.77 | 150 x 16 | 2700 | 1 | 1,525.4 | 10.0 | 152.5 | 5 | 157.5 | 62 | 95 | 59 | 95.0 | 56 |
| | F | 50 x 9 | 3.53 | 150 x 16 | 2700 | 1 | 764.9 | 8.5 | 90.0 | 5 | 95.0 | 102 | 95 | 97 | 95.0 | 92 |

Note :

1) Symbols of products
   A : Angles
   C : Channels
   F : Flat bars

2) Rolling process : Single strand rolling

### 6.4.3 Process description

(1) Mill configuration

The mill configuration of the planned BRM is shown in Figure 6-4-4 "General Layout of Bar Rolling Mill" attached herein.

The planned BRM consists of the following major facilities;

a) Billet receiving/conveying facilities
b) Reheating furnace facilities
c) Roughing mill train
d) Intermediate mill train
e) Finishing mill trains
f) Crop and cobble shears
g) Dividing shears
h) Cooling bed facilities
i) Cold shears
j) Small bundling facilities
k) Large bundling facilities
l) Shipping conveying facilities
m) Cold shear facilities for irregular length bars

(2) Basic plant parameters

1) Type of mill : Full continuous type mill

2) Number of rolling strands : One strand rolling at the fixed pass line, except for the finishing stands in case of slit-rolling for D10 to D14

3) Billet reheating furnace : Natural gas fired walking beam type furnace of max. 210 t/h

4) Number of mill stands : Twenty-two in total (including 4 stands per line in 2 finishing mill lines, i.e. 8 stands for finishing mill train in total)

5) Type of mill stands : (Refer to Table 6-4-5 "Mill Data" on the next page.)

6) Max. rolling speed

- For slit rolling : 25 m/sec (for slit rolling)
- For non-slit rolling : 18 m/sec (for non-slit rolling)

7) Bar cooling bed

- Quantity : Two lines of cooling bed facilities
- Type & length : Walking beam type with approx. 110m long

8) Cold shear

- Quantity : Two lines of cold shear facilities
- Type & capacity : Down-cut type with the cutting capacity of approx. 350 tons

9) Bar finishing line

- Quantity : Two lines of bar finishing facilities
- Consisting of : Bar traversing/conveying, bar counting/bundling, and bar collecting facilities, etc., including irregular bar handling line

Table 6-4-5 Mill Data of BRM

| TRAINS | STAND DATA | | | | Mill Motor Power (kW) | Remarks |
|---|---|---|---|---|---|---|
| | Stand No. | Type | Roll Size (mm) | | | |
| | | | Diameter | Barrel | | |
| Roughing | 1 | H | 450 | 400 | 600 | |
| | 2 | V | 450 | 400 | 1,000 | |
| | 3 | H | 450 | 400 | 1,000 | |
| | 4 | V | 450 | 400 | 1,000 | |
| | 5 | H | 400 | 350 | 1,100 | |
| | 6 | V | 400 | 350 | 750 | |
| | 7 | H | 400 | 350 | 1,100 | |
| | 8 | V | 400 | 350 | 1,000 | |
| Intermediate | 9 | H | 380 | 700 | 1,400 | |
| | 10 | V | 380 | 700 | 1,100 | |
| | 11 | H | 380 | 700 | 1,400 | |
| | 12 | H/V | 340 | 700 | 1,100 | |
| | 13 | H/V | 340 | 700 | 1,000 | |
| | 14 | H | 340 | 700 | 1,000 | |
| Finishing | 15A | H/V | 340 | 700 | 750 | |
| | 16A | H | 340 | 700 | 600 | |
| | 17A | V | 340 | 700 | 600 | |
| | 18A | H | 340 | 700 | 750 | |
| | 15B | H/V | 340 | 700 | 750 | |
| | 16B | H | 340 | 700 | 600 | |
| | 17B | V | 340 | 700 | 600 | |
| | 18B | H | 340 | 700 | 750 | |
| Remarks | 1) For mill type<br>H : Horizontal type mill<br>V : Vertical type mill<br>H/V : Combination type mill (convertible to horizontal and vertical type)<br>2) Total power of mill motors from No.1 to No.18 stands is 19,950 kW. | | | | | |

(3) Process description

1) Billet receiving/storage

A 150 mm sq. continuous cast billet produced in the continuous billet casting machine of the steel making plant will be delivered to the BRM in two processes (a) the Hot charging process and (b) the Cold charging process as described below.

(a) Hot charging process

Billets cast by the continuous billet casting machine will be delivered to the BRM without stocking at the billet storage yard and will be charged into the billet reheating furnace through billet transferring facilities such as a roller table, a conveyor, etc., while the said billets are still in a hot or warm condition.

(b) Cold charging process

After being cooled, the billets cast by the continuous billet casting machine will be delivered to and stocked at the billet storage yard. The cold billets stocked at the storage yard will be loaded onto the billet receiving table and then charged into the billet reheating furnace through the roller table.

The handling of cold billets at the billet storage yard will be carried out by the overhead traveling cranes.

2) Billet reheating

The billet reheating furnace will be of the continuous/walking beam type. After being charged, the billets inside the furnace while being transferred by walking beam mechanism to the discharging side will be heated/soaked to the predetermined temperature (about 1,050℃ to 1,150℃) required for hot rolling.

The heated/soaked billets in the furnace will be discharged one by one from the furnace to the first mill stands of the rolling mill line at the discharging side of the billet reheating furnace.

3) Rolling and hot shearing

The rolling mill line will be divided into one roughing mill train, one intermediate mill train and two finishing mill trains with the following mill stand arrangement;

| | |
|---|---|
| - Roughing mill train | : 8 mill stands<br>(No.1 to No.8) |
| - Intermediate mill train | : 6 mill stands<br>(No.9 to No.14) |

- Finishing mill train : 4 mill stands per line
  (No.15A to No.18A and 15B to 18B)

After being discharged one by one from the billet reheating furnace to the first mill stand (i.e. No.1 mill stand), the heated/soaked billet will be rolled down to the specified size of bar product by the roughing mill through finishing mill trains in accordance with the predetermined rolling schedule as shown in Figure 6-4-3 "Rolling Process".

For the smaller size bars produced by the slit rolling process, the rolling material will be slit at the predetermined rolling positions by means of the slitting unit as shown in Figure 6-4-1 "Typical Mechanism for Slit Rolling".

