1–4 Power Supply to Ferrochrome Plant and Local Electric Power Conditions

At a point approximately 6 Km from the size of the ferrochrome plant, there is the Er Roseires Hydroelectric Power Station, the largest facility in Sudan, from which the electric power will be supplied to the former.

The annual power production by the Er Roseires Hydroelectric Power Station stands at approximately 610 GWH as of 1981 as mentioned earlier. It is estimated that after the installation of the No.5 and No.6 units in/or after 1983, the capacity will be increased to 900 to 1,000 GWH. It is considered that it will not be a big problem to meet the abovementioned power requirements by the ferrochrome plant. However, as described above, the seasonal fluctuation of the Er Roseires power station's output is conspicuous. In addition, the power requirements by the general consumers show a significant growth. In view of this, it will be necessary to study in detail on the power supply during the peak hours of the critical months and at the same time, work out any remedial procedures to satisfy the power requirements under such circumstances.

1–5 Power Receiving Plan for Ferrochrome Smelting Plant

As mentioned above, as a result of our study on the power receiving method when the electric power is received from the Er Roseires power station, the following plan has been worked out considering the loss of power transmitted. That is, as to Case A, the electric power is transmitted to the smelting plant from the Er Roseires power station by means of 11 kV transmission line over a 6 km distance as indicated in Fig. 5-4. For Case B, the electric power is received via the switching station at 220 kV near the Er Roseires power station and then is transmitted to the smelting plant after it was dropped to 33 kV by means of transformer capable of 220/33 kV, 18,000 kVA as indicated in Fig. 5-5.

Transformers for the electric furnace and the electric motor will be installed as power receiving facilities for the ferrochrome plant.

1–6 Electricity Cost

As a result of the trial balance of electricity cost using the afore-listed tariff in the case of purchasing the electric power from PEWC, it was found that both Case A and Case B do not make much difference as seen from Table 5-9.

The trial balance of electricity cost is calculated herein based on 300 operating days per year with furnace downtime set for 65 days (June 28 through August 31) during which period electric power of 100 and 200 kW only are used. However it should be noted that in introduction of special rate can be considered for an customer having consumption in excess of current tariff, like a ferrochome plant.

Fig. 5-4 Single Line Diagram (Case A)

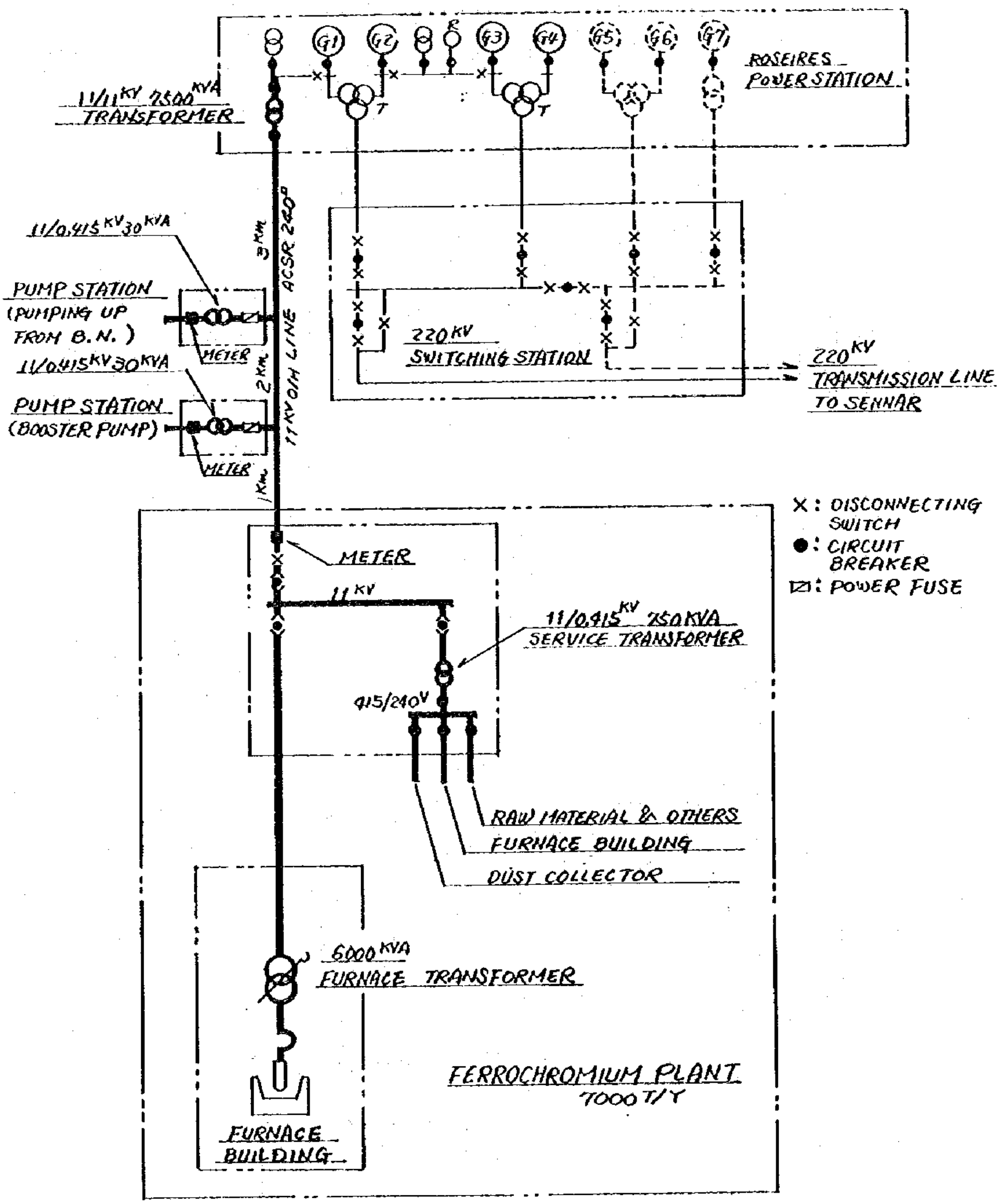


Fig. 5-5 Single Line Diagram (Case B)

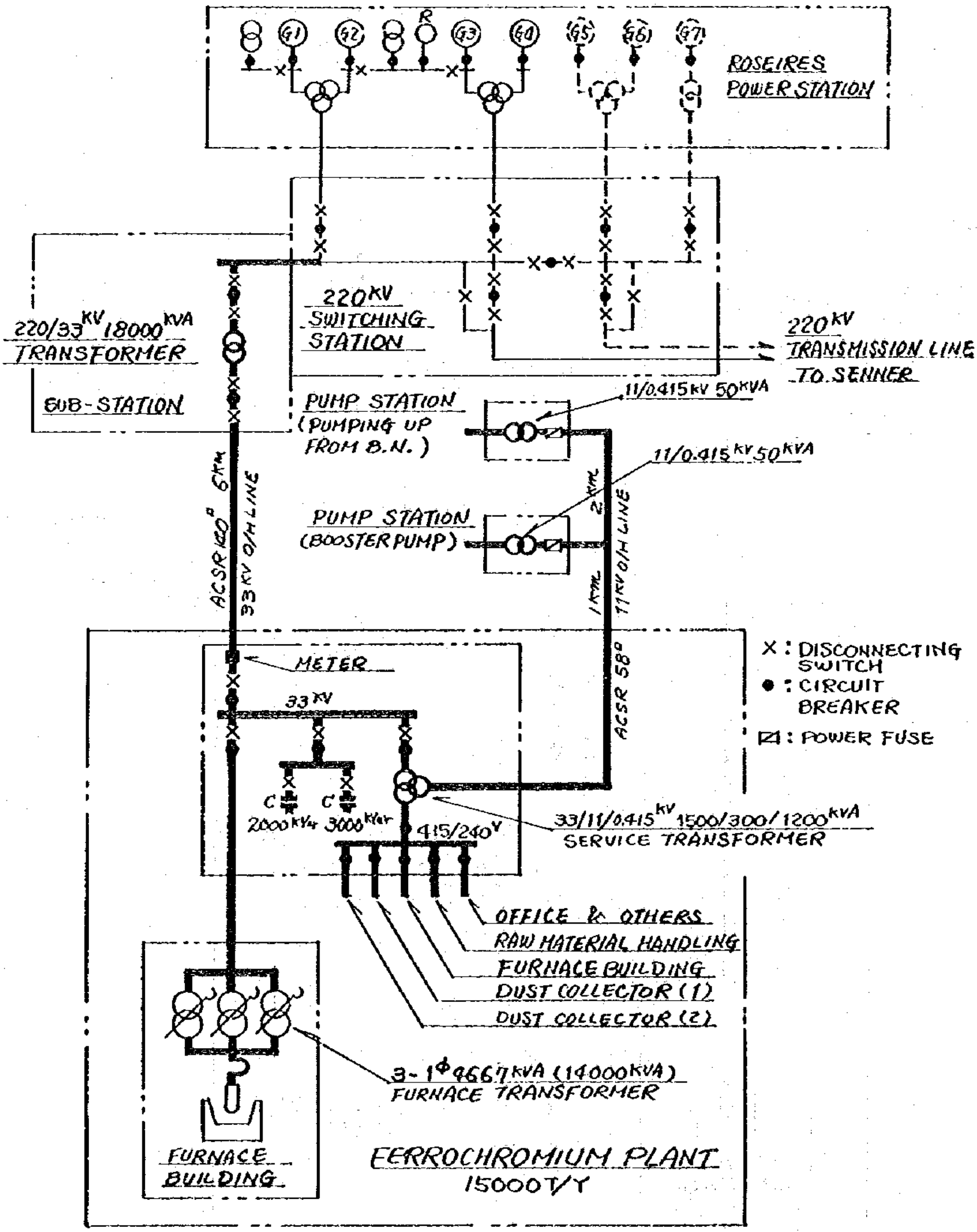


Table 5-9 Trial Balance of Electricity Charge for Ferrochrome Plant

(a) Case A (7,000 t/yr. production)

