JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF COMMERCE & INDUSTRY
THE SULTANATE OF OMAN

# THE FEASIBILITY STUDY
# OF
# THE DIRECT REDUCTION PLANT BASED STEEL COMPLEX PROJECT
# IN
# THE SULTANATE OF OMAN

## FINAL REPORT

## SUMMARY



FEBRUARY 1999

KOBE STEEL, LTD.
IN ASSOCIATION WITH
NKK CORPORATION

JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF COMMERCE & INDUSTRY
THE SULTANATE OF OMAN

# THE FEASIBILITY STUDY OF THE DIRECT REDUCTION PLANT BASED STEEL COMPLEX PROJECT IN THE SULTANATE OF OMAN

## FINAL REPORT

## SUMMARY

FEBRUARY 1999

KOBE STEEL, LTD.
IN ASSOCIATION WITH
NKK CORPORATION

## CONTENTS

APPENDIX

Appendix A4-1-1 Ranges and Limits of Steel Products and Regions

## CONTENTS OF TABLES

# CONTENTS OF FIGURES

# ACRONYMS AND ABBREVIATION

Organization

| | |
|---|---|
| IISI | International Iron and Steel Institute |
| JICA | Japan International Cooperation Agency |
| MOC | Ministry of Communications. |
| MOCI | Ministry of Commerce and Industry |
| MOEW | Ministry of Electricity and Water |
| MOFA | Ministry of Foreign Affairs |
| MOF | Ministry of Finance |
| MOHE | Ministry of Higher Education |
| MOHL | Ministry of Health |
| MOHO | Ministry of Housing |
| MONE | Ministry of National Economy |
| MOOG | Ministry of Oil and Gas |
| MORE | Ministry of Regional Municipalities and Environment |
| MOSL | Ministry of Social Affairs and Labor |
| NFPA | National Fire Protection Association |
| PDO | Petroleum Development Oman LLC |
| WHO | World Health Organization |

Position

| | |
|---|---|
| CB | Chairman of Board |
| DGM | Deputy General Manager |
| GM | General Manager |
| MD | Managing Director |

Unit (Measurement)

| | |
|---|---|
| MIGPD | Million Imperial Gallon Per Day |
| Mpa | Megapascal = 10 bar = 10.1972 $kgf/cm^2$ |
| NTU | National Turbidity Unit |
| ppm | parts per million |
| dB | decibel |
| MMBTU | Million BTU(British Thermal Unit) |
| DWT | Dead Weight Ton |
| RO. | Rial Omani |
| scf/d | Standard cubic feet per day |
| TCF(tcf) | Trillion Cubic Feet |

Major Technical Terms

| | |
|---|---|
| AI | Analysis and Inspection Facilities |
| AC | Alternating Current |
| BOD | Biochemical Oxygen Demand |
| DC | Direct Current |
| DCF | Discounted Casting Machine |
| DCW | Direct Cooling Water |
| DR | Direct Reduction |
| DRI | Direct Reduction Iron |
| EIA | Environmental Impact Assessment |
| EIS | Environmental Impact Statement |
| FES | Fume Extraction System |
| FPC | Flicker and Power Factor Compensator |
| GT | Gas Turbine |
| GIS | Gas Insulated Switchgear |
| GPT | Ground Potential Transformer |
| HBI | Hot Briquetted Iron |
| HHF | High Harmonic Filters |
| HHV | High Heat Value |
| HRSG | Heat Recovery Steam Turbine |
| ICW | Indirect Cooling Water |
| IRR | Internal Rate of Return |
| LA | Lightning Arrester |
| LF | Ladle Furnace |
| LHV | Low Heat Value |
| NGR | Neutral Grounding Resister |
| ONAF | Oil Natural Air Force |
| ONAN | Oil Natural Air Natural |
| OJT | On-the Job Training |
| RO | Reverse Osmosis |
| SFC | Static Flicker Compensator |
| SC | Static Capacitor |
| SS | Suspended Solid |
| ST | Steam Turbine |
| SVC | Static Var Compensator |
| TDS | Total Dissolved Solid |

| | |
|---|---|
| TR | Transformer |
| TSP | Total Suspended Particulates |
| TSW | Treated Sewerage Water |
| UPS | Uninterruptive Power Source |
| WTS | Water Treatment Station |

# Chapter 1. INTRODUCTION

## 1.1 Background

THE SULTANATE OF OMAN (hereinafter referred to as Oman) has been actively promoting socioeconomic development under its long-term vision called" Oman 2020" . The principal objective of Oman 2020 is the long-term transformation of the country's economic structure from the present dependence on oil production. The key component of this strategy is expansion of the manufacturing industry. Under the current Fifth Five-Year Economic Development Plan, the Government of Oman appears to be pushing the steel making, petrochemical, fertilizer and aluminum sectors as future key industrial sectors using the country's abundant natural gas resources.

With the subsequent preparation of infrastructure and utility development plans, the Government of Oman made a request in April 1997 to THE JAPAN INTERNATIONAL COOPERATION AGENCY (hereinafter referred to as JICA) for a feasibility study for the construction of a new steel complex based on the direct reduction plant at Salalah, which will be projected by the private sector. In response to this request, JICA twice dispatched a pre-study team to Oman and exchanged a scope of work (S/W) between the Government of Oman in September 1997, in which the process and scope of the study were defined.

In March 1998, the Government of Oman requested JICA to study Sohar as the plant site in addition to Salalah, and both parties agreed in May 1998 that the plant site selection would be studied for Salalah and Sohar, and that a feasibility study should be completed on the selected site. The JICA Study Team made a technical and economic evaluations of Salalah and Sohar with a recommendation. Based on the recommendations, the Government of Oman chose Sohar as the plant site in September 1998.

This feasibility study was conducted and completed only for Sohar as the plant site.

## 1.2 Member of the Study Team

The Study Team was organized by Kobe Steel, Ltd. in association with NKK Corporation consisting of 13 members.

## 1.3 Authorities and Personnel from Oman

Through four field surveys in Oman, the Study Team had many meetings with the Steering Committee of the Sultanate of Oman and also visited many authorities and corporations, and met a lot of people concerned with collecting the data and information for this feasibility study.

## 1.4 Plant Site Selection

In response to the request of the Government of Oman in March 1998 to study Sohar as the plant site in addition to Salalah, JICA and the Government of Oman agreed in May 1998 that the plant site selection of the Steel Complex would be studied for Salalah and Sohar, and that the feasibility study should be completed on the selected site.

In accordance with the methodology agreed by the Steering Committee, JICA Study Team made technical and economic evaluations and submitted the evaluation reports with the recommendations to the Steering Committee.
Based on the recommendations of JICA Study Team, the Government of Oman decided on Sohar as the plant site. Therefore this feasibility study was completed only for Sohar as the plant site.

## Chapter 2. OBJECTIVE AND SCHEDULE OF THE STUDY

### 2.1 Objectives of the Study

The objectives of the study are to conduct a feasibility study on a new Direct Reduction Plant Based Steel Complex using natural gas based on market analysis, preparation of plant construction and operation plans plus financial and economic analysis of the said complex, and to define the requirements for the construction of the plant in terms of the development of infrastructure and provision of the utilities, port and port facilities, etc.

### 2.2 Overall Schedule of the Study

The feasibility study was conducted from January 1998, including four times of field surveys in Oman with cooperation and assistance of the Steering Committee. Draft Final Report was submitted to the Steering Committee in November 1998 for review and comment. The Final Report was submitted in February 1999 after revision of the Draft Final Report taking account of the requirements and comments from the Steering Committee.

## Chapter 3. MACRO ECONOMY AND INDUSTRIAL POLICY

### 3.1 Present Situation of Macro Economy

In 1997 the performance of the Oman economy depended largely on the non-oil sector which showed a growth rate of 6.2 % in current prices. The oil sector registered a negative growth of 1.2 % in 1997. Combining both sectors, GDP grew by 3.1% in 1997 as against 11% in 1996 and 6.8% in 1995. The external current account deficit reached RO 21 million in 1997, from a surplus of RO 107 million in 1996. On the fiscal matters, the official budget deficit which reached 4.4% of GDP in 1996 is likely to fall to 0.7% of that in 1997. However, when compared with the fiscal outrun for 1995 ( deficit of 9.0% of GDP ), the situation in 1997 is still better. Regarding demand side of GDP, total consumption grew around 5.1% in 1996, but showed a lower growth of only 0.5% in 1997; whereas total investment has gone up by 29.8% in 1997 compared to 1996 level.

Table 3-1-1 GDP, Foreign Trade and Public Finance in Oman in 1991-1997

( Unit : Million O.R.)

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|
| GDP | 4,361 | 4,788 | 4,804 | 4,967 | 5,307 | 5,890 | 6,075 |
| Industry | 2,154 | 2,336 | 2,196 | 2,241 | 2,467 | 2,907 | 2,957 |
| Agriculture* | 115 | 112 | 115 | 126 | 147 | 147 | 155 |
| Services | 2,145 | 2,385 | 2,543 | 2,668 | 2,774 | 2,927 | 3,078 |
| Foreign Trade Balance | +594 | +636 | +411 | +588 | +648 | +1,004 | +1,001 |
| Exports | 1,873 | 2,136 | 2,063 | 2,132 | 2,332 | 2,822 | 2,934 |
| Imports | 1,279 | 1,500 | 1,652 | 1,543 | 1,684 | 1,818 | 1,933 |
| Public Finance | | | | | | | |
| Revenue | 1,585 | 1,680 | 1,724 | 1,757 | 1,852 | 1,990 | 2,267 |
| Expenditure | 1,868 | 2,259 | 2,242 | 2,253 | 2,331 | 2,254 | 2,307 |
| Surplus or Deficit | -283 | -579 | -518 | -496 | -479 | -263 | -40 |

Source : Statistical Yearbook 1997 & Monthly Statistical Bulletin October 1998 by MONE.

Note: at current prices. * Fishing is contained.

On 1998 outlook, owing to the decline of international crude oil prices and the economic depression in Asian countries, such as Japan, S. Korea, and ASEAN, which are major importers from Oman, it is feared that the growth rate of GDP in 1998 will further slow down.

## 3.2 Present Social Environment

Omani social environment has considerably been changed mainly by high increase of population for these years. The population has grown around 3.6% per annum over the past ten years, added to increase of expatriates from Asia. Each industry sector has been allocated a percentage of Omani personnel to be employed as follows:

- Transportation, storage and communication 60%
- Finance, insurance and real estate 45%
- Industry 35%
- Restaurant and hotel 30%
- Wholesale and retail 20%
- Contracts 15%

## 3.3 Present Situation by Industrial Sector and Industrial Policy

Industrial production in 1997 in total, slowed down compared with 1996.

Table 3-3-1 Industrial Production by Sector

( Unit : Million O. R., % )

| Item / Year | 1994 | 1995 | 1996 | 1997 | 95/94 | 96/95 | 97/96 |
|---|---|---|---|---|---|---|---|
| Industry (1) + (2) | 2,241 | 2,467 | 2,907 | 2,956 | 10.1 | 17.8 | 1.7 |
| (1) Petroleum activities | 1,815 | 2,020 | 2,463 | 2,434 | 11.3 | 21.9 | -1.2 |
| Crude oil | 1,750 | 1,973 | 2,415 | 2,378 | 12.7 | 22.4 | -1.5 |
| Natural gas * | 65 | 47 | 48 | 56 | -27.7 | 2.1 | 16.6 |
| (2)Non-petroleum activities | 426 | 447 | 443 | 522 | 4.9 | -0.9 | 17.8 |
| Mining & Quarrying | 11 | 13 | 14 | 16 | 18.2 | 7.7 | 14.3 |
| Manufacturing | 216 | 247 | 246 | 254 | 14.4 | -0.4 | 3.3 |
| Electricity & Water | 49 | 49 | 55 | 65 | 0.0 | 12.2 | 18.2 |
| Construction | 150 | 138 | 129 | 187 | -8.0 | -6.5 | 45.0 |

Source : Monthly Statistical Bulletin, May 1998 by MONE

Note : at current prices. 95/94, 96/95 and 97/96 are growth rates (%). Natural gas * is associated oil and gas.

The government is taking a supporting policy for non-oil industries to promote manufacturing , etc. Support for the manufacturing industry, incentive available for manufacturing industrial trade is exemption from custom duties on imports of equipment and raw materials, exemption from income tax for a period of five years, soft loans for projects by the Ministry of Commerce & Industry and by the Oman Development Bank on financial support to the private sector, and etc.

In Oman, steel industry will entail development of a sizable export market in light of the limited scale of the domestic steel market. In order to make such exports possible, an essential point will be whether competitive steel products for the international market can be manufactured or not. Against the above background, the following government support policy for the steel industry in Oman is recommended.