The rolled bars finished into the specified size of bars product will be divided by the flying hot shear into a suitable length and multiple times of the predetermined length for the cooling bed length.

For crop/cobble-cutting or divide-cutting of rolled materials, five flying hot shears in total will be located respectively at the following places;

- Between No.8 and No.9 mill stands : No.1 Crop/cobble shear
- Before each finishing mill train : No.2 (A & B) Crop/cobble shears
- After each finishing mill train : Dividing shears
  (one for each finishing line)

4) Bar cooling/cutting

The bars divided into the predetermined length by each dividing shear will be delivered to the bar cooling bed through the run-in guiding equipment consisting of the run-in guide trough system and the run-in roller table system, depending on the final size of bar product, as described below.

(a) A run-in guide trough system will be used for rolling smaller bars, where high speed slit rolling will be performed.

    After the divided bar leaves the last mill stand, it will be delivered to the cooling bed through the guide trough lines. On the guide trough lines, the running speed of each bar will be reduced by the pinch roll and finally stopped by the mechanical braking device at a proper position in front of the cooling bed.

(b) A run-in roller table system will be used for rolling larger bars, where the bars will be rolled down without the slit rolling process.

After the divided bar leaves the last mill stand, it will be delivered to the cooling bed through the roller table. On the roller table, the running speed will be reduced by sliding the lifting plates between the rollers, while the plates are lifted, and finally stopped at a proper position in front of the cooling bed.

The cooling bed will be the rake type with a walking beam mechanism. The bars stopped in front of the cooling bed will be fed onto the rake of the cooling bed and then transferred by the walking beam mechanism, where the divided bars will be naturally cooled down.

At the end of the rake part, the cooled bars on the rake of the cooling bed will be collected in a group, of which a number of bars will be cut at a time by the cold shear, by the bar collecting device and then traversed in the said group onto the run-out roller table.

The cooled bars on the run-out roller table will be transferred in a group to the cold shear and then cut into the final product length.

5) Bar finishing

Cut bars will be transferred through conveyors and/or roller tables up to the bar bundling stations, where the bars, transferred in a group, will be pooled, counted and separated into the number of bars for a small bundles and/or large bundle and then finally bound in a large bundling form.

After being bound into a large bundle, each bundle of bars will be transferred to the bundle weighing machine and weighed individually. After weighing, each bundle of bars will be transferred to the bundle shipping conveyor and then transported by the overhead traveling cranes in the product storage area.

The last group of bars cut by the cold shear but having different lengths will be discharged from the finishing line to the irregular bar handling line.

6) Bar product storage

The bar bundles transported from bundle shipping conveyor will be stocked at the product storage yard and then delivered by road transportation facilities such as trucks, trailers, etc.

The handling of bar bundles in the product storage yard will be carried out by the overhead traveling cranes in a usual operation.

### 6.4.4 General layout

Figure 6-4-4 shows the general layout of the planned BRM.

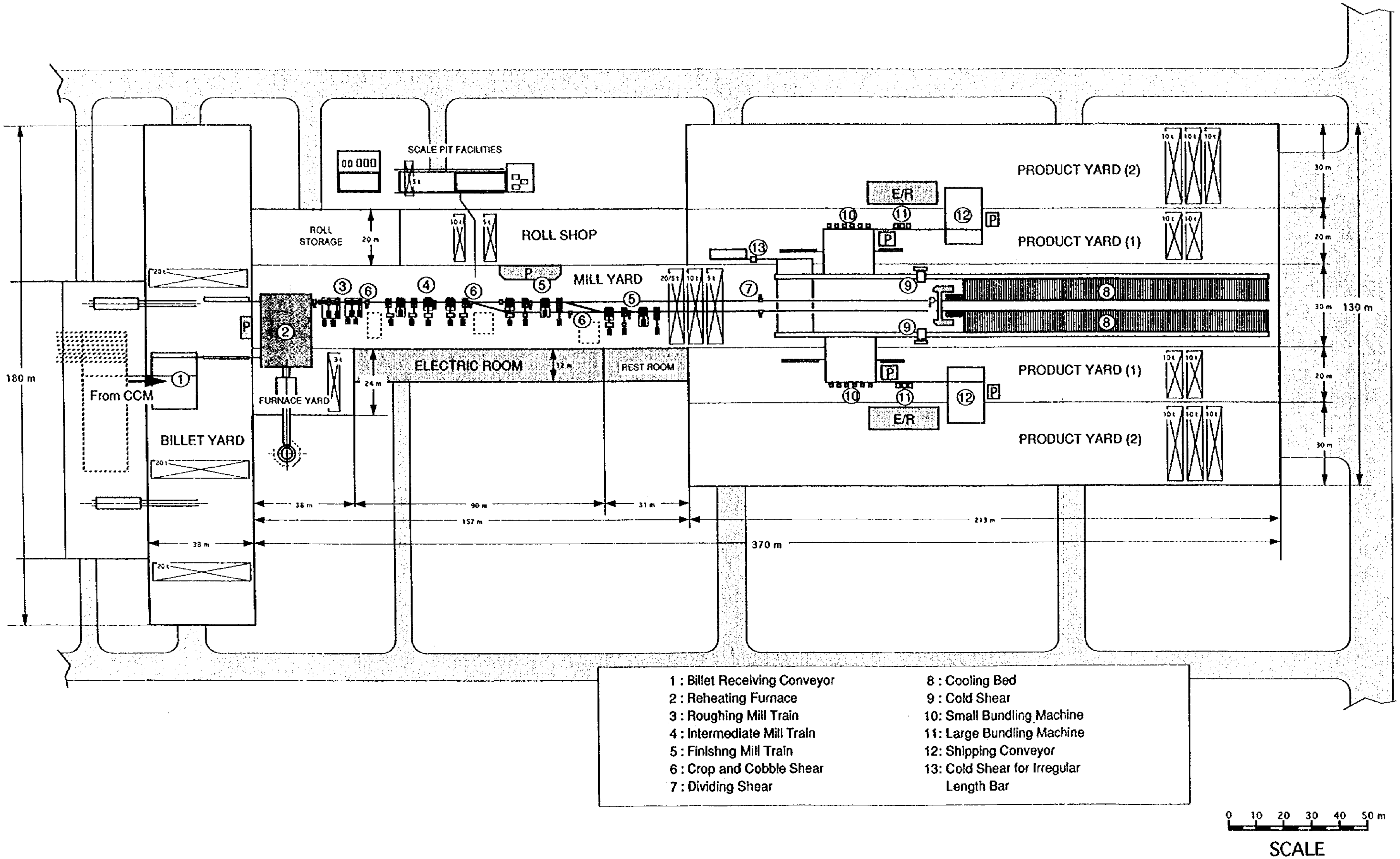



Figure 6-4-4 General Layout of Bar Rolling Mill Plant

### 6.4.5 Unit consumption

Table 6-4-6 shows unit consumption of materials, utilities, rolls, by-products and waste.