Service Capacity Charge	S£0.4 x 6,500 KVA x 12 months	= S£ 31,200.00
Demand Charge		
– Operation (10 months)	S£1.2 x 5,500 KVA x 10 months	= S£ 66,000.00
– Repair (2 months)	S£1.2 x 500 KVA x 2 months	= S£ 1,200.00
KWH Charge		
– Critical Season (Mar. 1 ~ Jun. 27) (operate)		
Peak hour	S£0.057 x 4,500 KW x 119 days x 11 hrs.	= S£ 335,758.50
Off-peak hour	S£0.025 x 4,500 KW x 119 days x 13 hrs.	= S£ 174,037.50
– Critical Season (Jun. 28 ~ Aug. 31) (repair)		
Peak hour	S£0.057 x 100 KW x 65 days x 11 hrs.	= S£ 4,075.50
Off-peak hour	S£0.025 x 100 KW x 65 days x 13 hrs.	= S£ 2,112.50
– Other Seasons (Sept. 1 ~ Feb. 28) (operate)		
Peak hour	S£0.0375 x 4,500 KW x 181 days x 11 hrs.	= S£ 335,981.25
Off-peak hour	S£0.0155 x 4,500 KW x 181 days x 13 hrs.	= S£ 164,121.75
TOTAL Payment per year		= S£1,114,487.00
Total Consumption in KWH		= 32,556,000
Unit Price per KWH		= S£ 0.0342329 (US $0.0433)

(b) Case B (15,000 t/yr. production)

Service Capacity Charge	S£0.4 x 15,000 KVA x 12 months	= S£ 72,000.00
Demand Charge		
– Operation (10 months)	S£1.2 x 12,000 KVA x 10 months	= S£ 144,000.00
– Repair (2 months)	S£1.2 x 500 KVA x 2 months	= S£ 2,400.00
KWH Charge		
– Critical Season (Mar. 1 ~ Jun. 27) (operate)		
Peak hour	S£0.057 x 10,000 KW x 119 days x 11 hrs.	= S£ 746,130.00
Off-peak hour	S£0.025 x 10,000 KW x 119 days x 13 hrs.	= S£ 386,750.00
– Critical Season (Jun. 28 ~ Aug. 31) (repair)		
Peak hour	S£0.057 x 200 KW x 65 days x 11 hrs.	= S£ 8,151.00
Off-peak hour	S£0.025 x 200 KW x 65 days x 13 hrs.	= S£ 4,235.00
– Other Seasons (Sept. 1 ~ Feb. 28) (operate)		
Peak hour	S£0.0375 x 10,000 KW x 181 days x 11 hrs.	= S£ 746,625.00
Off-peak hour	S£0.0155 x 10,000 KW x 181 days x 13 hrs.	= S£ 364,715.00
TOTAL payment per Year		= S£2,474,996.00
Total Consumption in KWH		= 72,312,000
Unit Price per KWH		= S£ 0.0342266 (US $0.0433)

2. Industrial Water

2–1 Outline of Industrial Water

(1) Blue Nile River

The Blue Nile originates in the Ethiopian plateau, flowing into Sudan and joining at Khartoum, the White Nile, which has its source in the lake and lagoon area of the East African plateau and flows into Sudan from the south. Then, the downstream of the confluence turns to the Nile River, penetrating Sudan, and finding its way into the Mediterranean after traversing Egypt.

The Blue Nile supplies approximately 4/7 of the water quantity of the Nile's main stream and as such is influenced by the Nile's floods. While the White Nile makes up the remaining approximately 3/7 and maintains almost the same flow throughout the year.

Usually the Blue Nile rises in June, reaching the peak level early September and hitting the bottom level in May after gradually subsiding. Approximately 60% of the annual flow runs during the two months of August and September. During the 6 months of the dry season (December through May), the flow amounts to only 7%. The estimated maximum flow is of 33 million tons/hour downstreams of the Roseires Dam. The estimated minimum flow is of 1 million tons/hour.

The projected ferrochrome plant requires industrial water for cooling the electric furnaces. Water will be taken in at a point approximately 4 km downstreams from the Roseires Dam for use as cooling water for the plant.

(2) Water quantity

The main purpose of industrial water is as cooling water. The water analytical value of the Blue Nile is shown in Table 5-10 and Table 5-11.

In the case of source water, turbidity and total hardness are the factors to be considered against required composition value as cooling water. It is said that turbidity reaches the values of 4,000 to 7,000 ppm at the time of floods. In order to reduce the value to a required level of 50 ppm, a settling pond and a filter device are necessary.

As to total hardness, the source water and treated water show approximately 100 ppm as against the demand value of 50 ppm. This value does not do any harm in practical use.

Therefore, in this project, we planned to use the water as industrial water after settling and removing suspend-solids in the source water.

Table 5-10 Water Quality of Blue Nile

		As of March 10, '59	As of Feb. 4, '60
Water Temperature (0°C)		27	27
pH		8.1	8.1
Dionic Reading		130	180
Total Dissolved Solids	(ppm)	135	140
Total Hardness	($CaCO_3$)	72	118
Total Alkalinity	($CaCO_3$)	90	120
Calcium	(Ca)	21	43
Magnesium	(Mg)	5	2
Silicate	(SiO_2)	10	15
Sulphate	(SO_4)	10	10
Chlorite	(Cℓ)	6	6
Nitrate	(N)	0.8	0.8
Ammoniacal Nitrogen	(N)	0.04	0.06
Albuminoid Nitrogen	(N)	Nil	0.32
Dissolved Oxygen		6.1	7.5
Biochemical Oxygen Demand		2.4	1.1

Remarks:
1) Water was sampled at a bridge across the Blue Nile between Damazin and Roseires.
2) Ammonia nitrogen recorded up to 0.06 ppm as N.
3) Albuminoid nitrogen recorded up to 0.32 ppm as N.
4) Calcium hardness recorded as low as 10 ppm as Ca but with corresponding increase in magnesium.

Source: Tender Estimate for Power Plant Vol. 2.

2–2 Water Intake Plan

In Damazin, service water for living is used in the residential area and it comes from the Blue Nile. For 9 months from June through September, the 200 mm dia. pipe is installed at a point 407 m above the sea level on the Roseires Dam, penetrating through the latter at the two places. Water is taken in through one of the places and supplied by natural head to a subtank in the booster pumping station located at a point 455 m above the sea level through the approximately 650 m long, 200 mm dia. piping. For 3 months from July through September, it is difficult to take in water because of plugging the intake holes on the dam with soil and sand. During this period, Water is supplied by means of a pump to the subtank from the Blue Nile approximately 400 m downstreams from the dam. The water level of the Blue Nile changes on every 10 m range so that the pump position is moving according to the circumstances. Water is supplied to a pool inside water treatment works approximately 3 km from the booster pumping station. The water treatment works are composed of source water tank, settlement tank, filter device and treatment tank (500 m^3). The treatment capacity is 800 m^3/day and the water supply is made to residents in the Damazin area. The price of service water for living is S£ 0.175/m^3.

There is a future plan to take in water from the unused 200 mm dia. hole on the Roseires Dam. This is for service water for living and, therefore, cannot be used as cooling water under the equipment plan. For this reason, separate water intake facilities were projected. Water will be taken in by submerged pump from a proximate place on the Blue Nile approximately 4 km downstreams from the Roseires Dam and supplied to a stock tank installed at the river bank. From this tank, water is fed by pump to the settlement tank inside the plant through piping.