- Establishment and provision of infrastructure under government initiative at inexpensive cost
- Public financial policy at low interest with regard to development investment Steel projects require a large investment
- Collection and collation of domestic and export market data under government initiative
- Training of specialists in steel production technology

## 3.4 National Development Plan

Omani government initiated its process of economic development through launching the First Five-Year Plan in 1976. Since then, Oman has successfully completed four Five-Year Plans and now is passing through the Fifth Plan ( 1996 - 2000 ). Main points in the Fifth Five-Year Development Plan are as follows.

- This Plan is based on promotion of economic structure outside petroleum sector, and places greater emphasis on economic diversification, an expanded role for the private sector and development human resources.
- In order to promote industries outside petroleum sector, the government focuses on developing industries that depend on domestic resources, with special priority to be given to gas.
- In terms of priority of industries and investment opportunities, there are five industries where need to be developed in Oman in short-to- medium term:
  -- Aluminum. -- Petrochemicals and Hydrocarbon. -- Plastics.
  -- Engineering goods. -- Minerals (non-copper)

- The government carry out arrangement of infrastructure such as roads, ports, electricity, water and telecommunications.
- The government set the main items of GDP in the Fifth Five-Year Development Plan as shown in Table 3-4-1.

Table 3-4-1 Balance of GDP and its Uses during Fifth Five-Year Plan ( 1996-2000 )

( Unit : Million O.R. % )

| Item | Fifth plan | | | | | Annual growth rate | |
|---|---|---|---|---|---|---|---|
| Year | 1996 | 1997 | 1998 | 1999 | 2000 | 96-2000 | (91-95) |
| A: Resources | | | | | | | |
| (1) Oil sectors | 1,974 | 1,997 | 1,996 | 1,994 | 2,131 | 1.1 | 11.4 |
| Crude oil | 1,908 | 1,924 | 1,915 | 1,905 | 1,909 | -0.7 | 12.8 |
| Natural gas | 66 | 73 | 81 | 89 | 222 | 36.4 | -28.3 |
| (2) Non-oil sectors | 3,766 | 4,280 | 4,738 | 4,861 | 4,556 | 6.3 | 4.1 |
| Goods producing sectors | 706 | 911 | 916 | 1,142 | 1,133 | 13.7 | 8.2 |
| Mining | 21 | 28 | 30 | 25 | 27 | 9.7 | 52.3 |
| Agriculture & fisheries | 153 | 184 | 177 | 234 | 220 | 7.7 | 20.8 |
| Manufacturing | 274 | 353 | 308 | 337 | 429 | 12.2 | 11.6 |
| Electricity & water | 56 | 62 | 73 | 85 | 88 | 12.4 | 0.1 |
| Building & construction | 202 | 284 | 328 | 461 | 369 | 21.7 | -8.1 |
| Services producing sectors | 3,060 | 3,369 | 3,822 | 3,719 | 3,423 | 4.4 | 3.3 |
| (1)+(2) | 5,740 | 6,277 | 6,734 | 6,855 | 6,687 | 4.5 | 6.7 |
| (3) Imputed banking services | -124 | -123 | -130 | -133 | -131 | -0.2 | 20.7 |
| (4) Custom duties | 47 | 57 | 67 | 69 | 62 | 6.6 | 9.1 |
| Total GDP at market prices (1)+(2)+(3)+(4) | 5,663 | 6,211 | 6,671 | 6,791 | 6,618 | 4.6 | 6.5 |
| B: Uses | | | | | | | |
| Final consumption | 4,163 | 4,342 | 4,475 | 4,745 | 4,910 | 4.0 | 6.9 |
| Gross capital formation | 994 | 1,482 | 1,986 | 1,734 | 1,125 | 7.2 | 1.7 |
| Surplus of exports of goods & non-factors services | 506 | 387 | 210 | 312 | 583 | 4.9 | 11.7 |
| Exports of goods & non-factors services | 2,486 | 2,629 | 2,633 | 2,723 | 2,820 | 3.8 | 9.4 |
| Imports of goods & non-factors services | -1,980 | -2,242 | -2,423 | -2,411 | -2,237 | 3.5 | 8.9 |

Source : Table 8-4 and 8-5 in the Fifth Five-Year Development Plan, July 1997, by MONE.

Note : At 1995 prices. (3) is minus items, and (4) is plus items. A: Resources, B: Uses.

## Chapter 4. MARKET STUDY

### 4.1 Present Situation of Steel Demand in Oman

#### 4.1.1 Domestic steel demand

Steel demand by product in Oman since 1991 is as indicated in Table 4-1-1. Total steel demand shows a sharp increase during the two year period 1996~97. In terms of steel products, bars & wire rods exhibit by far the highest figures, followed by pipes.

Table 4-1-1 Demand for Steel Products in Oman

(Unit:1000tons)

| Year / Products | Total | Bars & wire rods * | Sections * | Sheets & plates | Pipes |
|---|---|---|---|---|---|
| 1991 | 256 | 123 | 22 | 7 | 104 |
| 1992 | 256 | 121 | 31 | 16 | 88 |
| 1993 | 311 | 165 | 27 | 22 | 97 |
| 1994 | 265 | 151 | 21 | 11 | 82 |
| 1995 | 215 | 131 | 12 | 21 | 51 |
| 1996 | 642 | 487 | 24 | 26 | 105 |
| 1997 | 689 | 288** | 12 | 53 | 336 |

Source : Custom Statistics of Oman.

Note : * Ranges and limits of steel products are shown at Appendix A4-1-1.

** The figure for "Bars & wire rods" in 1997 includes the domestic production of an estimated 60,000 tons

From the above, it can be seen that although steel demand in Oman is increasing in recent years, the domestic market remains small at a national level of around 600,000 tons. In Oman, steel demand relies on the construction sector including projects related to petroleum and gas development, and building construction.

#### 4.1.2 Present steel consumption by product and by sector

The present steel consumption by product and sector is estimated as follows.
It is presented in Table 4-1-2 based on the Custom statistics of Oman, the field survey and final steel consumption experience in Japan, Saudi Arabia, Thailand, etc. The consumption pattern for steel products is heavily skewed towards the construction sector.

Table 4-1-2 Estimation of Present Steel Consumption by Product and by Consumption Sector in Oman

(Unit : 1000 tons, %)

| Sector / Product | Total | Bars & rods | Sections | Sheets & Plates | Pipes |
|---|---|---|---|---|---|
| Construction | 630 ( 94 ) | 380 ( 97 ) | 20 ( 100 ) | 30 ( 75 ) | 200 ( 91 ) |
| Manufacturing, others | 40 ( 6 ) | 10 ( 3 ) | 0 ( 0 ) | 10 ( 25 ) | 20 ( 9 ) |
| Total | 670 ( 100 ) | 390 ( 100 ) | 20 ( 100 ) | 40 ( 100 ) | 220 ( 100 ) |

Source : Field survey.
Note : Total figures by steel product are the average figures of 1996 and 1997.

### 4.1.3 Special characteristics of the steel market in Oman

Special characteristics of the steel market in Oman is in concrete comparison with such countries as Saudi Arabia, Singapore, Thailand and Japan as follows.
The scale of the steel market is very small, and the composition of sector-wise and product-wise steel consumption is heavily skewed towards the construction sector and long products, respectively.

## 4.2 Current Steel Supply in Oman

Steel supply in Oman is only at a re-roller mill which commenced operation in 1997. This mill produces 60,000-70,000 tons of steel reinforcing bar per year by imported billet as raw material.

## 4.3 Supply and Demand Forecast for Steel Products in Oman

### 4.3.1 Steel demand forecast

Three cases of steel demand are forecast by two methodologies. Assumed macro-indicators are shown in Table 4-3-1. Two cases of steel demand are forecast by one methodology of elasticity rate analysis of steel consumption for GDP. One case of steel demand is forecast by another methodology that steel consumption of the construction sector and the other sectors is extrapolated and forecast from the growth of the gross capital composition and GDP respectively. The average figures for these three forecast figures in Table 4-3-2 are adopted as the final forecast.

Table 4-3-1 Forecast of GDP in 2000 and 2010 in Oman

(Unit : Million R. O. at 1995 Prices, % )

| Year | 1995 A | 1996 B | 2000 C | 2010 D | | C/A | C/B | D/C* | |
|---|---|---|---|---|---|---|---|---|---|
| GDP | 5,288 | 5,663 | 6,618 | a 10,376 | b 12,658 | 4.6 | 4.0 | 4.6* | 6.7 |
| Gross Capital Formation | 795 | 994 | 1,125 | 2,255* | | 7.2 | 3.1 | 7.2* | |

Source : The Fifth Five-Year Plan. "Vision 2020".

Note : Annual growth rate of GDP in 2000 - 2020 by "Vision 2020" is 6.7%.

GDP (b) in 2010 comes from the above annual growth rate. GDP (a) in 2010 comes from the same annual growth rate of The Fifth Five-Year Plan. Gross Capital Formation * in 2010 comes from the same annual growth rate of The Fifth Five-Year Plan.

Table 4-3-2 Final Forecast of Steel Consumption by Product

(Unit : 1000 tons; %)

| Product/Year | 1985 a | 1996 b | 2000 c | 2005 | 2010 d | b/a * | c/b * | d/c * |
|---|---|---|---|---|---|---|---|---|
| Bars and rods | - | 300 | 350 | 470 | 640 | - | - | - |
| Sections | - | 15 | 20 | 25 | 30 | - | - | - |
| Sheets and Plates | - | 30 | 35 | 45 | 60 | - | - | - |
| Pipes | - | 170 | 195 | 270 | 360 | - | - | - |
| Total | 362 | **515 | 600 | 810 | 1090 | 3.3 | 3.9 | 6.2 |

Note : * The average growth rate.

** Figure in 1996 b is the average figure among 1995, 1996 and 1997. Because the original figure is supposed to contain many stocks.