Table 6-4-6 Unit Consumption, By-Products and Wastes of BRM

| Item | Unit Consumption | Remarks |
|---|---|---|
| [Raw Material] | | |
| 1) Cast Billet | 1,031 kg/t-bar | |
| [Consumables] | | |
| 2) Roll | 0.270 kg/t-bar | |
| [Utilities] | | |
| 3) Electricity | 90 kWh/t-bar | |
| 4) Water (Industrial) | 0.05 $m^3$/t-bar | As make-up water |
| 5) Natural Gas | 280,000 kcal/t-bar | |
| [By-products & Waste] | | |
| 6) Scrap | 22.7 kg/t-bar | As return scrap |
| 7) Scale | 8.25 kg/t-bar | |

Remarks: Consumption, by-products/waste mentioned above shows the bar product-ton base.

### 6.4.6 Organization and personnel

Table 6-4-7 shows the expected organization and personnel.

Table 6-4-7 Organization and Personnel of BRM

| Section Manager | Assistant Section Manager | Engineer | Foreman | Assistant Foreman | Worker | Remarks |
|---|---|---|---|---|---|---|
| 1 x 1 | 1 x 1 | 3 x 1 | 1 x 4 | 1 x 4 | 7 x 4 | Billet yard & furnace operation |
| | | | | 1 x 4 | 10 x 4 | Rolling mill line |
| | | | | 1 x 4 | 16 x 4 | Bar cutting/finishing line |
| | | | | 1 x 4 | 12 x 4 | Product yard |
| | | | | 1 x 4 | 15 x 4 | Crane operation |
| | | | 1 x 1 | 1 x 1 | 6 x 4 + 7 | Roll shop work |
| 1 | 1 | 3 | 5 | 21 | 247 | Total : 278 |

### 6.4.7 Major equipment list

Refer to Appendix A6-4-1 "Bar Rolling Mill Plant Equipment List".

## 6.5 Lime Calcining Plant

### 6.5.1 Outline

A lime calcining plant will be constructed to deliver burnt lime to the Steel Making plant. Burnt lime is a very active material and it hydrates easily to calcium hydroxide when exposed to moisture. The calcium hydroxide creates a problem in not making a suitable slag in the electric arc furnace. The lime calcining plant will, therefore, be located nearby the Steel Making plant to supply the required amount of burnt lime.

### 6.5.2 Basic design

- Annual production : 50,400 tons (330 d/y x 24 h/d)
- Daily production : 160 t/d on average (24 h/d)
- Hourly production : 6.67 t/h on average
- Product quality
  - Residual $CO_2$ : Max. 3%
  - Reactivity : Min. 350 mlit (4 N - HCl, 50 g, 10 min.)
  - Size : 40 - 5 mm
- Limestone size : 50 - 20 mm
- Kiln fuel : Natural gas

(1) Production plan

1) Production

The requirement of the Steel Making plant for burnt lime will be gradually increased year by year. However, burnt lime will be produced at the nominal capacity of 50,400 t/y from 2006 and the surplus burnt lime will be sold in the domestic market.

2) Raw material (limestone)

Limestone produced in the country will be used as the raw material in the plant. Consumption of raw material will be 2.0 tons per ton of burnt lime. Fines of limestone are expected to be about 10%.

3) Utility unit consumption

The average unit consumption of utility is expected to be as follows when the lime calcining plant is operated.

- Electricity : 50 kWh/t
- Natural gas : 100 $Nm^3/t$
- Water : 0.02 $m^3/t$
- Compressed air : 55 $Nm^3/t$

6.5.3 Description of process and equipment (Refer to Figure 6-5-1)

Limestone, the raw material for the lime calcining plant, is stock piled in the open-air limestone storage yard and transferred by dump truck to the receiving hopper. From the hopper, the limestone is transported by conveyor to the limestone storage bin and stored there. The capacity of the limestone storage bin is about three days' consumption.

Limestone discharged from the bin is screened by 20 mm mesh to remove stone less than 20 mm and charged by conveyor into the weigh hopper on the top of the lime kiln.

Limestone is preheated, calcined and cooled in the lime kiln. Heated in the kiln, limestone is calcined to burnt lime by the following reaction.

$$CaCO_3 \rightarrow CaO + CO_2$$

The lime kiln consists of two towers, which are used for calcining and regenerating, alternately. The cycle of each kiln is about 120 cycles/day. The kiln can be divided to preheating zone, calcining zone and cooling zone from the top. Limestone undergoes the above reaction as it descends in the kiln.

Supporting equipment for the kiln are to be installed: a blower for combustion air, a natural gas combustion system, hydraulic equipment, a dust catcher, etc.

Burnt lime is discharged from the kiln to the conveyor and after weighing, transferred to the product screen. The screen separates the burnt lime to + 40 mm and - 5 mm and lumps of + 40 mm are crushed by a jaw crusher and returned to the product screen. Fines of - 5 mm are briquetted by the briquetting machine and stocked in the product bin. Burnt lime of 5 - 40 mm is sent by conveyor directly to the product bin. The product bin can hold about two days' consumption of burnt lime.

Burnt lime discharged by the vibrating feeder from the product bin is, after weighing, transferred by belt conveyors to the Steel Making plant.

Dust collecting facilities are installed at certain places in the raw material facilities, lime kiln and product facilities where dust tends to occur. After being collected by the dust collector, product dust is briquetted and sent to the product bin.