3. Transportation

3–1 Roads

(1) Status quo of roads in Sudan and future plan

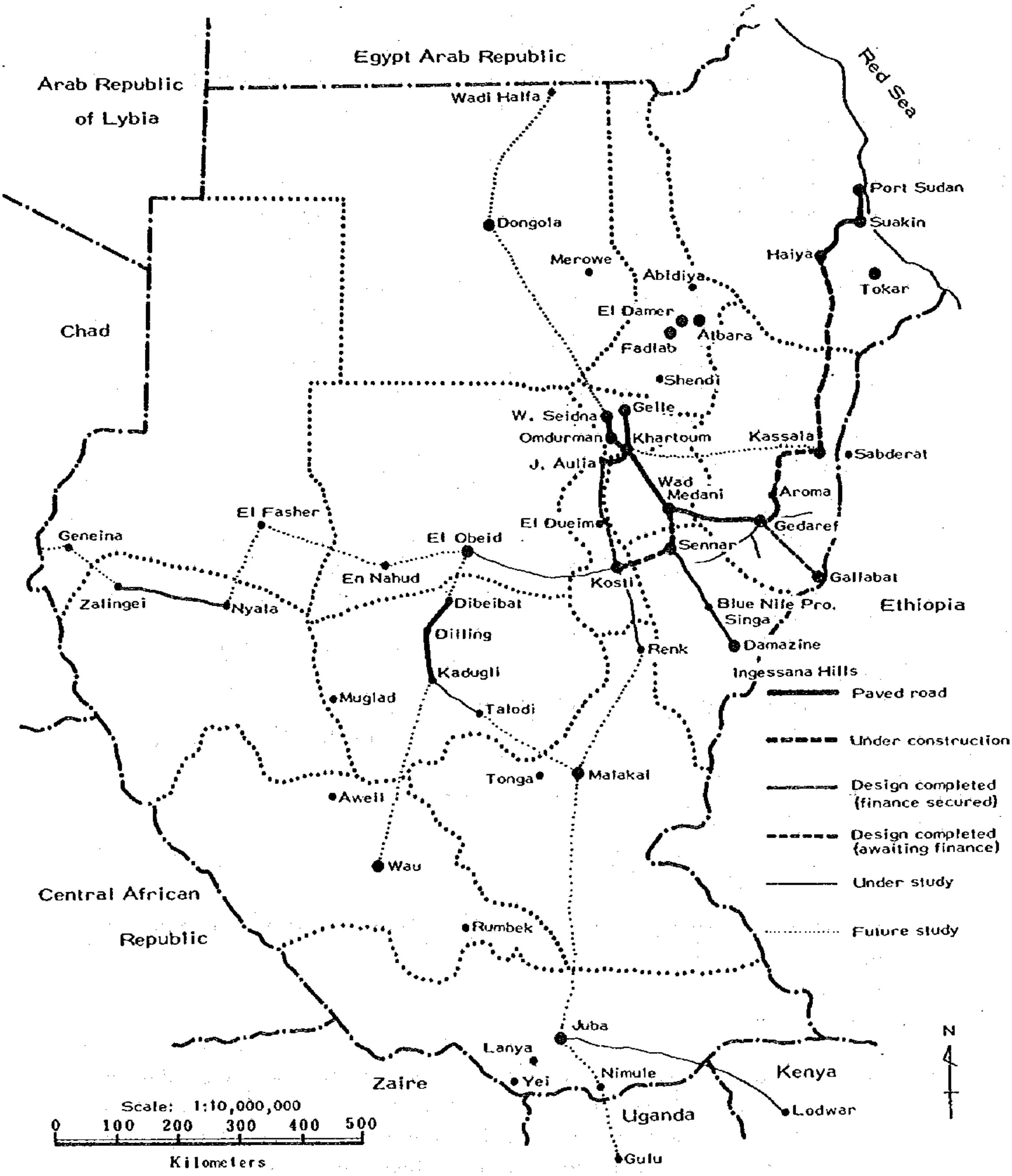
The Democratic Republic of the Sudan is a country which has the largest area (approximately 6.8 times as large as Japan) in Africa. However, the total distance of its paved roads is only about 1,500 km. On top of that, these roads are located only in the surroundings of Khartoum, the capital, and serve as routes linking Khartoum with Port Sudan, the sole port in Sudan. The other roads called "tracks" are primitive ways, extending 20,000 km. In addition, most of these roads almost do not allow passage of vehicles during 6 months of rainy season.

The route map in Sudan is shown in Fig. 5-6.

1) Existing roads (paved roads)

Name of Road	Distance (Km)
Khartoum North/El Kabashi/El Geile	42
Khartoum North/Jebel Aulia	36
Omudruman/Wadi Saidna	22
Khartoum/Wad Medani	187
Wad Medani/Gedaref	227
Gedaref/Kassala	217
Kassala/Haiya	350
Haiya/Suakin/Port Sudan	206
Ed Dibeibat/Dilling/Kadugli	186
Wad Medani/Senner	107
TOTAL	1,580

Fig. 5-6 Road map in Sudan



2) Roads under constructions (paved roads)

Name of Road	Distance & Description (Km)
Senner/Singa/Damazin	233
Nyala/Kas/Zalingei	210
Jebel Aulia/El Dueim	158
El Obeid/Ed Dibeibat	Only improvement
El Fasher/Nyala	217
El Dueim/Rabak	110
Reinforcing of Wad Medani/Khartoum Ondurman/Dongola	(83) Only improvement
TOTAL	928

3) Roads under study (roads under survey & designing)

Name of Road	Distance & Description (Km)
Kadugli/Talodi	90
El Geile/Sheudi	Under feasibility study
Juba/Kopoeta/Loduor	
(Sudan/Kenya, Total 580 km long of which 335 Km in Sudan side.)	
Kositi/Umm Ruwaba	Under feasibility study

Source: Road and Bridges Public Corporation.

(2) Composition of road network

The roads in Sudan are classified in the following two categories from a viewpoint of importance.

1) Trunk roads

These roads are important routes linking city with city or city with port or city with place for agricultural produce collection, etc. They are under the direct control of the central government which builds and maintains the roads. The responsible government agency is "Roads and Bridges Corporation".

2) Provincial roads

The roads serve as accesses to small cities off the trunk road or to the centers for collection of various products. Sometimes they are routes linking small cities with towns or villages under the control of the state government which builds and maintains them. Most of the provincial roads are "tracks" and sometimes are covered with gravel as improved roads. Of these provincial roads, access roads (feeder roads) to the turnk roads covering a distance of 400 km are now in the list of upgraded roads and will be improved under the Six Year Program.

(3) Structure of the road

All of the trunk roads are provided with two vehicle lanes. The paved roads are covered with asphalt. The standard road width is 10.0 m composed of 7.0 m asphalt-paved portion and a 3.0 m shoulder width (1.5 m x both sides). The asphalt thickness is 7 to 8 cm.

The limits to vehicle weight are 9.0 tons of axle load and the speed limits are 100 km/hour. In addition, the height limits are 4.8 m and the width limits 3.0 m.

When special cargo is transported, a police license is required. However, there are no tunnels on the road and all the bridges are open to traffic. But in the city area, attention must be paid to obstacles such as electric light cables.

Following the completion of a paved route between Port Sudan and Khartoum, there are an increasing number of 30-ton trailers using this route. The freight corresponds to US$63 ~76/ton

(4) Road between Port Sudan and Damazin

The road condition between Port Sudan and Damazin is as follows:

Name of Road	Distance (Km)	Pavement Condition
Port Sudan/Haiya	206	Asphalt
Haiya/Kassala	350	Asphalt
Kassala/Gedaref	217	Asphalt
Gedaref/Wad Medani	227	Asphalt
Wad Medani/Senner	107	Asphalt
Senner/Singa	58	Asphalt pavement will be completed by June, 1981.
Singa/Damazin	175	Asphalt pavement will be completed within 1982.
TOTAL	1,340	

The road between Port Sudan and Damazin stretches over a distance of 1,340 km of which the 58 km portion between Senner and Singa is currently under construction. Asphalt pavement will be completed by June, 1981. The route between Singa and Damazin will be paved with asphalt within 1982 in succession.

(5) Road between Damazin and Ingessana Hills

The route from Damazin to Ingessana Hills where chromium ore, main raw material for ferrochrome is produced are a provincial unpaved road. But it will be upgraded as an access road (feeder road) and will be remodelled (under the Six Year Program) soon.

Name of Road	Distance (Km)
Damazin/J. Agadi	33
J. Agadi/J. Buk	38
J. Buk/Gam (Ingessana Hills)	37
TOTAL	108

This access road will be further extended down the south to Kurmuk, a border town with Ethiopia. In addition, this road will possibly make a circle around the Ingessana Hills according to a plan.

Its structure is such that the width of the asphalt paved portion is 5.0 m and that of the shoulder 3.0 m (1.5 m x both sides).

(6) Road transportation

The road transportation in Sudan is mostly operated by the private sector.

Chromium ore produced at the Gam Mines of Ingessana Hills is carried by the 6-tonner to the 25-tonner truck owned by private sector over a distance between the Gam Mines and Damazin. The freight is US$13.3/ton.

3–2 Railways

(1) Status quo of railways in Sudan

All the railways in Sudan are operated by a national corporation called "Sudan Railways". Their entire distance is 4,756 km and is composed of a single 1,067 mm track. The available means of transportation in Sudan other than railways are take, waterways of 1,723 km mainly depending on the Nile River 20,000 km long roads and a scant stretch of airways. The waterways transport routes are limited and the roads are poorly maintained. For these reasons, cargo transportation almost exclusively depends on the railways. 1970 – 77 intercity traffic volume is indicated in Table 5-12.

The railways network is as shown in Fig. 5-7.

1) A railway line from Khartoum to Port Sudan on the Red Sea via Atbala in the north and one to Wadi Halfa and Karima near the border.

2) A railway line from Khartoum to El Obeid, Nyala and Wau in the west via Sennar.

3) A railway line making a short cut between Sennar and Haiya via Kassala.

4) A railway line from Sennar to Damazin.

5) Other short railway lines.

(2) Problems on railways

There are the following problems with the railways in Sudan.