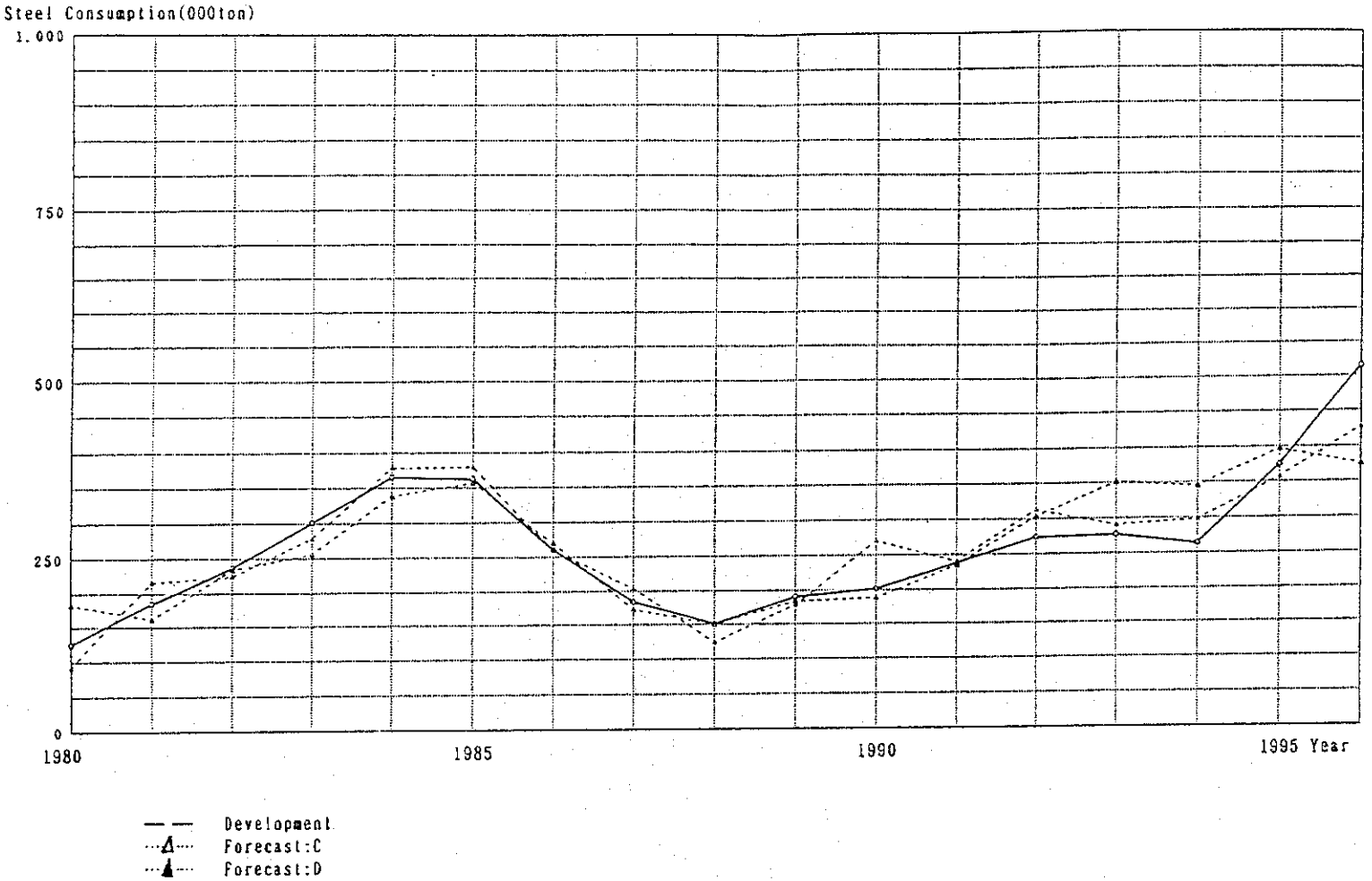



Figure 4-3-1 Development and Theoretical Figures of Steel Consumption in Oman

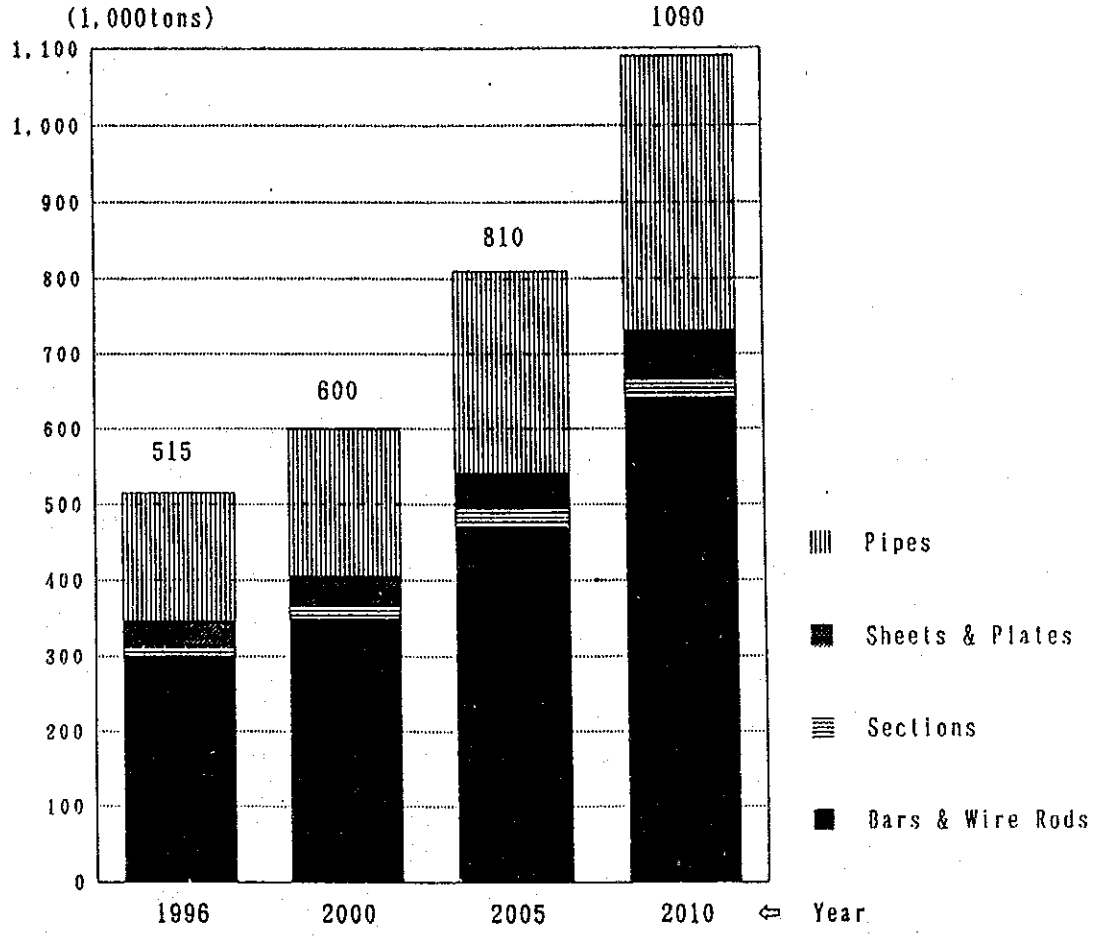



Figure 4-3-2 Final Forecast Steel Consumption by Product

### 4.3.2 Steel supply forecast

On the basis of interview survey of concerned personnel of the Ministry of Commerce and Industry as well as numerous end users of steel products, there are no projects planned at present to further expand steel production. As a result, it is assumed under this Study that steel supply volume in Oman will change little in the future.

### 4.3.3 Forecast of steel supply and demand balance

On the basis of Table 4-3-2 and the foregoing Section " Steel supply forecast " ,the forecast of steel supply and demand balance is collated in Table 4-3-3. According to this tabulation, production shortages by product in 2005 and 2010 will be 400,000 and 570,000 tons for bars & wire rods, 25,000 and 30,000 tons for sections, 45,000 and 60,000 tons for sheets and plates, and 270,000 and 360,000 tons for pipes, respectively. Production shortage is particularly large in the case of bars & wire rods, and pipes.

Table 4-3-3 Forecast of Steel Balance by Product

(Unit : 1000 tons)

| Product | Balance/Year | 1996 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| Bars and wire rods | Production A | 60 | 70 | 70 | 70 |
| | Consumption B | 300 | 350 | 470 | 640 |
| | Balance B - A | 240 | 280 | 400 | 570 |
| Sections | Production A | 0 | 0 | 0 | 0 |
| | Consumption B | 15 | 20 | 25 | 30 |
| | Balance B - A | 15 | 20 | 25 | 30 |
| Sheets and pates | Production A | 0 | 0 | 0 | 0 |
| | Consumption B | 30 | 35 | 45 | 60 |
| | Balance B - A | 30 | 35 | 45 | 60 |
| Pipes | Production A | 0 | 0 | 0 | 0 |
| | Consumption B | 170 | 195 | 270 | 360 |
| | Balance B - A | 170 | 195 | 270 | 360 |
| Total | Production A | 60 | 70 | 70 | 70 |
| | Consumption B | 515 | 600 | 810 | 1090 |
| | Balance B - A | 455 | 530 | 740 | 1020 |

### 4.3.4 Product selection based on domestic market study

Bars are selected as the product under this Project on the basis of domestic market study. It is the selected reason that the market for steel bars, primarily for reinforcing bars, exhibits the largest volume. Pipes which are on the next largest market comprises mostly seamless high quality pipes used for line pipes and drilling in the petroleum sector, and seamless pipes are considered extremely difficult to produce given levels of technology in developing countries.

## 4.4 Current Situation and Future Prospect of the International Steel Market

### 4.4.1 Present situation of the international steel market

World-wide steel imports exhibit the following characteristics by region during the 5 year period 1991 - 1996:

Table 4-4-1 Imports of Steel Products in 1991 - 1996 in World by Region

(Unit : Million tons; % )

| Region | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 96/91* | 1996* |
|---|---|---|---|---|---|---|---|---|
| Middle East | 7.6 | 9.0 | 10.4 | 8.1 | 8.3 | 7.4 | -0.5 | 3.3 |
| Asia | 50.0 | 54.6 | 92.3 | 86.1 | 85.1 | 80.4 | 10.0 | 35.3 |
| Africa | 5.4 | 5.8 | 5.4 | 6.7 | 7.2 | 5.5 | 0.4 | 2.4 |
| Western Europe | 73.5 | 75.3 | 66.3 | 78.1 | 89.4 | 82.2 | 2.3 | 36.1 |
| Eastern Europe | 6.0 | 7.4 | 9.7 | 11.1 | 11.0 | 11.6 | 12.9 | 5.1 |
| North America | 20.3 | 21.7 | 24.2 | 37.6 | 32.0 | 34.8 | 11.4 | 15.3 |
| South America | 3.1 | 4.0 | 3.6 | 4.3 | 5.2 | 4.1 | 5.8 | 1.8 |
| Oceania | 1.5 | 1.2 | 1.1 | 1.6 | 1.4 | 1.5 | 0.0 | 0.7 |
| World Total | 167.4 | 179.0 | 213.0 | 233.6 | 239.6 | 227.5 | 6.3 | 100.0 |

Source : IISI

Note : Steel products comprise semi-finished and finished products. Ranges of region are shown at Appendix A 4-1-1. 96/91* indicates annual growth rate ( % ); 1996* indicates share ( % ) by region.

- Total volume of world-wide steel imports shows an annual 6.3% growth rate, increasing from 167.4 million tons in 1991 to 227.5 million tons in 1996.
- The Asian market has made the greatest contribution to this increase, exhibiting an annual growth rate in imports of 10%. The Asian market alone accounts for around 35% of total steel imports world-wide, and is on a par with Western Europe in this regard (approx. 36%).
- Western Europe remains the largest steel importing region, showing stable growth in imports of around 2% per annum and a 36% share of world-wide steel imports in 1996.

- The North American steel import market has grown at an annual rate of 11%, and is third in terms of world-wide import share.
- The Middle Eastern share of world steel imports is low at only 3.3%.
- Eastern Europe shows a high annual growth rate in steel importation at 13% over the subject period; however, 1991 imports were at a bottom level due to the collapse of the Soviet Union, and the 1996 level of import is actually only a little over 50% of that prior to 1988.

### 4.4.2 Future outlook for the international steel market

In October 1997, the IISI released its world-wide, steel demand forecast by region. Details are shown in Table 4-4-2. From this, the following can be concluded:

Table 4-4-2 Demand Forecast of Steel Products in 2000 and 2005 World-wide

(Unit: million tons, %)

| Region, Country | 1995 | 2000 | 2005 | 2000/1995 | 2005/2000 |
|---|---|---|---|---|---|
| Japan | 80.0 | 80.0 | 80.0 | 0.0 | 0.0 |
| U.S.A. | 99.5 | 101.5 | 102.5 | 0.4 | 0.1 |
| Canada | 12.8 | 14.0 | 14.0 | 1.9 | 0.0 |
| EU(15) | 125.6 | 124.0 | 124.0 | -0.2 | 0.0 |
| China | 87.4 | 120.0 | 145.0 | 6.5 | 3.9 |
| Former USSR | 35.7 | 37.0 | 40.0 | 0.7 | 1.6 |
| Middle East | 9.0 | 12.0 | 14.5 | 5.9 | 3.9 |
| Other Asia | 121.1 | 137.0 | 165.0 | 2.5 | 3.8 |
| Africa | 14.1 | 15.5 | 17.5 | 1.9 | 2.5 |
| Other Western Europe | 14.5 | 16.0 | 17.0 | 2.0 | 1.2 |
| Eastern Europe | 17.3 | 18.0 | 21.0 | 0.8 | 3.1 |
| South America | 28.7 | 40.5 | 48.0 | 8.2 | 3.7 |
| Oceania | 6.5 | 7.0 | 7.5 | 1.5 | 1.4 |
| World Total | 652.2 | 722.5 | 795.5 | 2.1 | 1.9 |

Source: IISI, October 1997. Note: Steel products mean semi-finished and finished products.

- World-wide demand is projected at 722.5 million in 2000 and 795.5 million in 2005, indicating a steady average increase of around 2% per year from the 652.2 million tons in 1995.

- Demand in the Middle East is predicted to increase from 9 million tons in 1995 to 12 million tons in 2000 at an average rate of 5.9%. Demand will continue to grow after 2000 at an average rate of 3.9%, reaching 14.5 million tons in 2005.
- In the case of Asia, major growth in demand will continue, particularly in the case of China which is predicted to show a high growth rate in steel demand of 6.5% per year from 1995, reaching 120 million tons in 2000. China's demand will continue to grow after 2000 at an average rate of 3.9%, reaching 145 million tons in 2005. The rest of Asia (excluding China and Japan) will show a major increase in demand at 137 million tons in 2000 and 165 million tons in 2005.
- In the case of the Middle East, overall share of world steel demand will increase; however, this will still remain small at 1.8% in 2005. Other Asian countries (excluding China and Japan) are predicted to experience large growth in steel demand, increasing 19% by 2000 and 20.7% by 2005. The entire Asian region including China and Japan will account for 49%, or nearly half, of all steel demand world-wide in 2005.