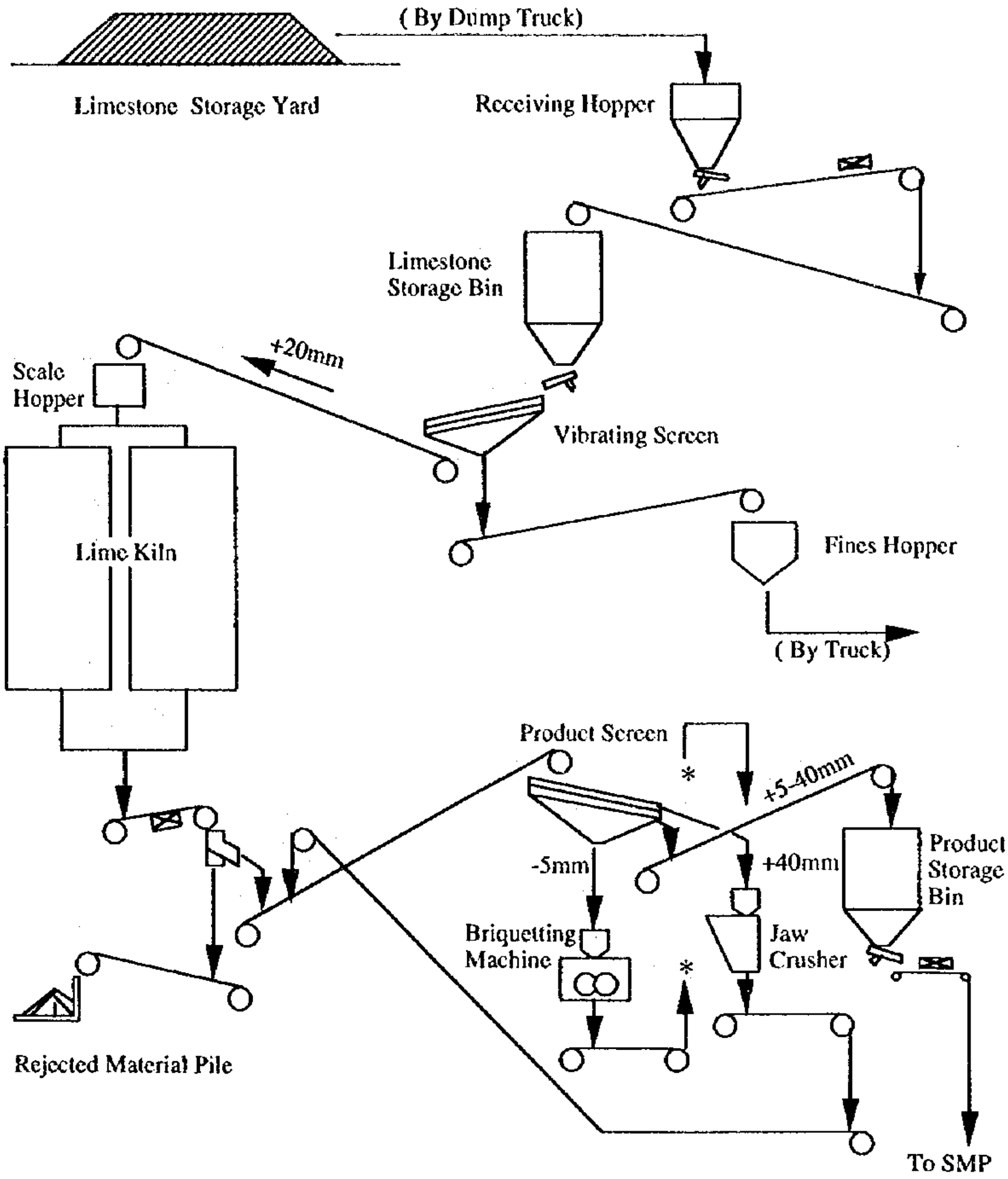



Figure 6-5-1 Lime Calcining Plant Material Flow

### 6.5.4 General layout of lime calcining plant

Below shows the preliminary general layout of lime calcining plant.

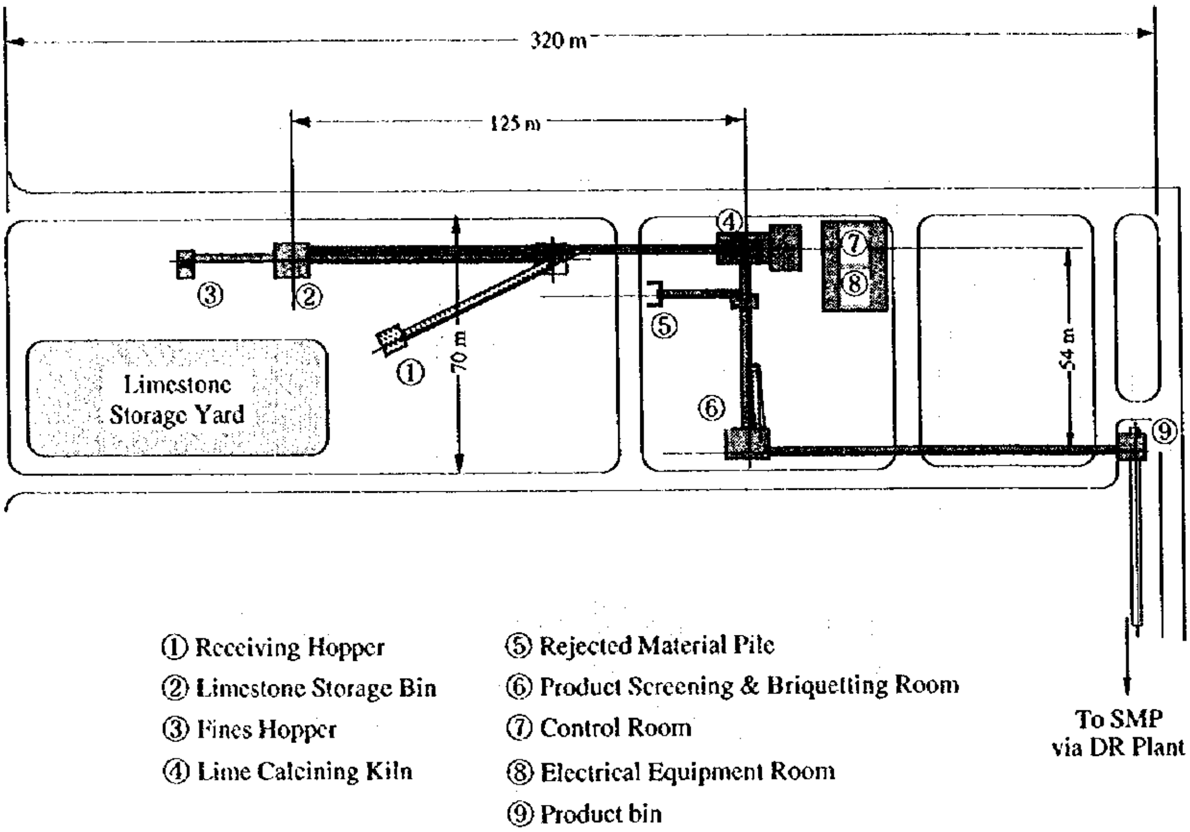



Figure 6-5-2 General Layout of Lime Calcining Plant

### 6.5.5 Organization and personnel

The organization and personnel to operate the plant are charted below.