1) The operating revenue of the Sudanese national railways shows a deficit.

Table 5-12 Intercity Traffic Volume 1970 – 1977

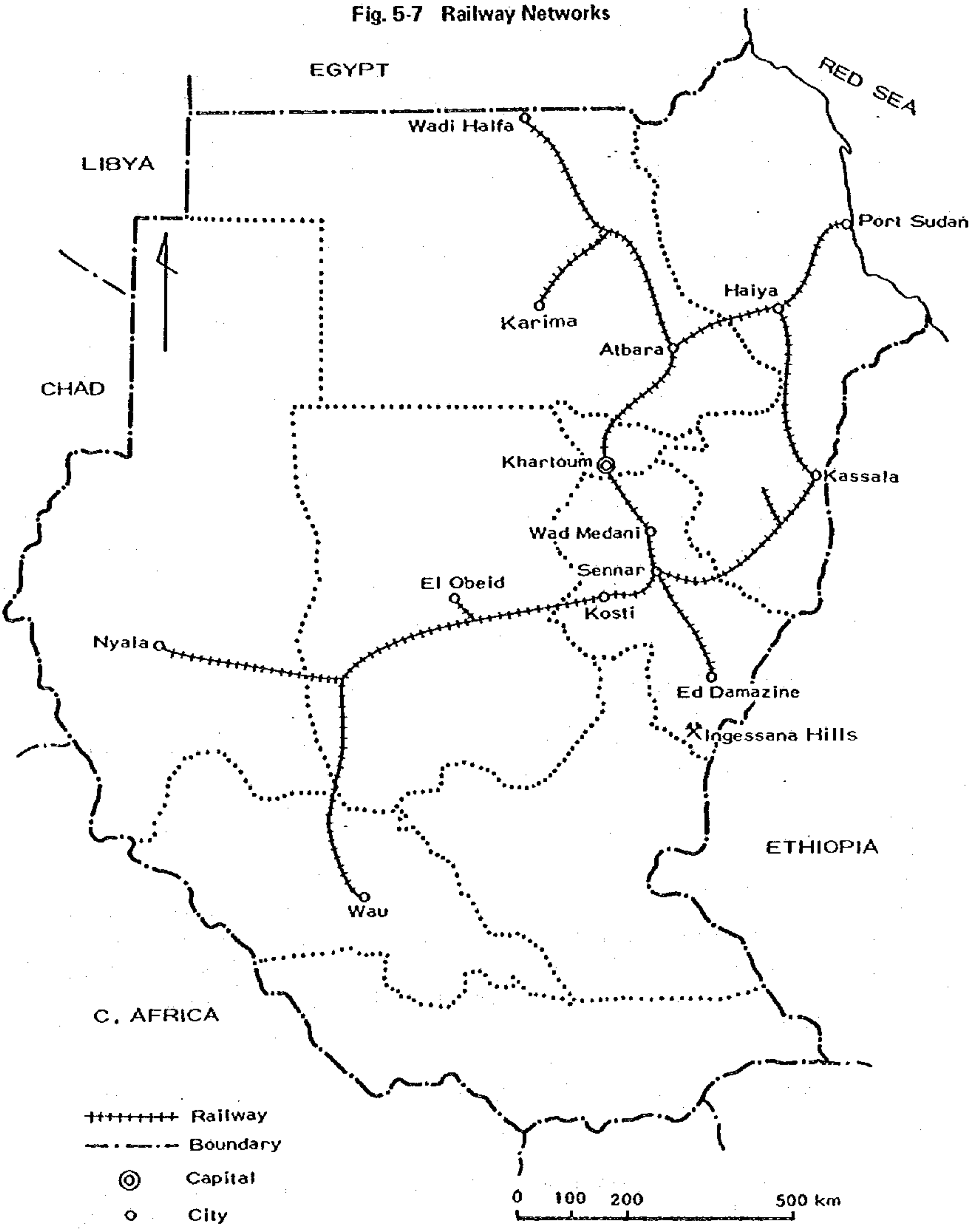
(Unit: in million S£)

	1969/1970		1970/1975		Five Year Plant Targets		Five Year Plan Achievements		Five Year (Expected) Traffic		Extended Five Year Plan Growth	
	T	P	T	P	T	P	T(%)	P(%)	T	P	T(%)	P(%)
Rail	2,697	1,014	2,274	1,102	4,000	1,170	57	94	2,800	1,150	4	13
Roads	922	3,480	2,464	5,840	–	–	–	–	3,787	6,000	311	72
River	80	72	82	88	117	101	70	86	83	88	4	22
Air	2	134	8	286	–	190	–	150	8	570	300	325
TOTAL	3,701	4,700	4,828	7,316	4,117	1,461	117	–	6,678	7,808	80	66

Remarks: T Ton-Km including freight only.
P = Pass-Km

Source: The Six Year Plan of Economic and Social Development 1977/1978 – 1982/83.

Fig. 5-7 Railway Networks



2) The tracks are poorly built.

Generally, ballast is not used and sleepers are laid directly on the ground. The height of the track ground is not sufficient and the length between the sleeper's edge and the track ground shoulder is also insufficient in many line sections (The standards of the Sudanese National Railways are shown in Table 5-13).

Table 5-13 Standard Tracks of the Sudan National Railways

Line Section		Standards of Track
Rail	Port Sudan Khartoum Sennar	90 lbs.
	Others	75 or 50 lbs.
Sleeper	Entire Lines	Wooden Sleeper (iron sleeper is seen used in some line section.)

Source: Sudan Railways.

3) Communication equipment

The exclusive telephone system is installed between the railway stations. Because of its becoming obsolete, it is almost not used.

4) Rolling stock

All trains are pulled by the locomotives. Rolling stock is composed of locomotive, passenger coach and freight car. As to the motive power system, the use of diesel engine is extensive. On the principal lines, the diesel engine is used as a traction engine. The steam locomotive is run between Damazin and Sennar and Babanousa and Sawark only.

Beside the locomotives, the passenger coaches and freight cars are considerably short.

5) In addition to the above problems, there are other numerous problems. In order to resolve these problems, the Six Year Program is prepared as shown in Table 5-14.

Table 5-14 Investment Plan for the Railways under the Six Year Program

(Unit: in million S£)

Name of Project	Total Cost	Six Year Plan Allocations
On going projects	Nil	Nil
New projects		
Track improvement		
1. Doubling Port Sudan-Haiya Section	26.00	15.00
2. Damazin-Senner Section	13.00	5.00
3. Re-sleeping Kassala Line	3.00	3.00
4. Signalling & Communication	3.00	3.00
5. Crossing Section	2.80	2.00
6. Conversion of Halts	0.65	0.65
7. Plant & Machinery	0.75	0.75
8. Modifications to Rolling Stock	1.50	1.50
9. Workshops & Workshop Facilities	4.00	2.00
10. Building & Artificial Installation Rolling Stock Requirements	2.00	1.00
11. Procurement of Freight Wagons,	20.00	20.00
12. Procurement of Locomotives	15.00	15.00
13. Block Allocation for Providing Additional Capacity	9.47	9.47
TOTAL Railways	101.17	78.37

Remarks: The above table is the list of projects included in the Six Year Plan Transport Public Sector Investments.

(3) Railway line between Port Sudan and Damazin

In the case of "via Atbara and Khartoum", the entire line distance between Port Sudan and Damazin is 1,286 km. However, in the case of "Via Kassala", the entire line distance is 1,134 km, thus shortening it by 152 km.

The route via Kassala shows an extremely little actual transportation service record in the past. However, in the latter stage of the Six Year Program, it is forecasted that the traffic volume will be almost the same as that of via Atbara. Consequently, ferrochrome, raw material bauxite or coke will be transported through Kassala. As to the transportation of the project ferrochrome smelting plant's construction materials and raw materials, attention should be paid to the following Clause.

1) The rail between Senner and Damazin is of the 50 lbs. type and for this, the axle load is 12.5 tons. Therefore, the weight is limited to 12.5 tons x 4 = 50 tons in the

case of 4 vehicle axles. These weight limits involve the weight of freight car so that the actual load will be less than 40 tons. And max. height 4.08 m, max. width 3.78 m and max. length 12.93 m.

2) Prior to cargo transportation, a transport schedule has to be submitted to the Sudan Railways for allocation of the freight cars. Since the freight cars are considerably short, this point must be sufficiently taken into consideration.

3) The tariff discount system is not applicable to whatever general cargo transportation at present.

4) The present tariff of chromium ore between Damazin and Port Sudan is S£ 742.05 (S£24.735 per ton) in the case of gondola car. This freight does not include loading/unloading charges.

(Unit: 1,000t)

Line Section	Distance (Km)	Traffic Volume	
		'75/'76	'82/'83
Port Sudan/Haiya	205	2,358	4,334
Haiya/Atbara	271	1,986	2,765
Atbara/Khartoum	313	1,976	2,285
Khartoum/Senner	270	837	2,285
Senner/Damazin	227	93	163
Total of line distance via Atbara & Khartoum	1,286		
Haiya/Kassala	247	372	2,310
Kassala/Senner	455	341	2,176
Total of line distance via Kassala	1,134		

(4) Siding into the projected ferrochome smelting plant

If a siding plan is submitted to the Sudan Railways, it will investigate in the field and prepare a budget and build it. The construction cost will be borne by the enterprise.