Supply and demand forecast in regions around Oman is discussed in detail as follows.
The Middle East region overall experiences excess steel demand, in other words a shortage of supply. In the future, it is predicted as shown in Table 4-4-1 that demand will grow at an annual rate of 4-6%. Behind this high rate of increase is the fact that many of the countries in the region are petroleum producing countries aggressively pursuing development plans to expand domestic employment opportunities, establish industries outside the petroleum sector, etc. in light of high population growth rate and eventual depletion of oil resources. This trend is particularly evident in the case of the Gulf countries. Excluding Oman, the present situation of steel demand in the other five GCC countries is indicated in Table 4-4-3.

Table 4-4-3 Production, Demand and Imports of Steel in GCC 5

(Unit: 1000 tons)

| Item | Steel Consumption | | | Steel Production | | | Steel Product Imports | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 | 1994 | 1995 | 1996 |
| Saudi Arabia | 3,435 | 3,596 | 3,519 | 2,082 | 2,283 | 2,278 | 1,459 | 1,835 | 1,985 |
| UAE | 1,732 | 1,857 | 1,653 | 96 | 96 | 90 | 1,641 | 1,764 | 1,580 |
| Kuwait | 514 | 533 | 721 | 2 | 2 | 24 | 513 | 532 | 702 |
| Qatar | 162 | 398 | 334 | 604 | 601 | 601 | 87 | 214 | 217 |
| Bahrain | 112 | 112 | 118 | 0 | 0 | 0 | 121 | 114 | 119 |
| Total | 5,955 | 6,496 | 6,345 | 2,688 | 2,886 | 2,903 | 3,821 | 4,464 | 4,603 |

Source : GOIC Data Bank

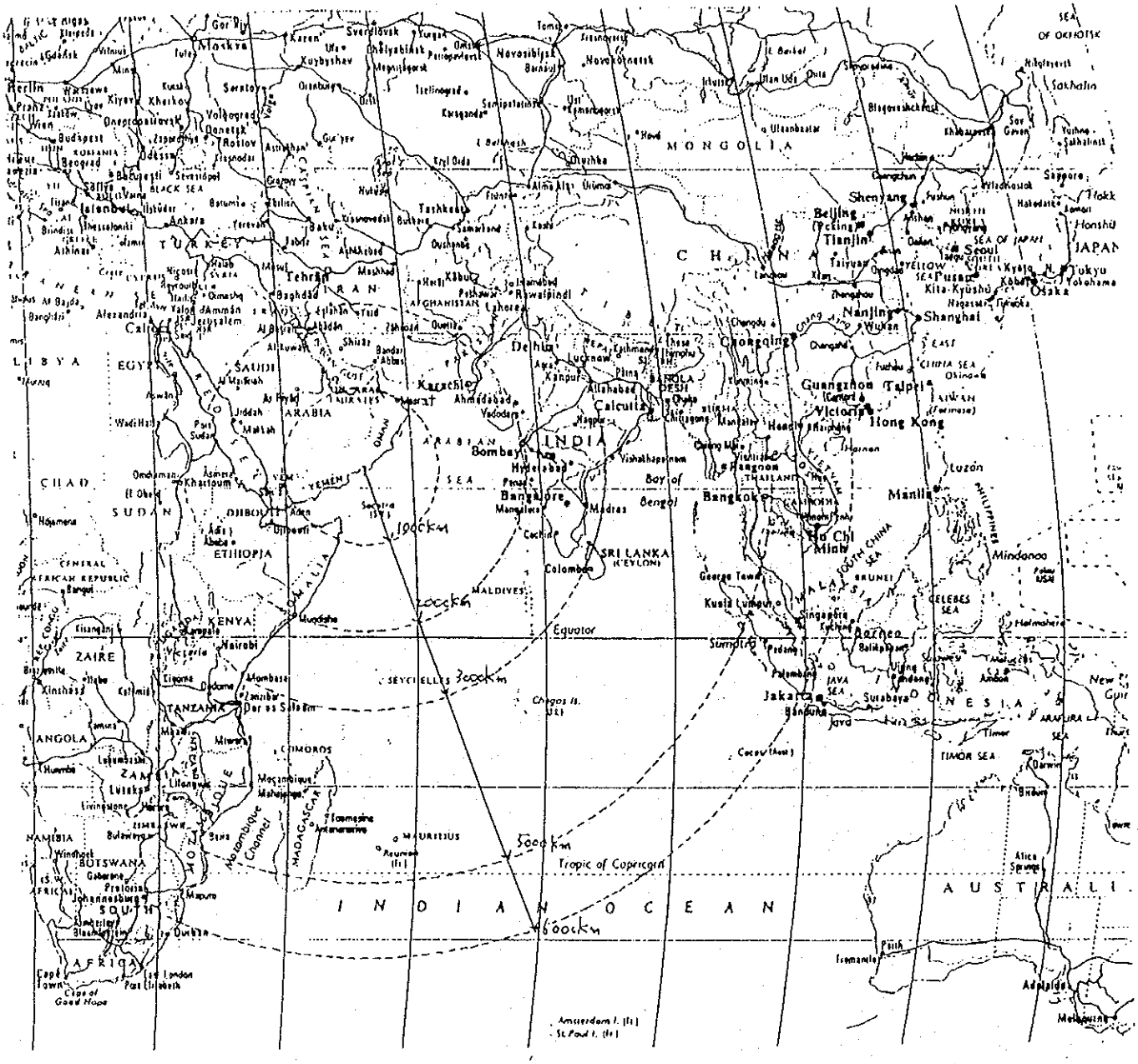



Figure 4-4-1 Map of Countries around Oman

Major steel production projects planned for the future in the GCC countries are shown in Table 4-4-4.

Table 4-4-4 Future Planned Steel Projects in GCC Countries

(Unit : 1000 tons)

| Country | Company | Product | Capacity | Start of operation |
|---|---|---|---|---|
| Saudi Arabia | Hadeed | Sheets | 850 | 1999 |
| | Universal Metal | Colored Sheets | 120 | 1998 |
| | Attieh Steel | Colored Sheets | 90 | 1998 |
| UAE | | Bars | 500 | 2000 |

Source : Metal Bulletin, Japan Iron & Steel Exporters' Association

Of the above, the executing enterprise for the UAE bar project has yet to be determined, and whether or not it will be implemented remains in flux. Its realization will ultimately depend on factors of funding and profitability. Steel projects in other parts of the Middle East include plans for expansion of facility production capacity by 1.6 million tons in Iran and 1.4 million tons in Egypt by 1999. In both cases these are production of flat steel products.

In terms of supply and demand balance by products, bar & wire rod production is expected to exhibit significant shortage in the future. On the other hand, the prevailing view is that flat steel production in the Middle East after 2000 as a result of production capacity increase in Saudi Arabia, Iran and Egypt, although still insufficient, will move much closer to being able to meet the demand of the region.

The main countries in East Africa are Kenya, Tanzania and South Africa. Total imports of steel products in 1994-1996 in these countries are as little as 600,000-700,000 tons. On the basis of these trends to date, little change in steel supply and demand in this region is anticipated in the future.

Among the South Asian countries, supply and demand behavior in the case of India which is relatively developed on steel industry will be a key factor in overall regional trend. Indian steel imports which shares 65-70 % of total of the South Asian countries are about 200,000 tons of long products and 1,500,000 tons of flat products. Volume of Indian long product import is small.

In the case of the ASEAN-5, shortage of steel production is large. So a number of steel production projects have been planned in the region. However, almost all of these have been abandoned due to the monetary crisis of 1997 and subsequent economic instability affecting these countries.

### 4.4.3 Future priority products in the Oman export market

In terms of the potential steel export market for Oman, the following can be concluded specifically in the case of bar & wire rod and flat products.

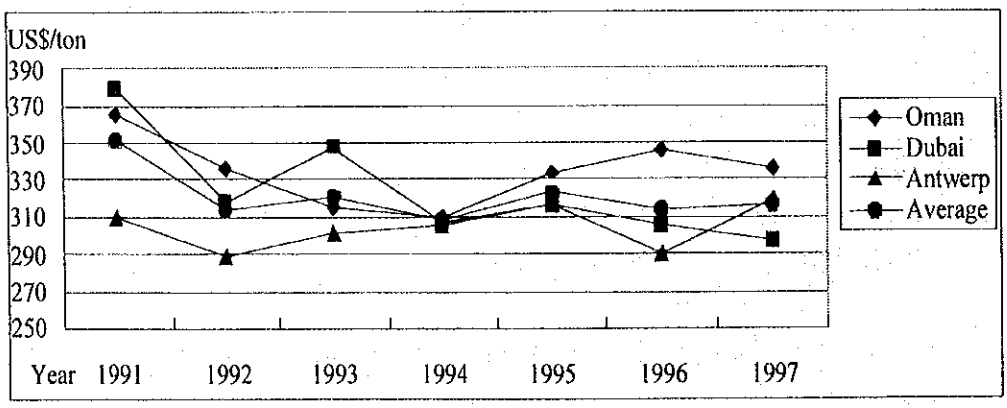
In the case of export markets relatively close to Oman including the other five GCC countries and nearby Middle East, bars & wire rods are more attractive products for the future than flat products. If consideration of export market is expanded to encompass the Asian region including ASEAN-5 and China, flat products are the more attractive product due to these large market. However, this would result in head-to-head competition with high quality steel produced by blast furnace manufacturers in Japan, Korea and Taiwan, as well as cheap flat products produced in the former Soviet Union.

In consideration of the above, bars & wire rods are deemed the most advantageous product in terms of export potential, under a new steel project in Oman.

## 4.5 Market Price of Bars

Most of domestic bars in Oman are actually supplied by the imports. 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.

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




Source : Oman and Dubai are from these Custom Statistics. Antwerp is from "Metal Bulletin".
Note : Based on CIF. Average is among Oman, Dubai and Antwerp.
Antwerp * is added freight. Bar is based on re-bar.

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 Figure 4-5-1.

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 Market for Bars of Oman

### 4.6.1 Domestic target market

The market for bars in Oman is almost all construction related. The overall construction sector comprises such building construction as housing, general building and factory, and civil works for infrastructure and utility structures including roads, port facilities, power stations, etc. Accordingly, focus in terms of domestic market must be given to the infrastructure and utility sector centering on national projects. A regional development program is being pursued under the Fifth Five Year Plan. Region-wise investment and gross capital formation under the program are collated in this plan. From these data, target regions are Muscat, Al Batinah, Ahd Dhaira, Ad Dakhliyay and Ash Sharqiyah.
Accordingly, it is concluded that these regions in all probability will comprise the major domestic markets for bars.

### 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 4-6-1.

Table 4-6-1 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 as follows with particular attention to volume of imported steel products around Oman and transport distance from Oman, etc.

- 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.

Table 4-6-2 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.

# 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 main production facilities as shown in Figure 5-1-1 "Process Flow of Steel Complex".

## 5.2 Product Mix

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.

## 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".

## 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 : 1,200,000 $m^2$ (800 m x 1,500 m)

(2) Natural gas

- 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)

(3) Electricity

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

(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 $m^3/h$

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.

The recommendable specification for the port/port facilities is 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

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".