Table 6-5-1 Organization and Personnel of Lime Calcining Plant

| Section Manager | Assistant Sec. Mgr. | Engineer | Foreman | Assistant Foreman | Worker | Remarks |
|---|---|---|---|---|---|---|
| | 1 | 1 | 1 x 4 | 1 x 4 | 3 x 4 | Shift Crew |
| | | | | 1 x 1 | 4 x 1 | Day Crew |
| | 1 | 1 | 4 | 5 | 16 | Total 27 |

### 6.5.6 Major equipment list

Appendix A6-5-1 attached hereto shows the Major Equipment list for the Lime Calcining Plant.

## 6.6 Electric Power and Distribution Facilities

### 6.6.1 Outline

(1) The substation in the plant shall mean the station receiving two incoming 132 kV power supplies supplied by the Ministry of Electricity and Water (MOEW) through under ground cables from the power station/power substation at Sohar and stepping it down to 33 kV and 6.6 kV. Electrical equipment at the plant will receive power at 33 kV or 6.6 kV from the substation.

(2) The 132/33 kV transformer will be installed separately for loads which generally do not generate flicker (clean loads) and for the loads which do (dirty loads).
- Clean loads : DRP, Billet CCM, BMP, Oxygen Plant and Utility
- Dirty loads : EAF and LF

(3) High harmonic filters (HHF) and a static var compensator (SVC) will be installed on the EAF & LF bus side.

(4) Diesel generators will be installed in the substation for emergency power supply.

### 6.6.2 Basic design

(1) Estimation of the demand power demand
The estimated demand power demand for the steel complex at full production is shown in Table 6-6-1.

(2) 132/33 kV transformers
The capacity of the transformers will be 110 MVA with two units for the EAF and LF and 80/110 MVA with two units for DRP, Billet CCM, BMP and other loads.

(3) Emergency power
Two diesel generator sets will be installed for emergency power supply.
Emergency power supply voltage will be 6.6 kV and 0.4/0.23 kV, and will be supplied to each shop whenever necessary.

(4) Supervising and control room
The supervising and control panels will be installed in an air conditioned room.

(5) 132 kV incoming cables

The 132 kV incoming cables will be supplied by MOEW under ground up to the gas insulated switchgears (GIS) of the 132 kV incoming panels in the substation.

6.6.3 Description of power distribution system

(1) 132 kV system

1) Gas insulated switchgears

The gas insulated switchgears (GIS) will be installed inside the substation.

The GIS will be equipped with receiving units, metering outfit (MOF), double main bus bars and a single feeder bus bar, bus tie units, transformer feeder units and other auxiliary devices.

2) 132/33 kV power transformers

The transformers will be installed in transformer yard beside the GIS room.

The transformer for the load generating flicker, will have a capacity of 110 MVA ONAN, will be an oil immersed type, suitable for outdoor use and will have an on-load tap changer.

The transformers for the loads which generally do not generate flicker, will have a capacity of 80/110 MVA at ONAN/ONAF, will be an oil immersed type, suitable for outdoor use and will have an on-load tap changer.

(2) 33 kV system

1) 33 kV switchgears

The 33 kV switchgears will be installed at 33 kV switchgear room in the substation.

The 33 kV switchgears will consist of two groups, one for the furnace load and the other for the non-furnace load.

The 33 kV switchgears will contain neutral grounding resistors (NGR), a main panel, feeder panels (including spare feeders), GPT panels, LA and SA panels and an auxiliary panel.

2) Static var compensator (SVC)

The SVC will be installed in the SVC yard in the substation.

The SVC will have a high impedance transformer, a thyristor equipment, an auxiliary control panel and thyristor control panel for flicker compensator, filters (2nd, 3rd, 4th, 5th and 6th harmonic filters) and a SVC supervisory panel.

(3) 6.6 kV system

1) 33/6/6 kV transformers

33/6.6 kV transformer will be suitable for outdoor use and installed in the transformer yard beside the 6.6 kV switchgears room for connecting to 6.6 kV loads.

The transformer will be of oil immersed type having 25/30 and 30/36 MVA capacity at ONAN/ONAF.

Each plant section will have one 33/6.6 kV transformer for connecting to 6.6 kV loads.

2) 6.6 kV switchgears

6.6 kV switchgears will be installed in the 6.6 kV switchgear room in the substation. The 6.6 kV switchgears will comprise a NGR panel, a main panel, a bus tie panel, a feeder panel, a GPT panel and a LA panel.

3) Static capacitor unit

Static capacitors will be installed in the transformer yard beside the 6.6 kV switchgear room and will be suitable for outdoor use, an oil immersed self cooled type having series reactor and discharge coil.

(4) Supervisory and control room

A control room will be provided on the 2nd floor of the 33 kV switchgear room.

The supervisory and control panel will be installed in the control room and will have meters, control switches, indication lamps, etc.

(5) Diesel generator

1) The diesel generator sets will be installed in the D/G yard in the substation.
2) The diesel generator sets will consist of diesel engines, generators, auxiliary transformers for station service, control panels, 6.6 kV distribution panels, starting systems, cooling systems and fuel systems.
3) The station service 6.6/0.4 kV transformer will be installed in the diesel generator yard.

   The transformer will be an oil immersed type, for outdoor use and will have a 500 kVA capacity at ONAN and will be provided with accessories.