3–3 Port

(1) Port facilities

Port Sudan is an ideal port favored by natual advantage on the Red Sea, 650 km north-east of Khartoum, the Sudanese capital and 1,134 km distance to damazin by railway (Via Kassala). The port has approaches, the main quays and South quays. Loading/unloading facilities are as shown in Table 5-15, and Table 5-16.

Table 5-15 Size of Berth

No. of Berth	Length (m)	Depth (m)	Width (m)
1.2.3.4.5.5A	825.0	L.S.W.L 8.6	50.0
6.7	365.0	10.7	50.0
8.9	375.0	10.7	50.0
11	98.0	8.7	40.0
15	205.0	10.7	120.0
16	72.0	11.4	120.0
17.18	278.0	11.4	100.0

Table 5-16 Loading/Unloading Facilities

Equipment	Capacity (t)	Quantity
Quay Cranes	5	33
Quan Cranes	15	2
Mobile Cranes	5	3
Mobile Cranes	7	10
Mobile Cranes	14.5	13
Mobile Cranes	30	2
Mobile Cranes	20	1
Forklift Trucks	2	1
Forklift Trucks	2.1	10
Forklift Trucks	2.7	21
Forklift Trucks	3	55
Forklift Trucks	8.9	10
Forklift Trucks	10	13
Forklift Trucks	25	2
Tractor		30
Trailer		63
Shunting Locomotive		3
Truck		73
Tanker		6

(2) Port service capacity

The maximum allowable weight of loads unloaded from a vessel is 15 tons. However, loads up to 75 tons can be handled, depending on the vessel's level. The maximum permissible length of loads is up to 40 feet. The present unloading capacity is 770 tons/day for imports and 739 tons/day for exports.

Vessels 35 feet in draft, 800 feet max. long (274,320 mm) with a capacity of approximately 15,000 tons can enter Port Sudan. The working hours at the port are from 6:00 to 14:00. Friday of every week and holidays are off-duty days.

(3) Unloading status

A siding is laid up to the quay and the freight train can pull in along the side of a vessel. Cargo can be transferred into the wagon immediately upon unloading from a vessel. Contact must be made at least 15 days in advance for wagon arrangement. At present, the number of available wagons is small. Therefore, it is very difficult to secure them. There are two types of the wagon: covered and open. Each of them is capable of 30 to 35 tons. Ten (10) units of them can be loaded per day.

Most of unloading cranes are of the 5-ton capacity. Therefore, if loading cranes capable of loading up to 5-ton cargoes are introduced, the working efficiency will be improved. It seems that the unloading capacity is determined by the availability of wagons and trucks for transportation. At present, it is difficult to make exclusive arrangements for the wagon only. Therefore, it is considered necessary to resort to the trucks.

Unless cargo is carried out within a specified period of one week after unloading from a vessel, an additional storage fee needs to be paid. In addition, if the unloading capacity is considered, it is ideal that a loaded volume aboard a vessel should be up to 3,000 tons.

There are many storage warehouses. In case it is necessary to store the cargo near the port area due to transportation schedule, numerous private-owned warehouses are available and some are under construction now. In view of this fact, sufficient storage space can be secured easily. It is also possible to keep the cargo outside provided a guardman and fencing are arranged. In this case, however, it is required to pay cargo removal and land utilization charges. Storage facilities and its capacity are as shown in Table 5-17.

Fig. 5-8 Layout of Port Sudan

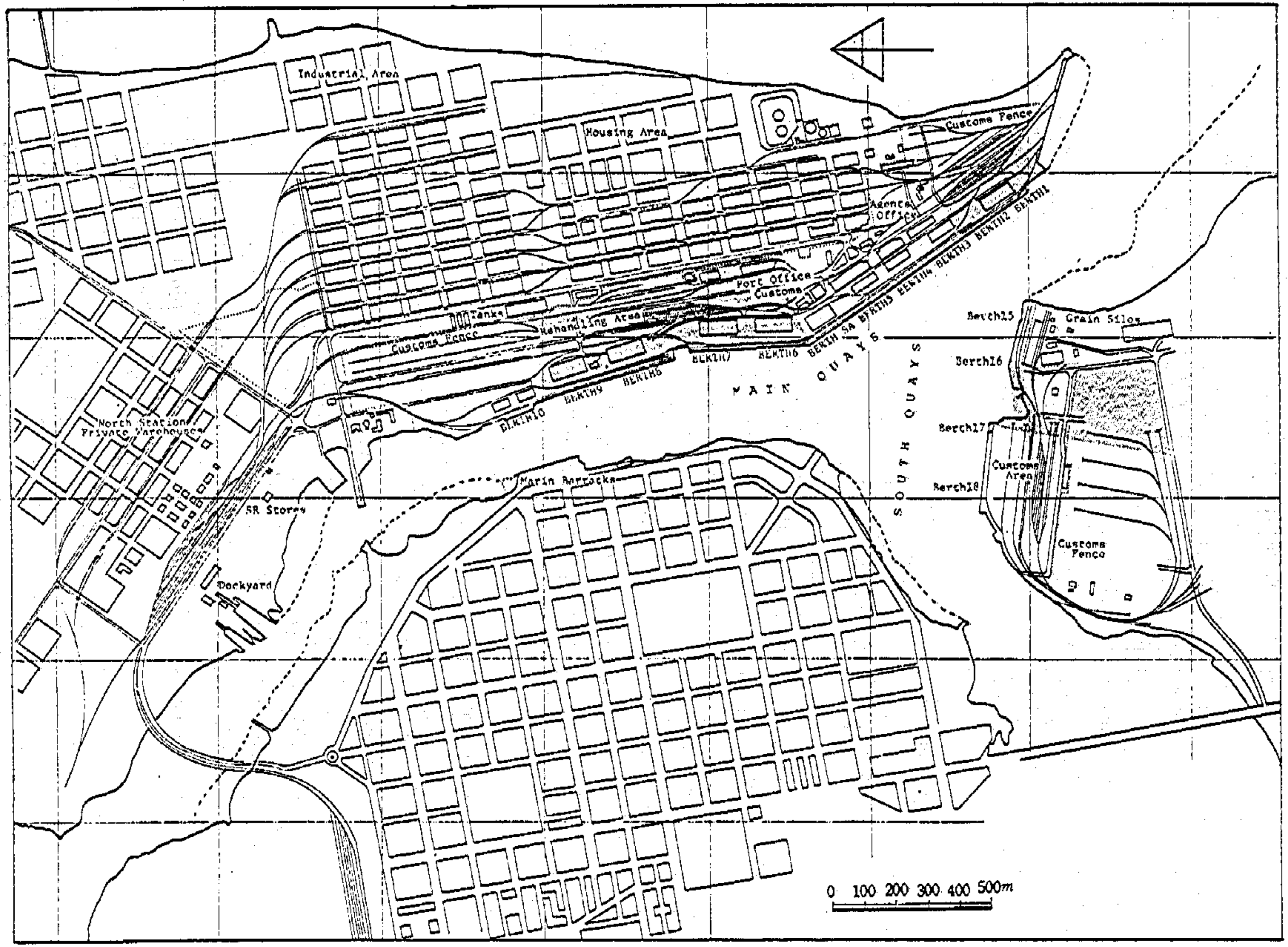


Table 5-17 Storage Facilities

Storage Area	Shed	Area (m^2)
Customs Zone	20 sheds	50,000
Privately-owned Sheds	112 sheds	460,000
Grain Silo	50,000 t	
Crude Tankage	70,000 t	
Open Storage Yard		485,000

(4) Import duty

1) Import duty related to construction

Existing import duty on general machinery

– Custom duty:	40% of CIF value
– Defense charge:	10% of CIF value
Total	50% of CIF value

Construction machinery and general machinery for plant construction will be subjected to special tax benefits, if permitted by the Sudanese Government as follows:

– Custom duty:	0%
– Defense charge:	10% of CIF value
Total	10% of CIF value

Other port-related car-load inspection cost is as follows:

– Sea port charge: – Portag storage:	} S£0.16/t
– Quays:	1.5% of CIF value
– Rent charge:	Storage charge (outdoor)

Storage period	Charge (S£)
0 ~ 7 days	Free
7 ~ 10 days	1.75/t·day
11 ~ 20 days	2.75/t·day
21 days~6 months	4.00/t·day

Over 6 months	Confiscation without any refundment

2) Import duty and export duty on raw materials and ferrochrome

The current import duty imposed on raw materials such as coke and bauxite is as follows:

– Custom duty:	10% of CIF value
– Defense charge:	10% of CIF value
Total	20% of CIF value

The current export duty on chromium ore is as follows:

– Custom duty:	10% of FOB value
– Defense charge:	0%
Total	10% of FOB value

No actual records on the ferrochrome export duty are available.

CHAPTER 6

FACILITY PLANNING

1. Project Plan for Ferrochrome Plant

1–1 Outline of Facility

Based on an agreement concluded under the Minutes exchanged with the Sudanese side on March 4, 1981 on the production scale of a ferrochome smelting plant, The Study Team have worked out the two finished product production versions of the project such as 7,000 tons/year (6,000 kVA x 1 unit, Case A) and 15,000 tons/year (14,000 kVA x 1 unit, Case B).