(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.) |

## 5.5 General Layout

The preliminary layout of the Steel Complex is shown in 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 |

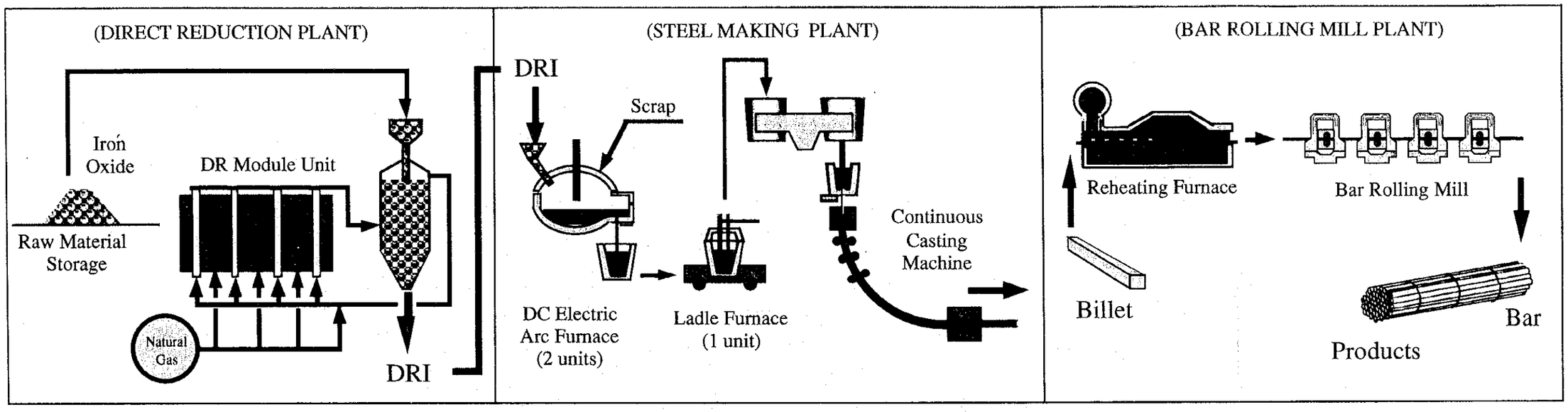
Table 5-6-2 Natural Gas Energy Consumption of Major Plants/Facilities