6.6.4 Organization and personnel

Organization and manpower for maintenance are shown on the Figure 11-3-1 and Table 11-3-1

6.6.5 Drawing list

(1) Single line diagram for 132kV and 33kV system
Refer to Figure 6-6-1
(2) Single line diagram for 6.6kV system
Refer to Figure 6-6-2
(3) Single line diagram for emergency power supply
Refer to Figure 6-6-3
(4) Layout of substation
Refer to Figure 6-6-4

6.6.6 Major equipment list

Refer to Appendix A6-6-1.

Table 6-6-1 Estimated Power Demand for the Steel Complex

| Plant / Shop | Production 1,000 t/year | Operation hour in year | Power consumption kWh/t | Power consumption GWh/year | Average Load MW | Load factor | Maximum demand MW |
|---|---|---|---|---|---|---|---|
| Direct Reduction | 1,300 | 8,000 | 100.0 | 130 | 16.3 | 0.9 | 18.1 |
| Lime Calcining | 50.4 | 7,440 | 50.0 | 2.52 | 0.34 | 0.9 | 0.4 |
| SMP | 1,200 | 7,440 | 695.0 | 834.0 | 112.1 | 0.7 | 159.0 |
| Bar Mill Plant | 1,164 | 6,400 | 90.0 | 104.8 | 16.4 | 0.77 | 21.3 |
| Oxygen Plant | | 8,000 | | 51.8 | 6.5 | 0.9 | 7.2 |
| Air Compressor | | 8,000 | | 16.9 | 2.1 | 0.9 | 2.3 |
| Sea Water | | 8,000 | | 37.1 | 4.6 | 0.9 | 5.2 |
| Water Treatment | | 8,000 | | 30.1 | 3.8 | 0.9 | 4.2 |
| Others (lighting, Air Con.) | | 8,000 | 13.7 | 16 | 2.0 | 0.9 | 2.2 |
| Total | | | 948.7 | 1223.2 | 164 | | 220 |
| Diversity factor | | | | | | | 1.1 |
| Annual operation | 1,200 | | 948.7 | 1223.2 | 164 | | 200 |