Table 6-1 shows main specification of the plant.

The outline of equipment of Case A and Case B is shown in Fig. 6-1 and Fig. 6-2 respectively.

Table 6-1 Specification of Ferrochrome Smelting Plant

Description	Unit	Case A	Case B
Ferrochrome Production	t	7,000	15,000
Transformer Capacity	KVA	6,000 x 1	4,667 x 3
Primary Voltage of Electricity Received	KV	11	33
Plant Site Area	m^2	50,000 (200m x 250m)	88,000 (220m x 400m)
Raw Material Consumption	t/yr.		
Chromium ore (5 ~ 75 mm)		15,300	33,700
Silica stone (3 ~ 50 mm)		900	2,200
Bauxite (3 ~ 50 mm)		2,100	3,400
Coke (5 ~ 30 mm)		3,500	7,400
Electrode paste (30 ~ 50 mm)		130	300
Load and consumption of Electric Power			
Electric Furnace load	KW	4,500	11,000
Average load	KW	4,000	9,000
Electric consumption	KWH/yr	32,600 x 10^3	72,300 x 10^3
Industrial Water Usage	t/hr.	70	175
Manpower Requirements	(persons)	151	211

Fig. 6-1 Ferrochromium Production Facility (Case A)

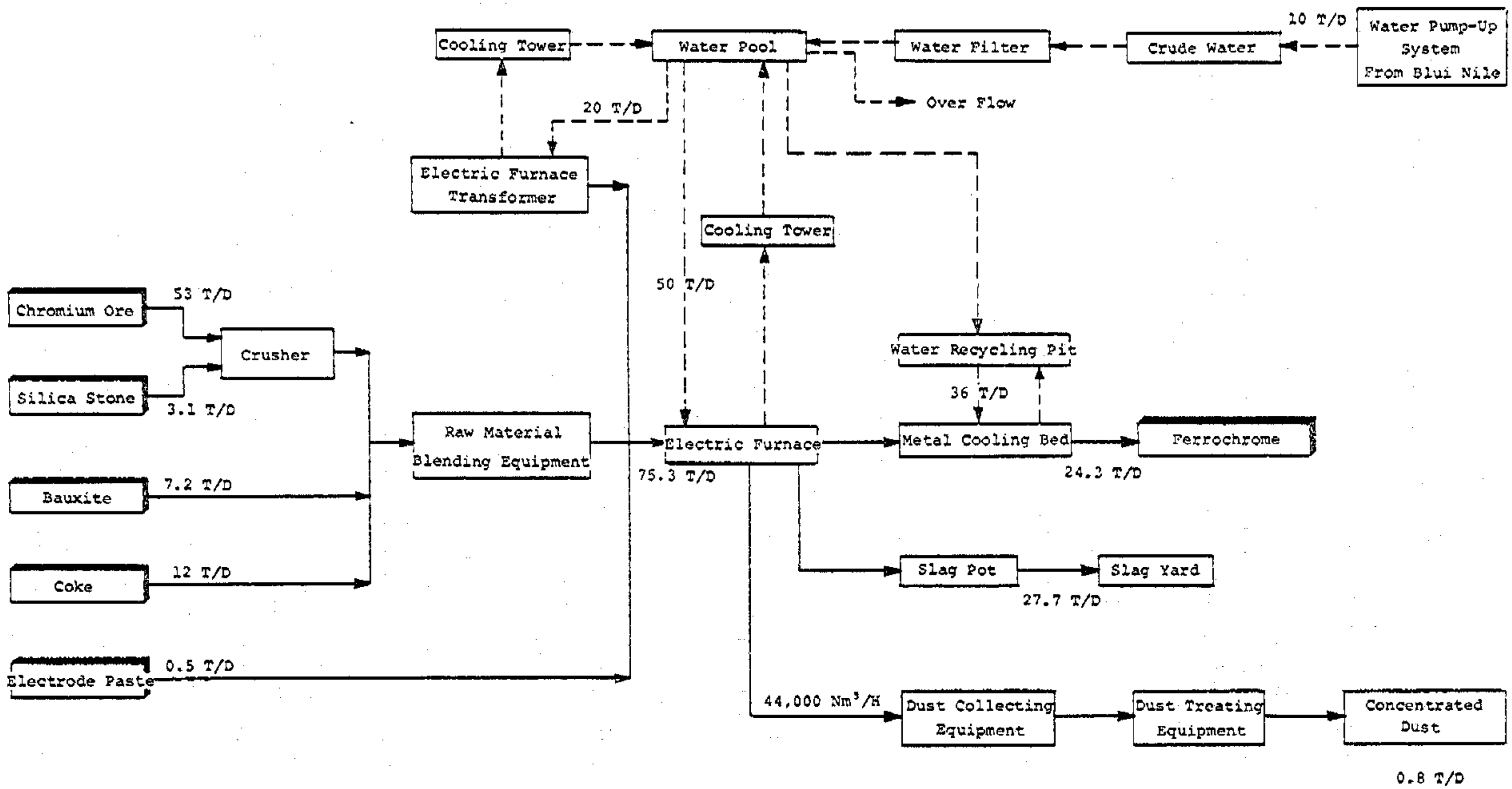
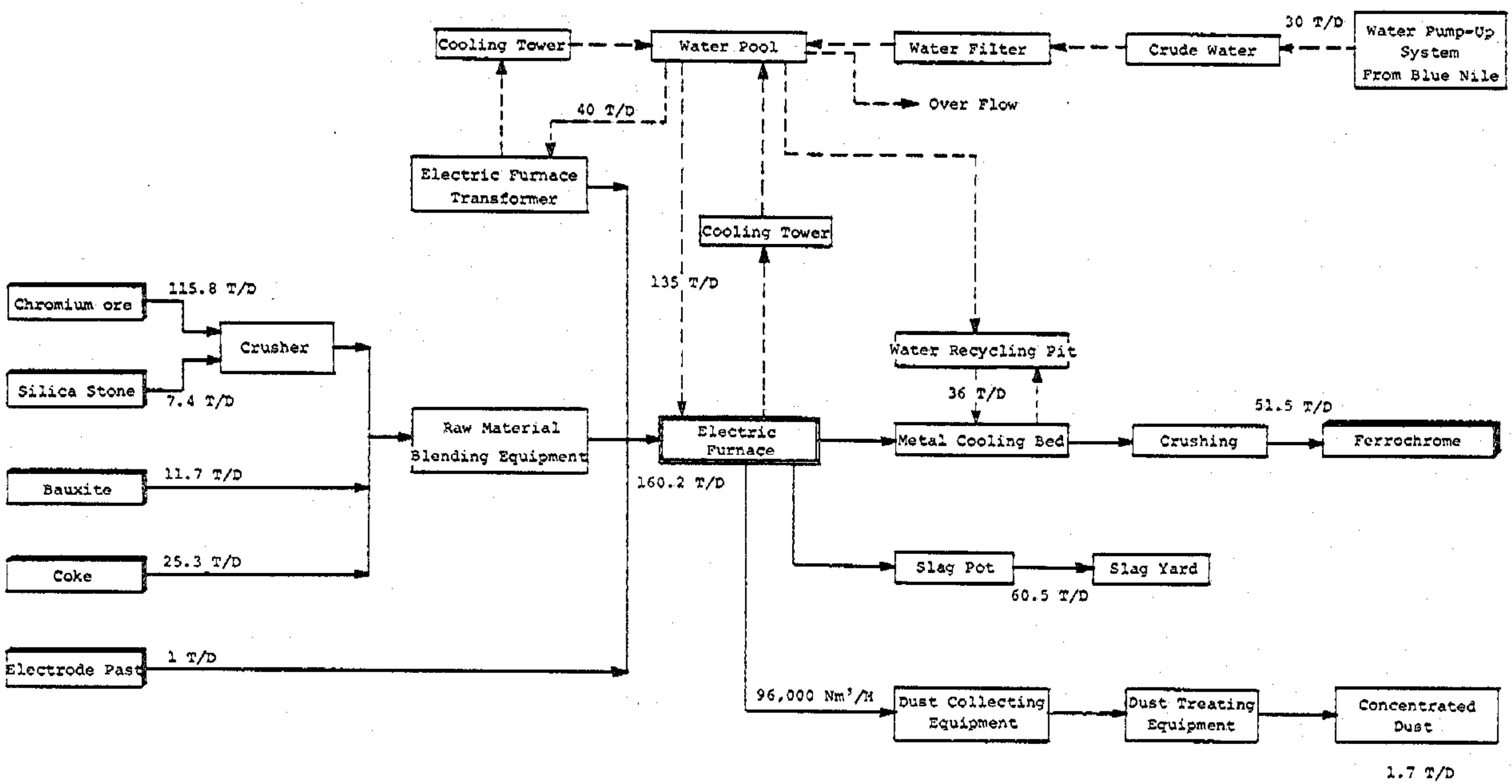


Fig. 6-2 Ferrochromium Production Facility (Case B)



1–2 Plant Site

The area finally indicated by the Sudanese side as a site for the projected ferrochome smelting plant is as shown in Fig. 6-3 and Fig. 6-4. This site is in the neighborhood north of a cotton mill approximately 3 km north of the Damazin station and is approximately 6 km away from the Er Roseires Power Station approximately 3 km of the Blue Nile River. This site is considered a convenient point from a viewpoint of transportation, industrial water, electric power supply, etc.