| 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 |

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) |




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

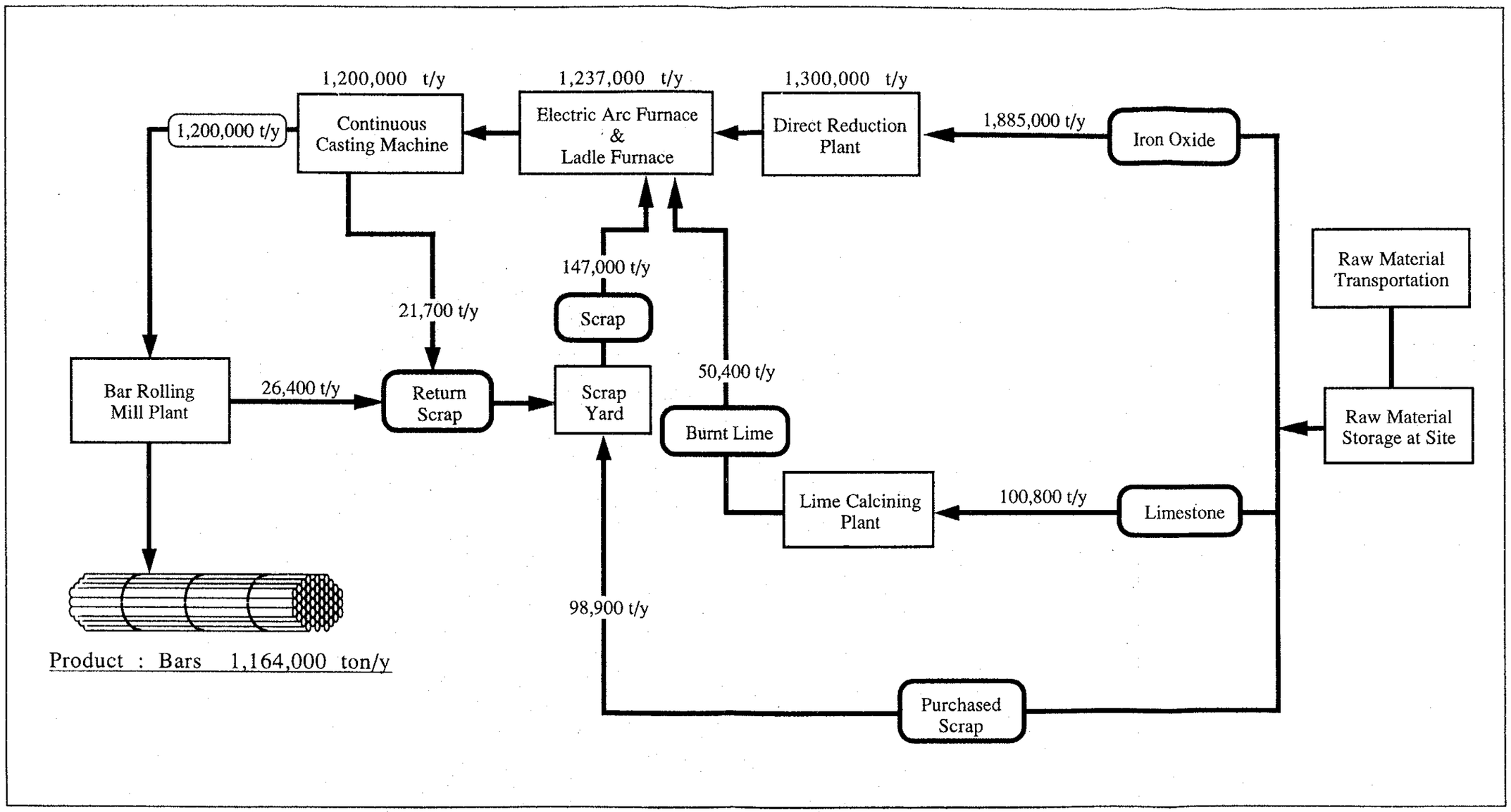



Figure 5-3-1 The Steel Complex Material Flow and Balance Sheet

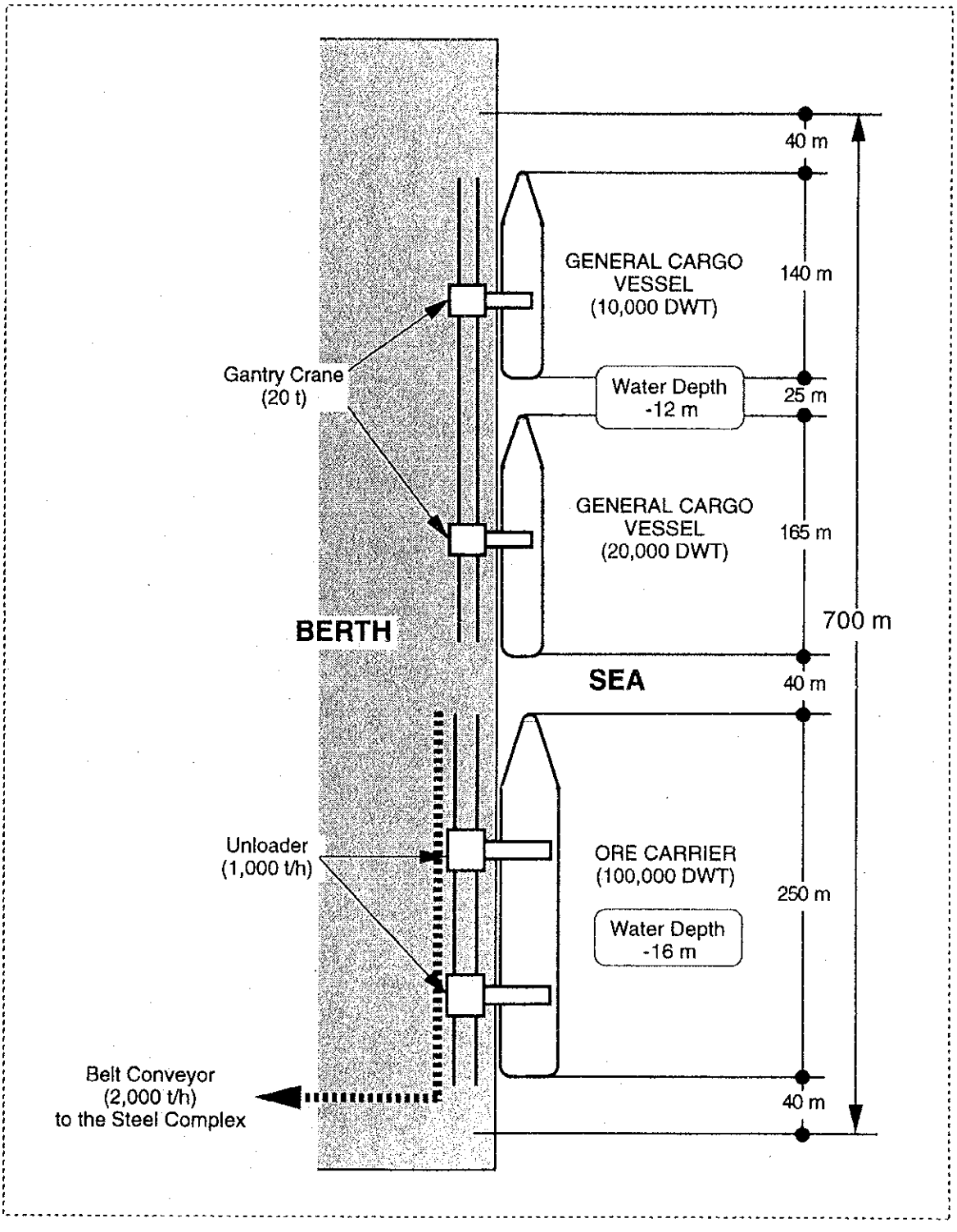



Figure 5-4-1 General Layout of Port Facilities

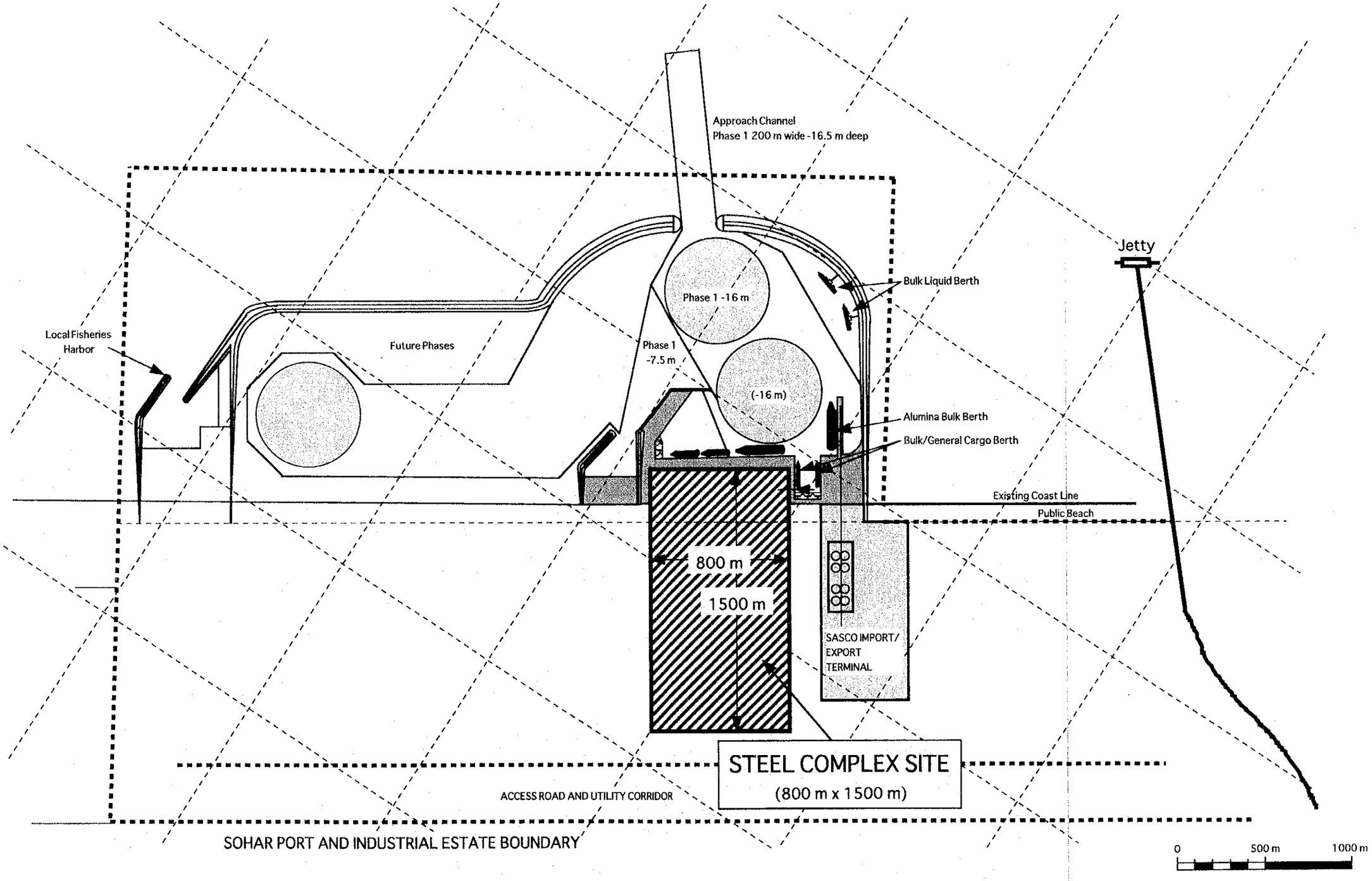



Figure 5-4-2 Sohar New Port Plan and the Steel Complex Site

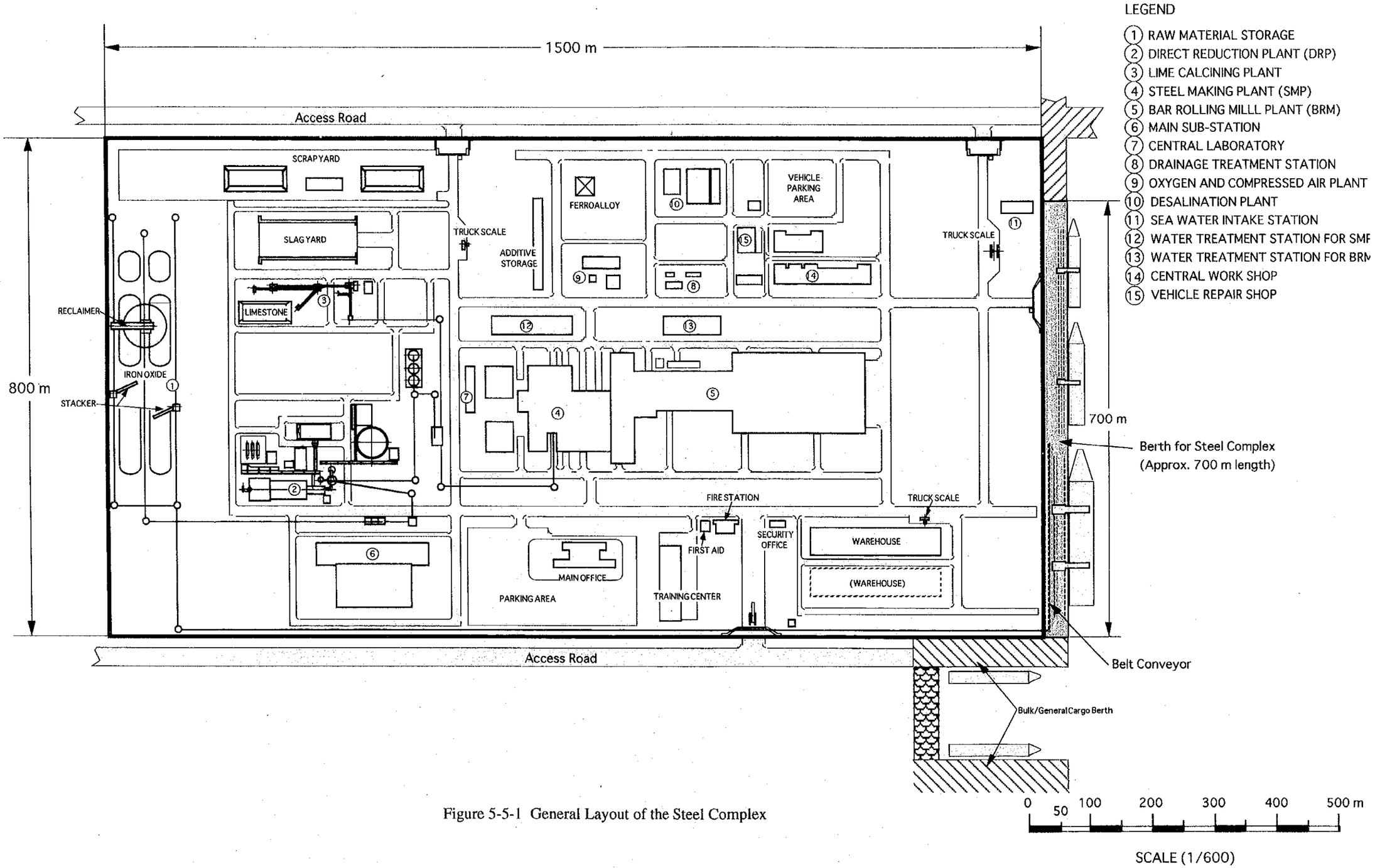



Figure 5-5-1 General Layout of the Steel Complex

# Chapter 6. APPLICABLE TECHNOLOGY FOR THE STEEL COMPLEX

## 6.1 Raw Material Handling Facilities

As import 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.

## 6.2 Direct Reduction Plant

### (1) Applicable process for direct reduction plant

Of the steel making processes by gaseous direct reduction - the EAF route presently occupies the second largest share of steel making operations in the world. Among those gaseous direct reduction processes, the following are the representative processes industrially proven or commercially available.

- 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<br>Lump | Pellets<br>Lump | Fines<br>(Size: sinter feed) | Fines<br>(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 *<br>(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 by 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.

(2) Outline

Basically, the direct reduction plant (DRP) for the Steel Complex is to adopt the MIDREX

Megamod® gas based direct reduction plant. Rated annual production plan is 1,300,000 tons of direct reduced iron per 8,000 hours.

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 %

The design base of the raw materials for DRP is 1,920,000 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;

(a) Oxide pellets : 100 - 70 wt %
(b) Lump ore : 0 - 30 wt %

(3) 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 $m^3$

(4) Plant description

DRP comprises of the process systems such as a reduction system, a reforming system, a process gas system, a heat recovery system, a seal gas and purge gas system, an emergency inert gas system, a material handling system, a water system, a fire fighting system and a dust collection system.

(5) General layout

Figure 6-2-1 attached hereinafter shows a preliminary general layout of the Direct Reduction Plant.

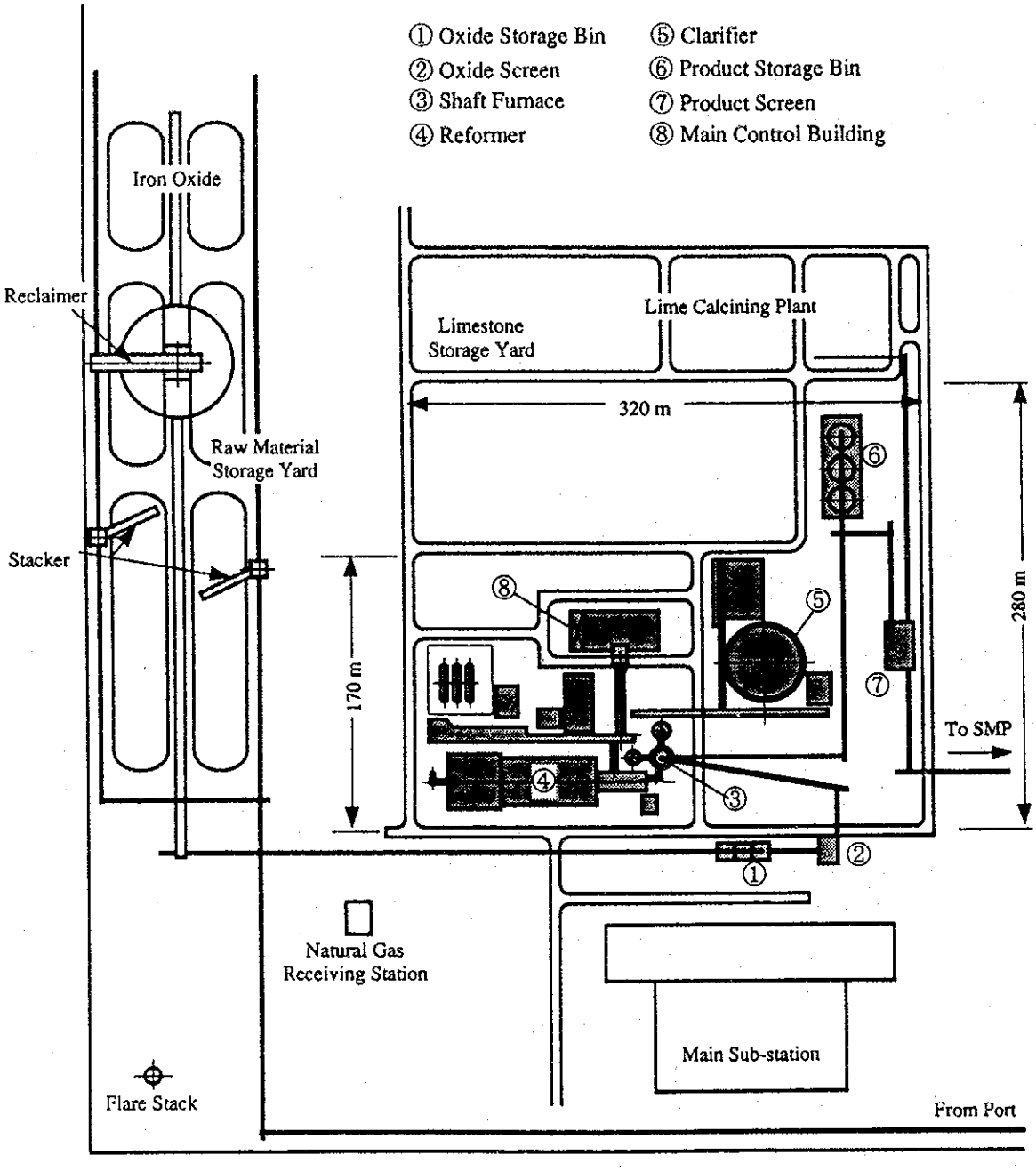



Figure 6-2-1 General Layout of the Direct Reduction Plant

## 6.3 Steel Making Plant

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

(1) Production:

Molten steel (MS) : 1,237,000 t/y = 150 t/heat x 13.3 heat/d x 310 d/y x 2 furnace

Billet (BT) : 1,200,000 t/y = 1,237,000 t/y x 97.0 %

(2) Products : Billet of 150 mm square x 16 m long

(3) Facilities:

Electric arc furnace (EAF)

| | |
|---|---|
| Type and numbers | : DC type x 2 |
| Capacity | : 150 t excluding 30 t of hot heel |
| Transformer | : 88 MVA |
| Raw materials | : DRI/scrap ratio = 90/10 |
| Tap-to-tap time | : 108 min. |

Ladle furnace (LF)

| | |
|---|---|
| Type and numbers | : AC (Alternating Current) type x 1 |
| Ladle capacity | : 150 t |
| Transformer | : 22 MVA |
| Operation time | : 20 - 40 min. |

Billet continuous casting machine (BT-CCM)

| | |
|---|---|
| Strand and numbers | : 8 st x 1 |
| Billet size | : 150 mm square x 16 m long |
| Casting speed | : 2.2 m/min., max. 3.0 m/min. |
| Casting time | : 49 min. |

Others

Handling facilities

Fume extraction facilities

Cranes

Electrical equipment, computer system and instruments

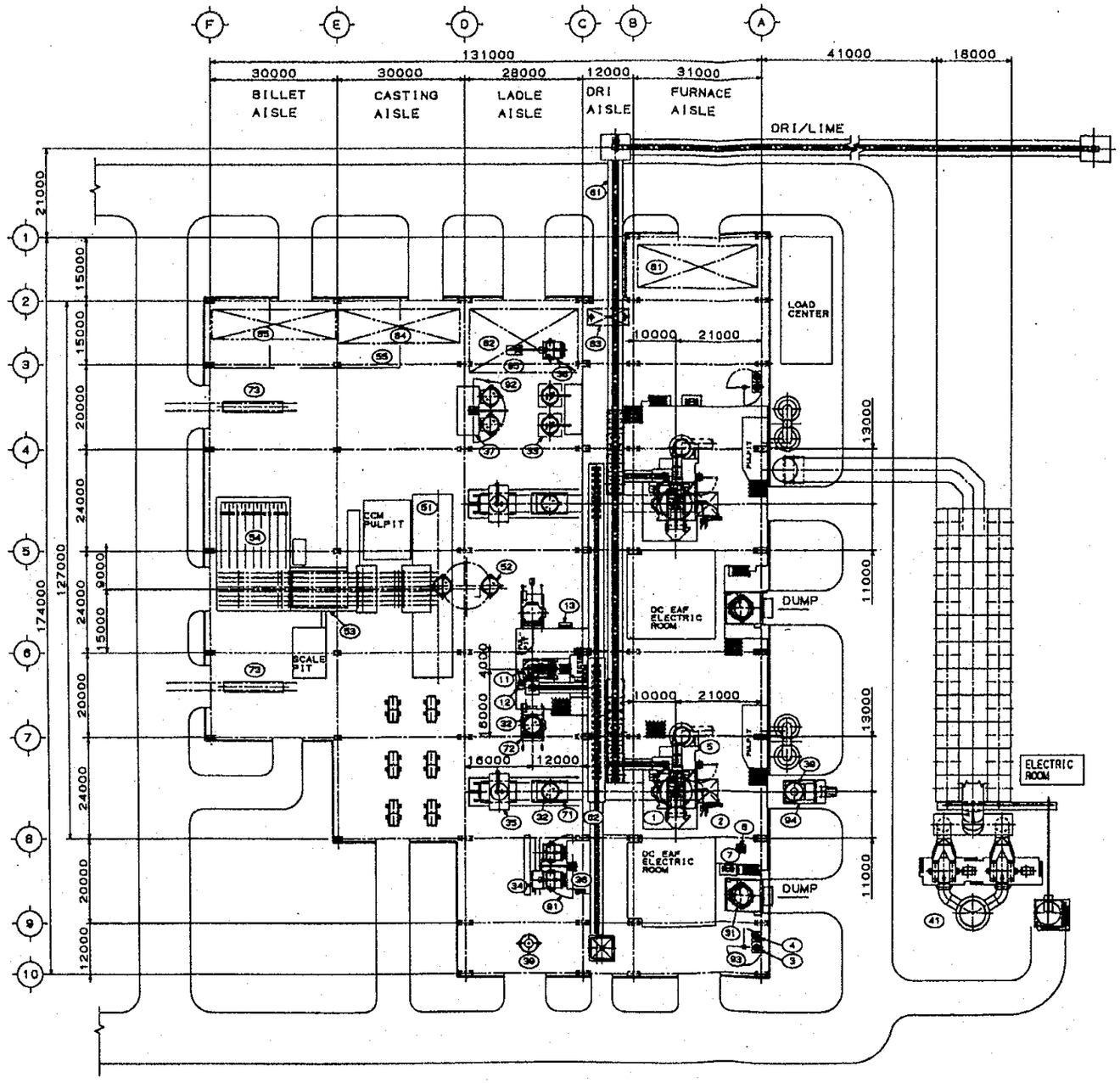
(4) Operating shift: Three shifts operation by four crews.