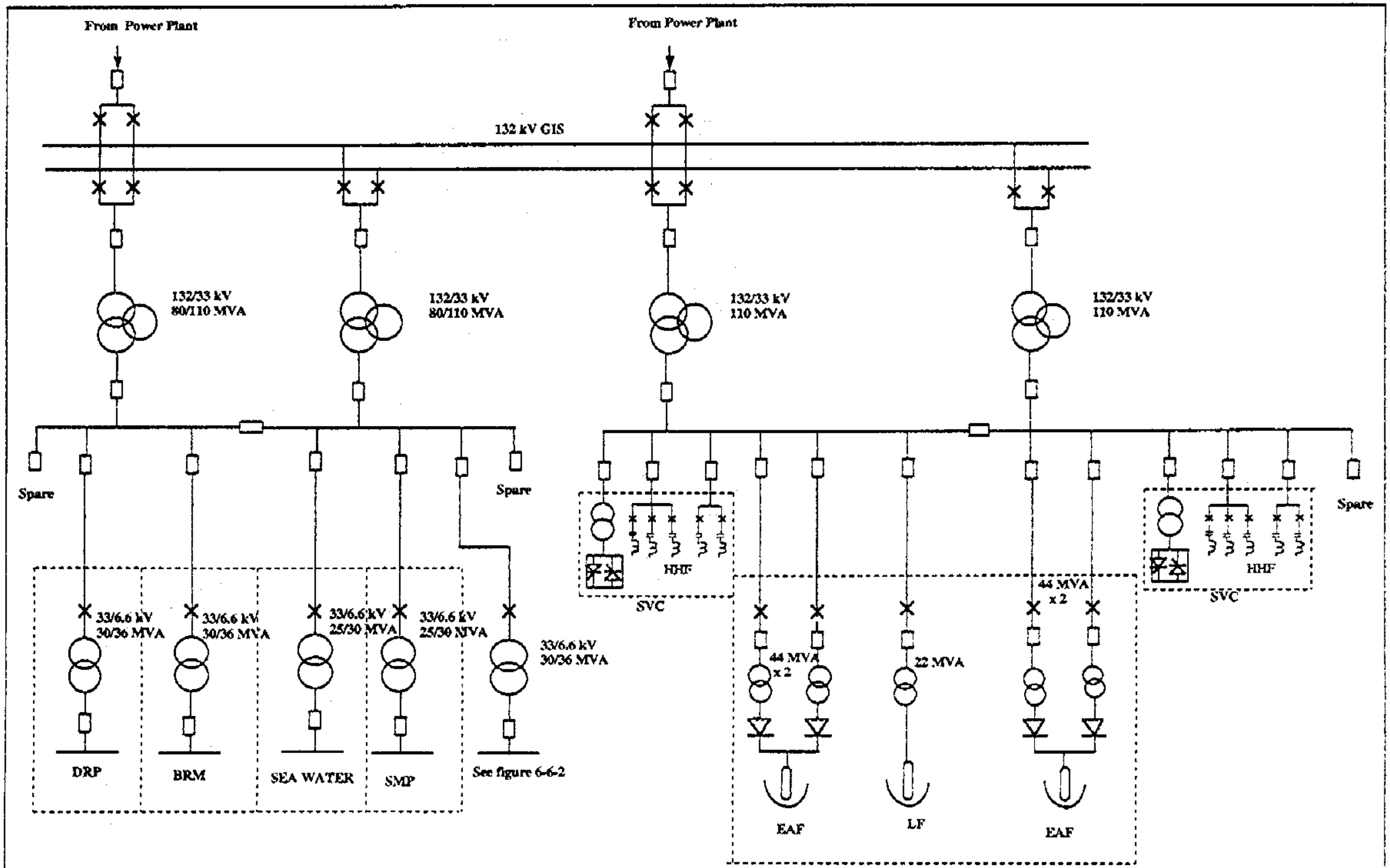



Figure 6-6-1 Single Line Diagram 220kV and 33KV System

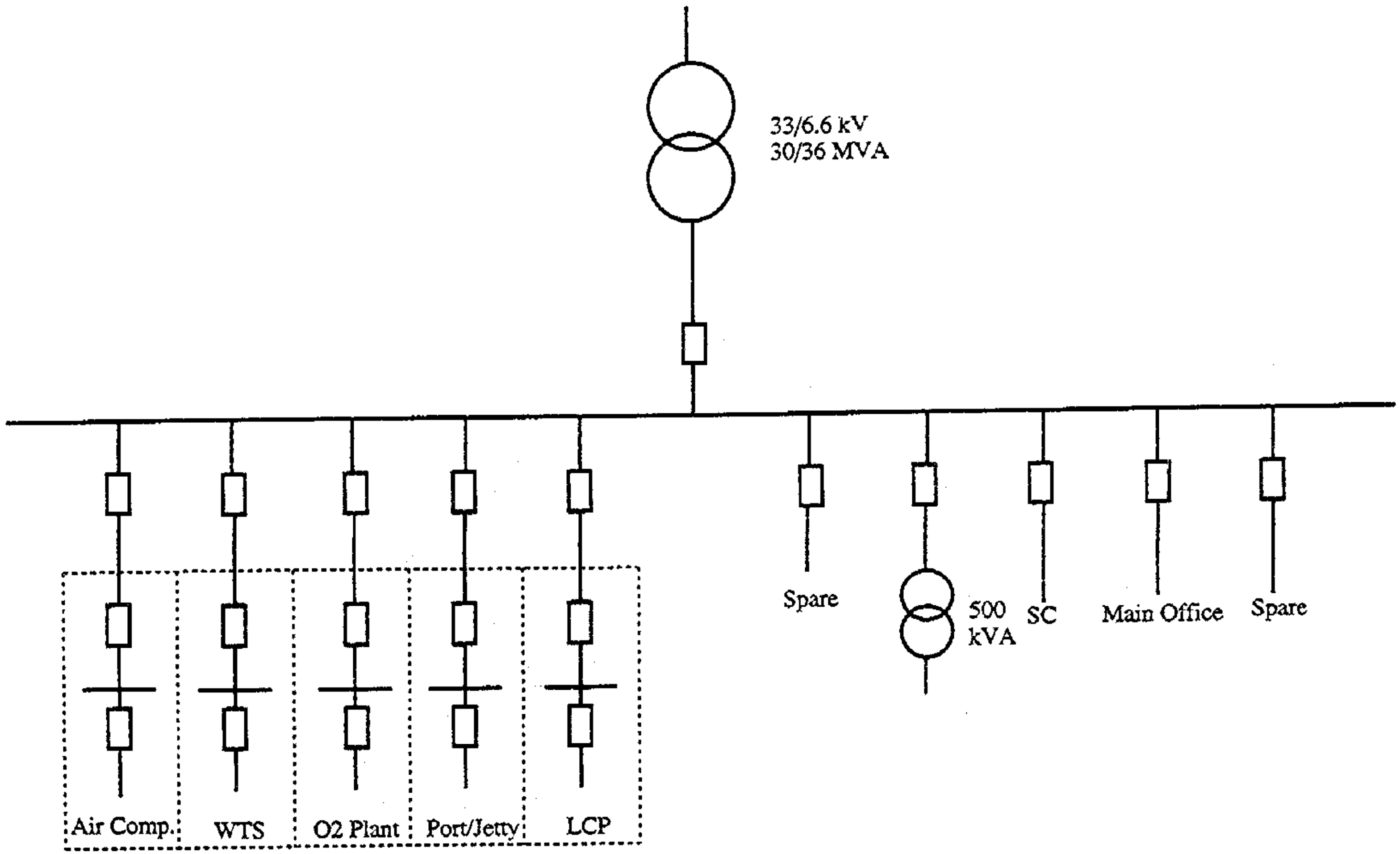



Figure 6-6-2 Single Line Diagram 6.6kV System

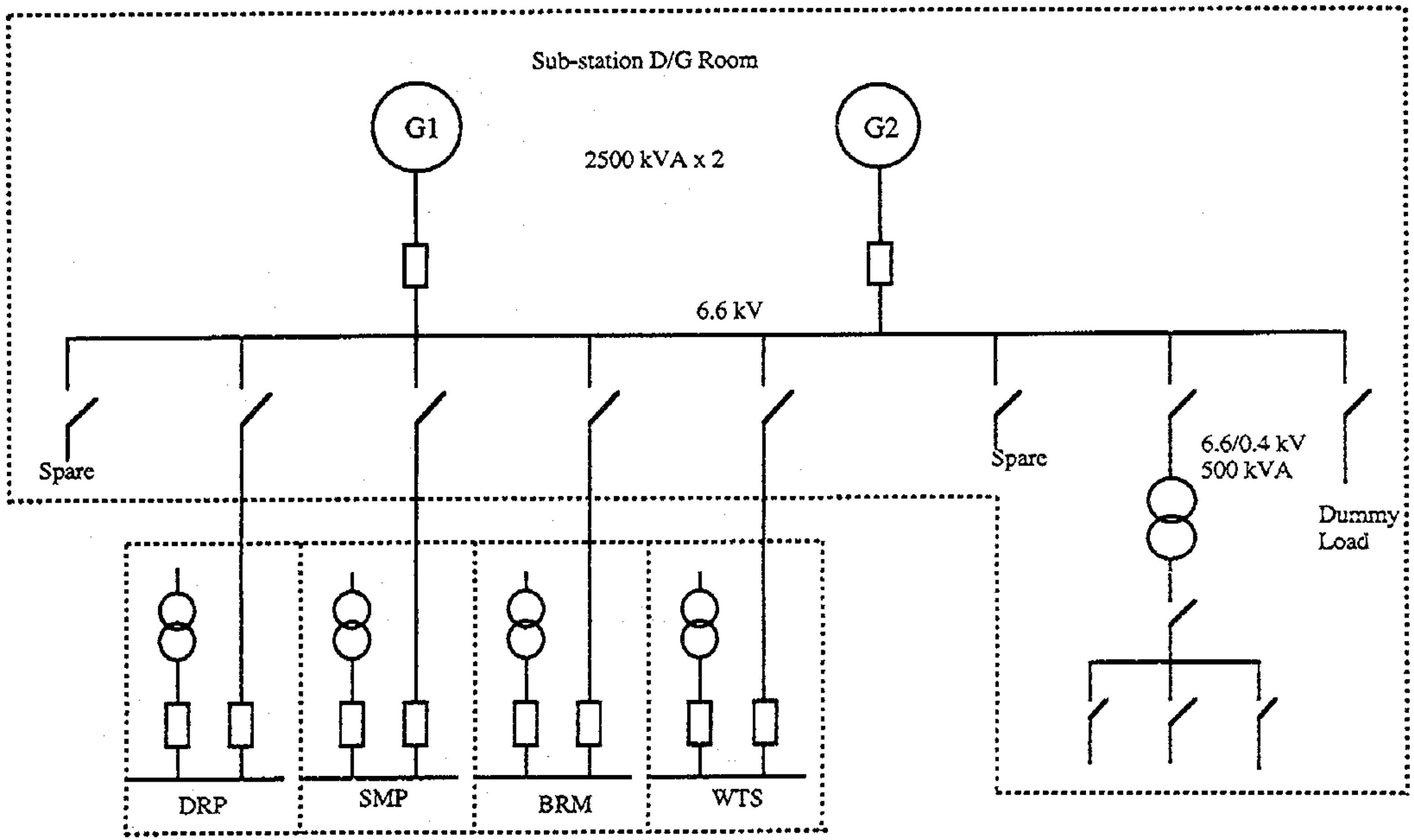
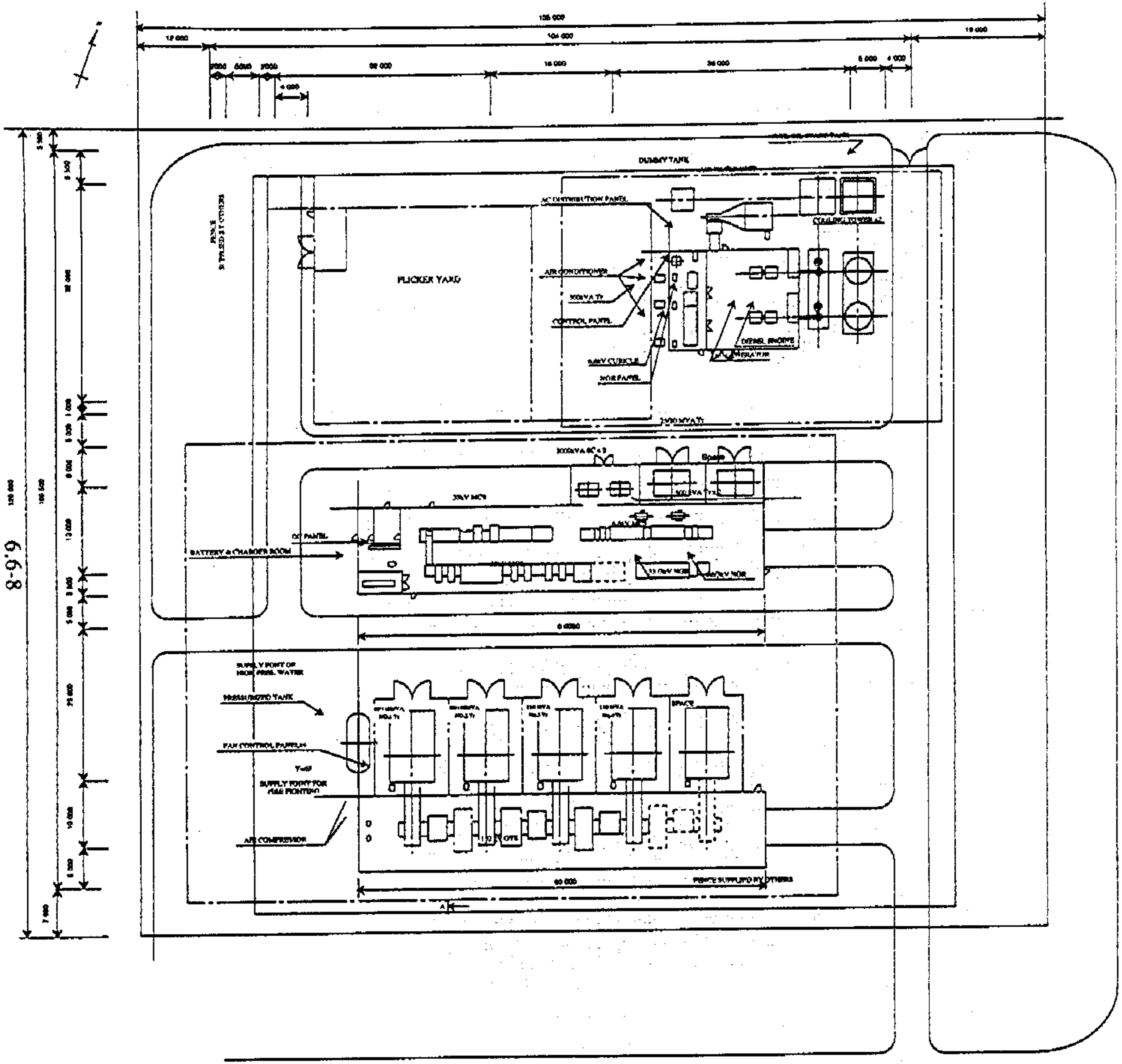
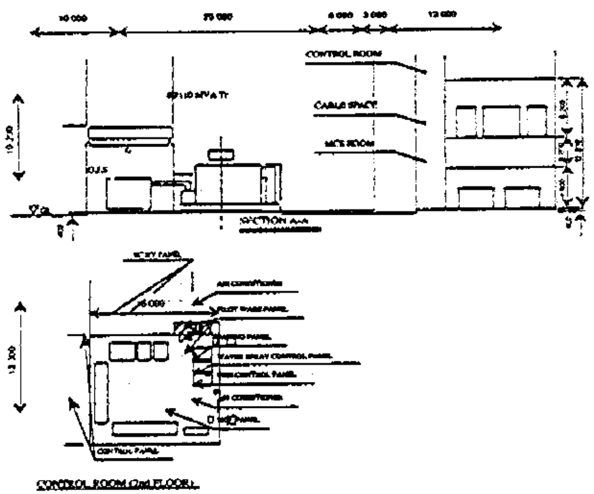



Figure 6-6-3 Single Line Diagram for Emergency 6.6kV and 380V System




| ABB REVIATION | FULL NAME |
|---|---|
| GIS | GAS INSULATED SWITCHGEAR |
| MCS | METAL CLAD SWITCHGEAR |
| S.C | STATIC CAPACITOR |
| Tr | TRANSFORMER |
| NGR | NEUTRAL GROUNDING RESISTOR |

Figure 6-6-4 Layout of Substation