The plant site point is topographically flat sparsely studded with shrubs and is composed mainly of cotton soil. The plant site prepared by the Sudanese side is such an extensive area as 600×10^3 m^2 extending 1,500 m in the east/west direction and 400 m in the north/south direction.

1–3 Plant Layout

As to onplant equipment arrangement, considering the impracticability of transportation during the rainy season, we estimated the outdoor raw material storage as 4 months' quantity. The raw materials will be dumped into the raw materials receiving hopper. However, the yard and the hopper will be arranged so that the transportation distance may be minimized.

The finished product yard is outdoor and capable of storing 3 months' quantity. Space will be made available for an additional yard facilities, if circumstances require them.

Haulage to and from the plant will be carried out mainly by truck. Roads are sufficiently maintained and arranged so that work may be performed smoothly. The electric furnace is located almost in the center of the site. The office and the service plant occupy a position which meets working requirements. The plant site occupying the smallest possible space and facilities inside the plant are compactly arranged at a minimized construction cost with considerations over the satisfactory working requirements on a daily basis.

For Case A and Case B, the project layout is shown in Fig. 6-5 and Fig. 6-6.

Fig. 6-3 Location Map of Project Area

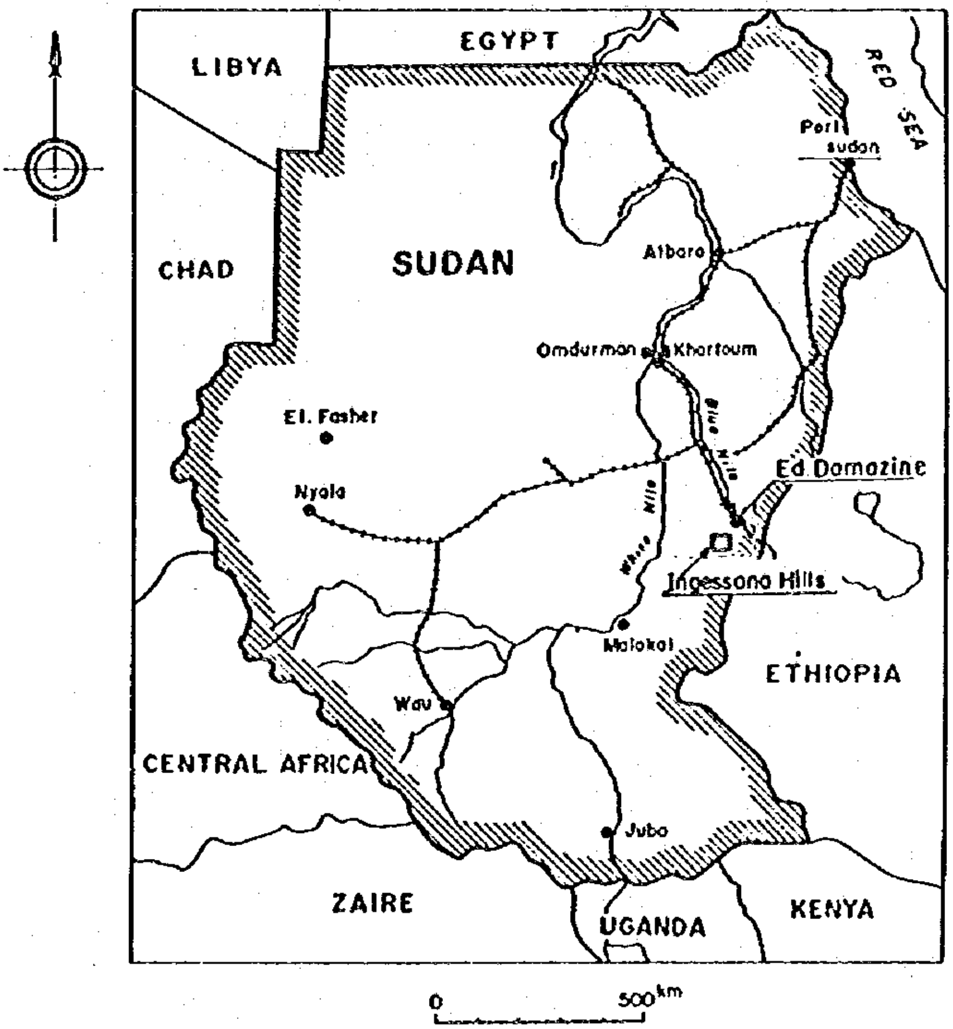


Fig. 3-3 Site for Ferrochrome Plant

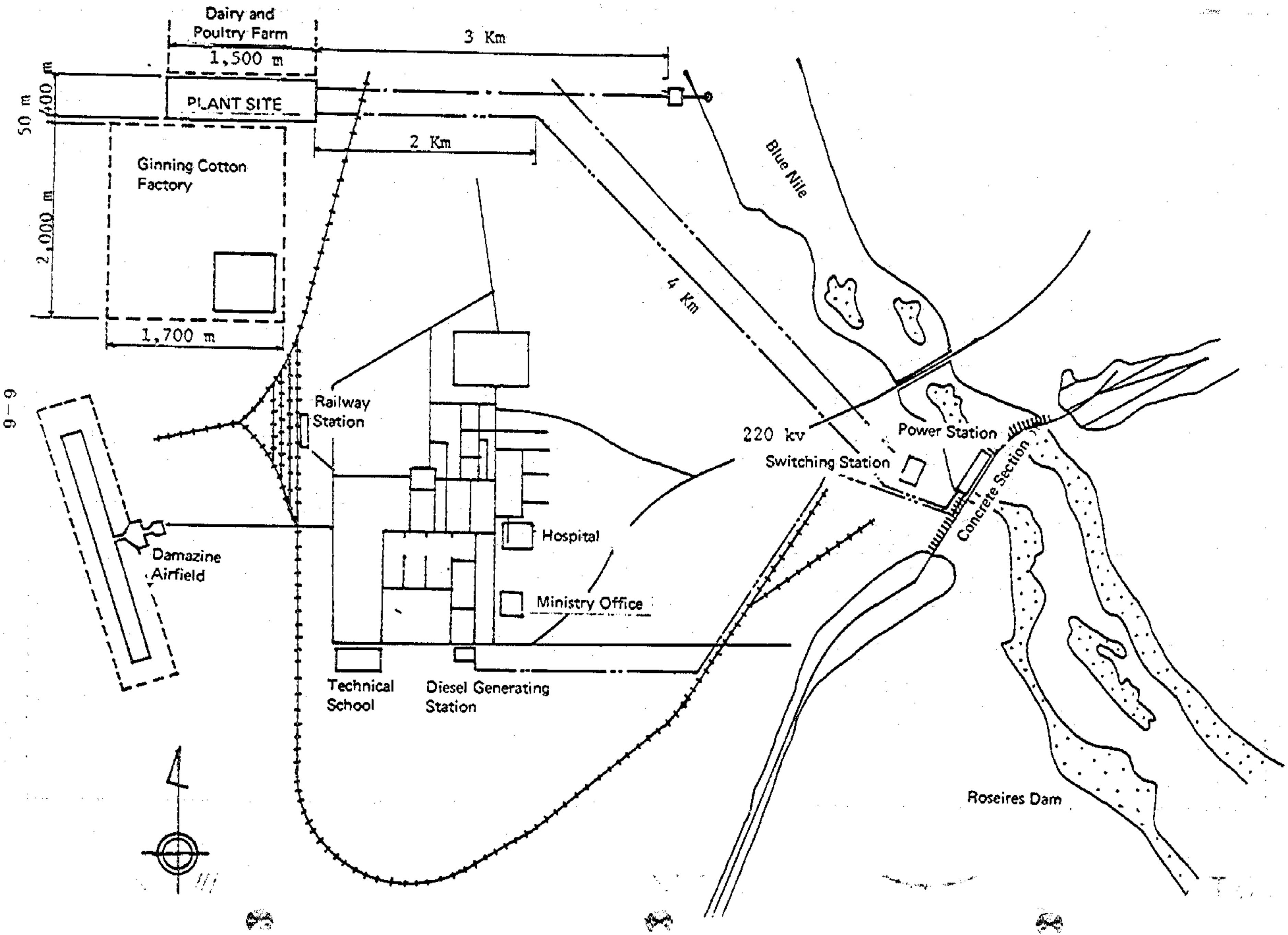


Fig. 6-5
Layout of FeCr Plant (Case A)