(5) Personnel: 267

(6) General layout: Figure 6-3-1

REVISION

| DESCRIPTION | SIGN | DATE |
|---|---|---|
| △ | | |




| 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) | 18m³ 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 | |

Figure 6-3-1 General Layout of Steel Making Plant



| | |
|---|---|
| JOB NO. | CUSTOMER |
| APPROVED | PROJECT |
| CHECKED | |
| CHECKED | TITLE: FIGURE 6-3-3 GENERAL LAYOUT OF STEEL MAKING PLANT (PLAN) |
| DESIGNED | |
| DRAWN | |
| DESIGN SECTION: IRON & STEEL ENGINEERING DIV. | SCALE: 1:800 |
| NKK NKK CORPORATION | DWG NO: AJ-0110-P80-01 △0 |

## 6.4 Bar Rolling Mill Plant

### (1) Outline

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.

### (2) Production plan

1) Production : About 1.2 million tons per year
   (i.e. 1,164,000 tons/year)
2) Products : Concrete reinforcing steel bars
   - Size of products : D10 to D32 (as deformed bars in straight form )
3) Initial material : Cast billet (from the continuous billet casting machine)
   - Section : 150 mm sq.
   - Length : 16,000 mm
4) Size-wise product mix for 1,164,000 tons per year
   Refer to Table 6-4-1.

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 | |

(3) Production capacity

a) Operational shift system : 3 shifts' operation by 4 crews
b) Available rolling hours (Tr) : 6,210 to 6,624 (h/y)
c) Average expected rolling rate (Pe) : 191.7 (t/h)
d) Production capacity (P = Tr x Pe) : 1,190,000 to 1,270,000 (t/y)

(4) Plant description/facilities

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

The basic plant parameters have been planned as follows;

1) Type of mill : Full continuous type mill, applying a high speed and slit rolling process for the smaller size bars
2) Number of rolling strands : One strand rolling at the fixed pass line, excepting the finishing stands in case of slit-rolling
3) Billet reheating furnace : Walking beam type furnace of max. 210 t/h
4) Number of mill stands : 22 in total
5) Max. rolling speed
   - For slit rolling : 25 m/sec (for slit rolling)
   - For non-slit rolling : 18 m/sec (for non-slit rolling)
6) Bar cooling bed : Two lines of walking beam type cooling bed facilities
7) Cold shear : Two lines of down-cut type cold shear facilities
8) Bar finishing line : Two lines of bar finishing facilities

(5) General layout

Refer to Figure 6-4-1.

(6) Personnel

Total personnel in BRM is 278.

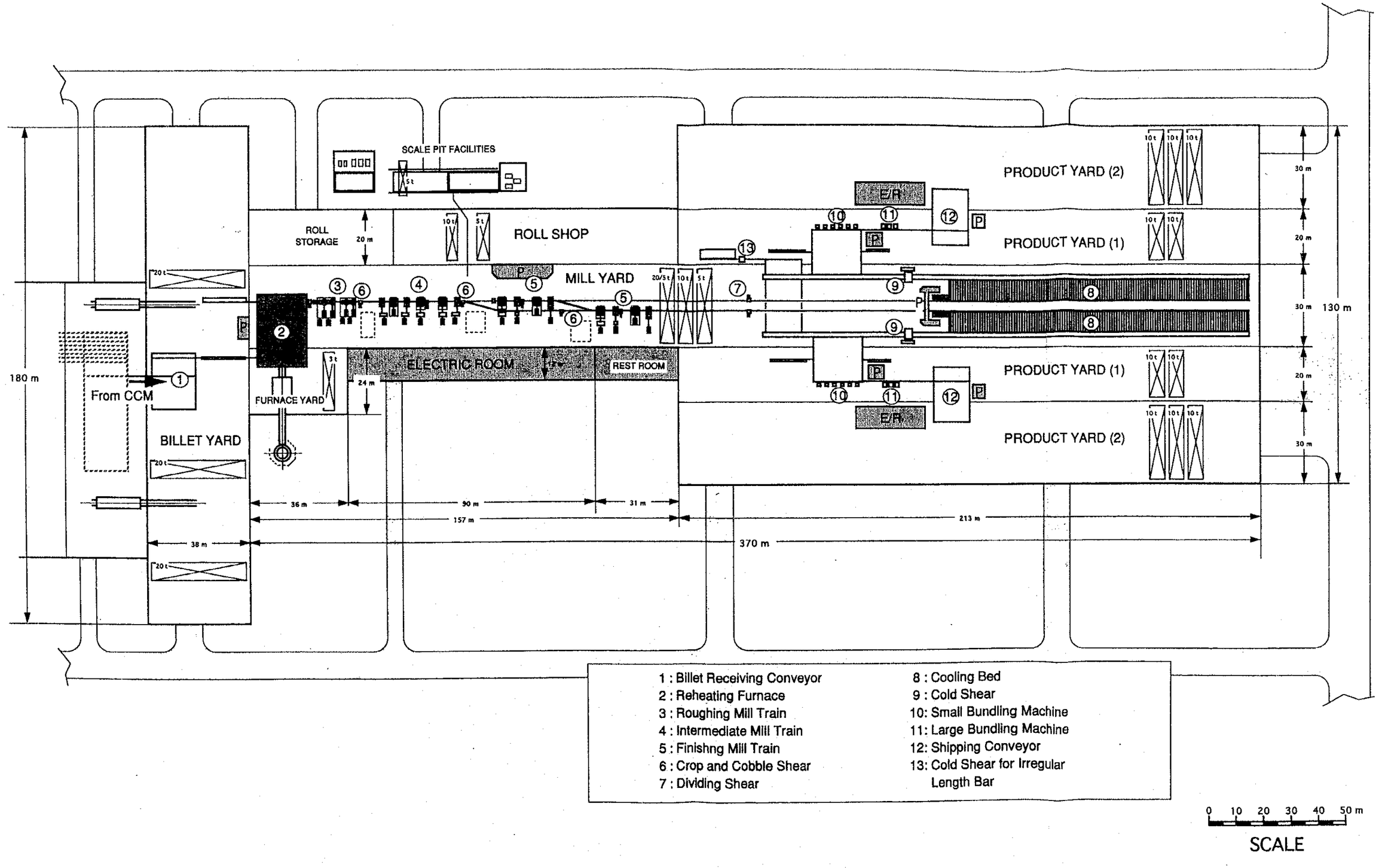



Figure 6-4-1 General Layout of Bar Rolling Mill

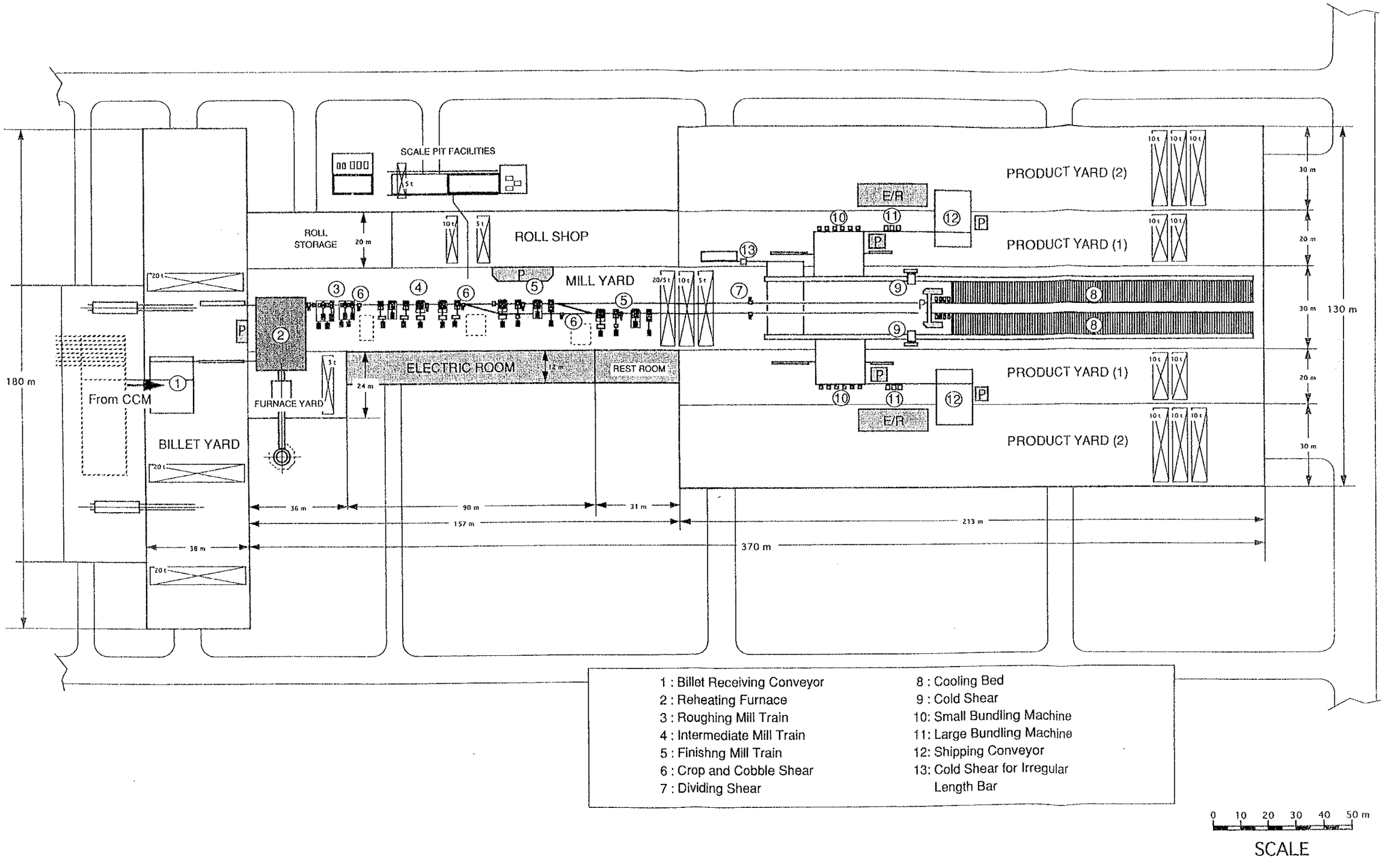



Figure 6-4-1 General Layout of Bar Rolling Mill

## 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 $Nm^3/t$

## 6.6 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 load) 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 power demand

The estimated 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 purpose. 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 Drawing list

(1) Single line diagram for 132kV and 33kV system

Refer to Figure 6-6-1

(2) Layout of substation

Refer to Figure 6-6-2

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 |

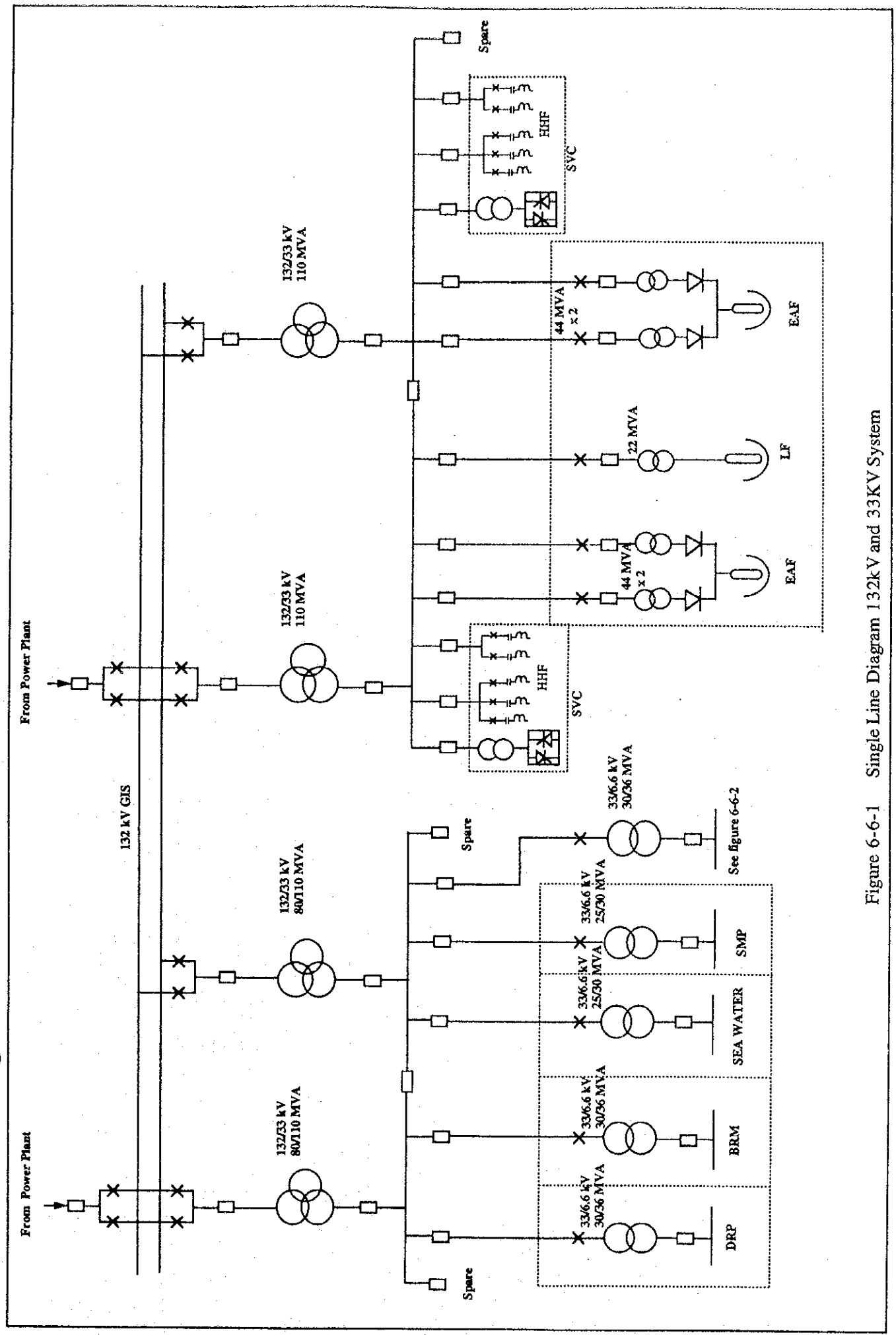
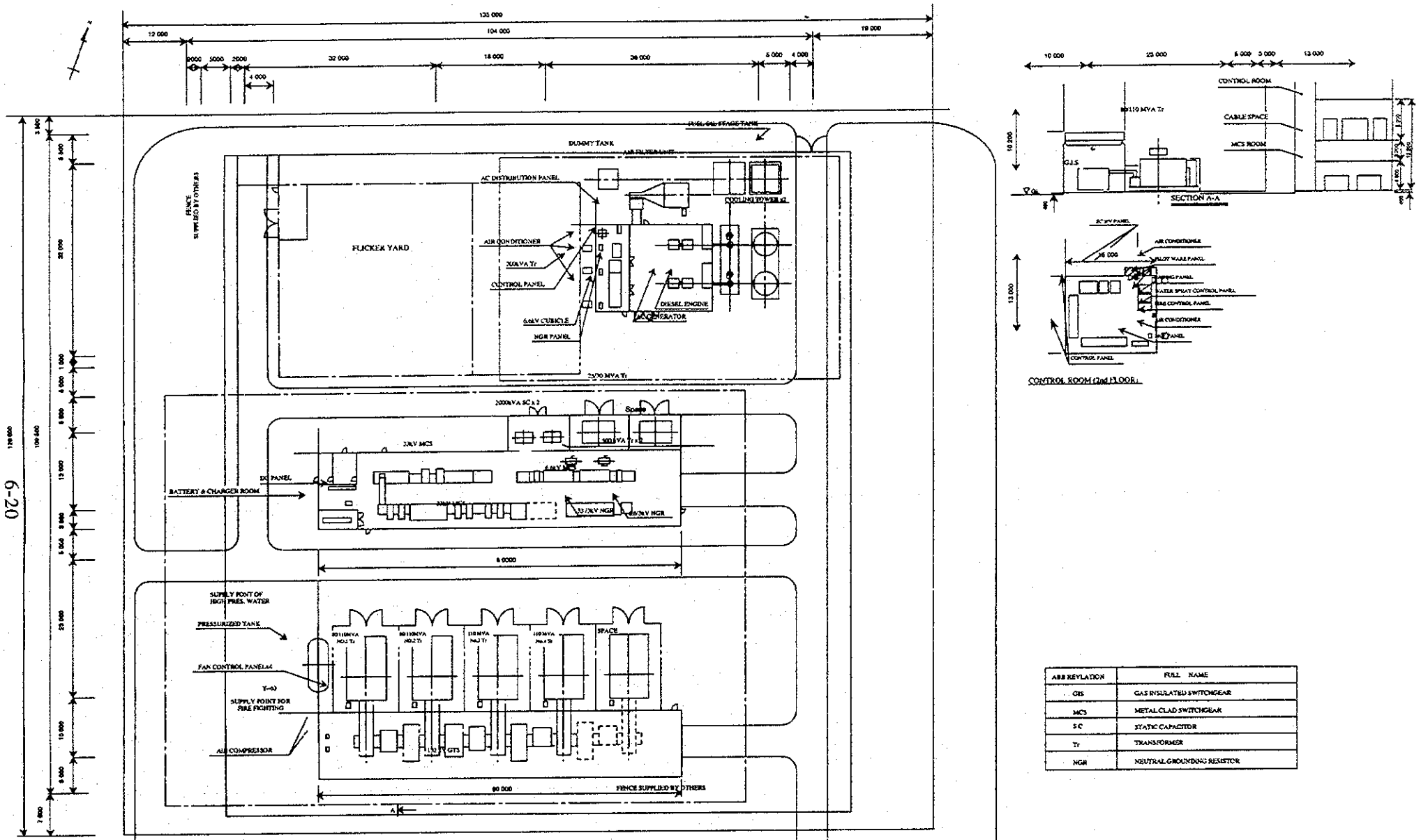



Figure 6-6-1 Single Line Diagram 132kV and 33KV System




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

Figure 6-6-2 Layout of Sub-station

## 6.7 Utilities

The plant utilities will consist of natural gas, oxygen gas, nitrogen gas, plant air, industrial water, potable water, cooling water, sea water, waste water, sewerage water, fire hydrant and yard piping.

(1) Natural gas

Natural gas from the government gas control system located next to the Steel Complex will be received at the battery point in order to meet the requirements of the Steel Complex and will be supplied to each plant through a pipeline.

(2) Oxygen gas, nitrogen gas and plant air

Oxygen gas, nitrogen gas and plant air will be generated by an air separation plant and an air compressor plant installed in the Steel Complex.

(3) Industrial water and potable water

Industrial water and potable water will be supplied from the desalination plant installed in the Steel Complex. Potable water will be supplied directly through pipeline to consumers by pumps which are installed in the desalination plant.

Industrial water will be received at the raw water reservoir and stored. Most of the industrial water will be supplied as make-up water for the cooling water system of each process.

Industrial water will also be supplied to the fire hydrant system from the reservoir.

(4) Cooling water

In order to reduce consumption of industrial water, closed-type recirculation system and change to other cooling medium such as sea water and air will be employed.

Here, to see the advanced situation for utilization of water, a water recovery ratio (WRR) has been employed.

Water recovery ratio (WRR)

= {( Recycled quantity - Make-up water quantity)/( Recycled quantity)} x 100

Water recovery ratio (WRR) in this conceptual plan is calculated and results is as follows:

WRR = (14,246-189)/14,246 = 98.7 %

Some steelworks in Japan have maintained a WRR of 95-96 %.

As seen from the above, the conceptual plan has already exceeded this advanced level.

(5) Sea water

Sea water will be fed from Sohar port. The sea water intake system to be located at the raw material berth will consist of a bar screen, a drum screen, circulation pumps, chlorination equipment and electrical equipment.

Sea water will be pumped by circulation pumps and delivered to the Steel Complex through a pipeline. Sea water will be used as a cooling medium in the Steel Complex and then discharged outside the breakwater.

(6) Waste water

Waste water from the water recirculation system will be quite little and waste water from the Steel Complex will be almost the same as the sea water explained above quantitatively and qualitatively.

(7) Sewerage water

Potable water will be used for drinking, washing, in the canteen, etc. and discharged as live sewerage.

Live sewerage will be gathered by the pumping station located in each office and plant and transferred to the sewerage water treatment station in the Steel Complex.

The treated water will be re-used in the Steel Complex for plantation and slag cooling.

(8) Fire hydrant

The fire hydrant supply system located in the raw water receiving station will supply water to the outdoor fire hydrant system all the time as per the requirements of NFPA.

(9) Yard piping system

A yard piping system will connect supply systems, plants, recirculation system and discharge systems.

Pipelines will generally be installed on a pipe rack for easy maintenance.

Pipelines for potable water, waste water and fire water main will be laid underground.

## 6.8 Maintenance Shop

Maintenance shop consists of machine shop, overhaul and assembling shop, steel frame shop, electrical repair shop and vehicle repair shop.

In order to maintain all the plant equipment, periodical repair, major repair and emergency repair are required. For the purpose of smoothly achieving maintenance work, Maintenance & Utilities Department consisting of Mechanical maintenance section, Electrical maintenance section, Utilities section and Maintenance coordination section will be organized to take charge of all the maintenance work.

## 6.9 Analysis and Inspection Facilities

Analysis and inspection facilities will be installed for the Steel Complex and be used for carrying out quality control work including routine analysis of DRI, molten steel, cast billets, and finished products.

The analysis and inspection facilities will consist of two groups of equipment: one for analysis needed for the steel making process and raw materials and the other for physical and metallurgical inspection of semi-finished and finished products. The first group of equipment will be installed in a building (called the analysis center) to be constructed beside the steel making plant. The other group of equipment will be installed in a building (called the material testing center) to be constructed beside the BRM building.

The system and equipment will be installed to eliminate individual difference among operators and also to avoid as much as possible complicated manual measuring so that stable analysis and inspection results will be obtained.

## 6.10 Transportation Facilities in the Steel Complex

Transportation facilities in the steel works include transporting and storing of scrap, limestone, additives, refractories, electrodes, slag, mill scale, waste materials and others required for keeping the production of approximate 1,200,000tons per year of bar products.

The facilities of intra-works transportation cover the following:

1) Movable equipment such as crawler crane, crawler shovel, wheel shovel, forklift, etc. for unloading and loading

2) Transportation equipment such as dump truck, flat deck truck, slag pot carrier, etc. for transportation
3) Warehouse for brick, electrode, additives and spare parts
4) Scrap yard for storage and preparation of scrap
5) Limestone storage yard
6) Slag yard
7) Truck weighing equipment

## 6.11 Administration Facilities

The following administration facilities shall be considered.
The design and system of each facility shall be made in accordance with the international codes and requirements of local practice and regulation.

(1) Main office
(2) Training center
(3) First aid
(4) Security office
(5) Fire station
(6) Site offices for each facility
(7) Parking area and other

## 6.12 Civil and Building Work

Civil and building work will cover land preparation and all foundations and building items required for the construction and installation of the Direct Reduction Based Steel Complex facilities listed below, and the design basis shall be established in accordance with the relevant clause of the latest issue of international codes and standards and their equivalents.

(1) Land preparation including gate and perimeter fence
(2) Raw material storage facility
(3) Direct reduction plant facility
(4) Steel making plant facility
(5) Bar rolling mill plant facility
(6) Lime calcining plant facility
(7) Electric power and distribution facility
(8) Utilities
    1) Water treatment station

2) Natural gas receiving station

3) Water intake

4) Sewage treatment station

(9) Maintenance shop

(10) Analysis and Inspection facility

(11) Transportation facility

(12) Administration Facility

(13) Road and paving

(14) Drainage systems for storm water, waste water and sanitary sewage