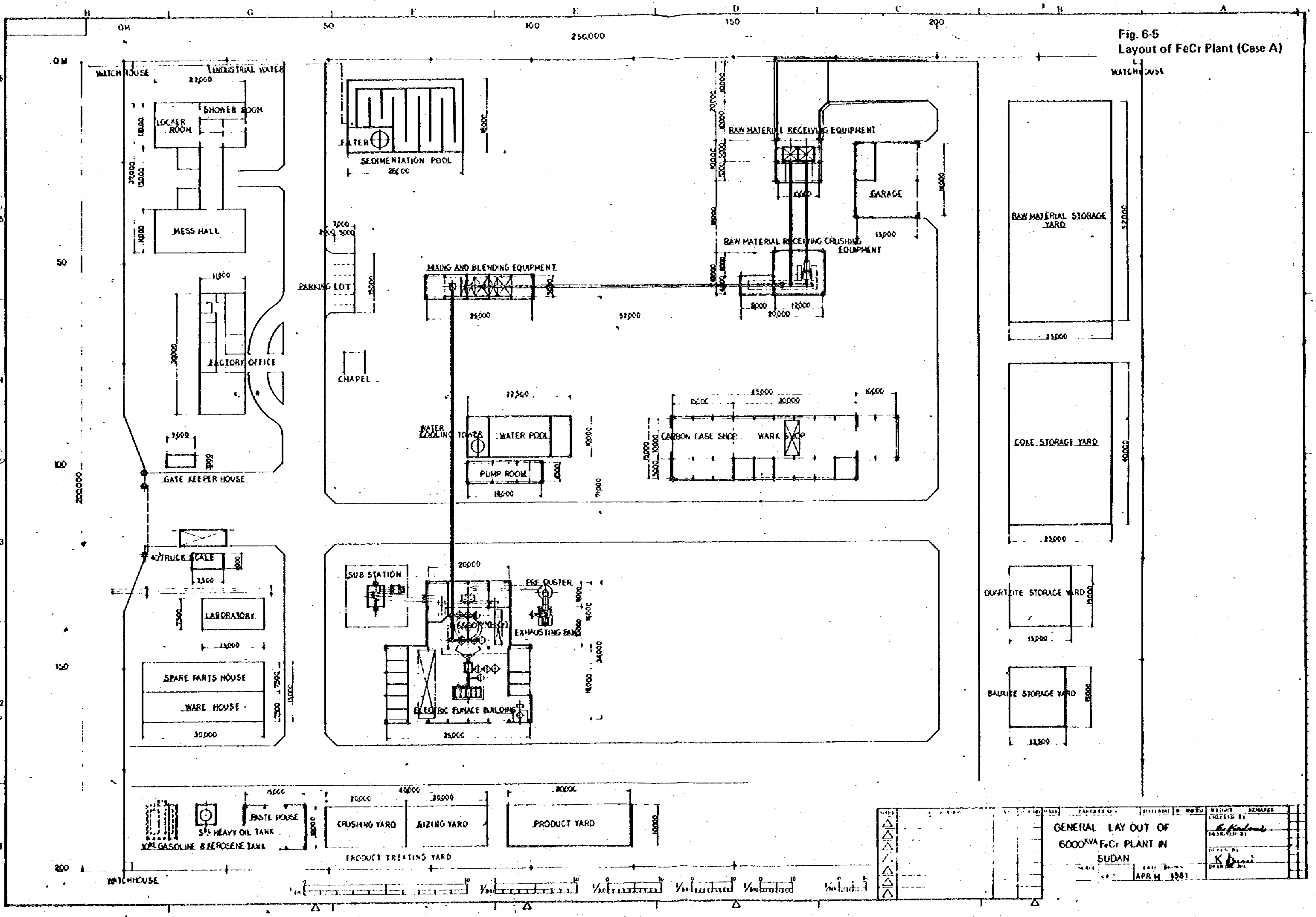
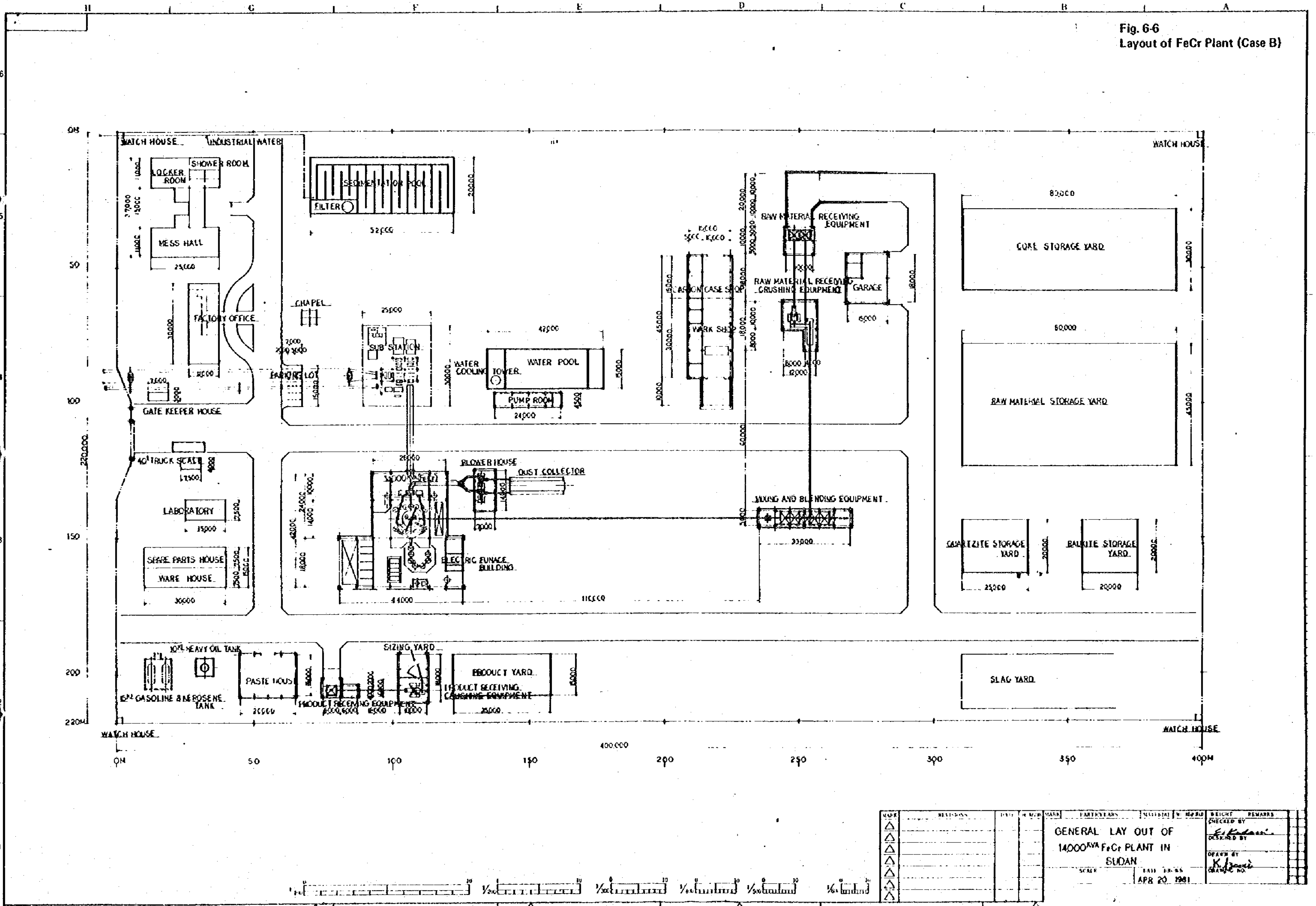


Fig. 6-6
Layout of FeCr Plant (Case B)



1–4 Manufacturing Process

The manufacturing process of high-carbon ferrochrome is shown in Fig. 6-7 and Fig. 6-9 for Case A, and Fig. 6-8 and Fig. 6-10 for Case B. The electric furnace cross-section drawing is shown in Fig. 6-11 for Case A and Fig. 6-12 for Case B. Explanation is given below on each item.

(1) Raw material receiving process

Chromium ore and silica stone are hauled in bulk by truck from Ingessana Hills. Then, these raw materials are unloaded by shovel loader and stored at the concrete-floored stockyard. Bauxite, coke and electrode paste of foreign origin will be unloaded at Port Sudan and transported to the Damazin station by freight train.

Freight train loads are discharged by shovel loader and transferred to a 10-ton dump truck. This operation is carried out inside the station yard, where unloading space is required.

Bauxite and coke will arrive in bulk. However, it is considered that electrode paste will arrive in a 1-ton flexible container bag or in container packing. The unloading will be performed by forklift and then the load be placed aboard the dump truck.

Bauxite and coke will be stored in the outdoor concrete-floored stockyard. In order to prevent electrode paste from becoming soft at high temperature and sticking together to 30 to 50 mm size blocks which need to be crushed when used, it will be stored indoors.

(2) Raw material processing & blending process

Chromium ore and silica stone are scooped up by shovel loader from the stockyard and dumped onto a 10-ton dump truck. The truck climbs up a ramp for raw material discharge into a receiving hopper. The raw materials fed with a proper quantity by a vibration feeder located below the receiving hopper are sorted out by means of 50 mm mesh vibration screen into two different sizes; more than 50 mm and less than 50 mm. Those over 50 mm in size are charged into the crusher to be crushed to the sizes of less than 50 mm. While those under 50 mm do not pass through the crushing system, because their sizes shall have been adjusted by suppliers for use.

These raw materials will be placed onto the raw material storage tank's top by means of tilting belt conveyor.

For raw material blending, in Case A, each individual item of raw materials will be fed in a proper quantity by means of vibration feeder located at the lower part of each raw

Fig. 6-7 High-Carbon Ferrochromium Manufacturing Flow Sheet (Case A)

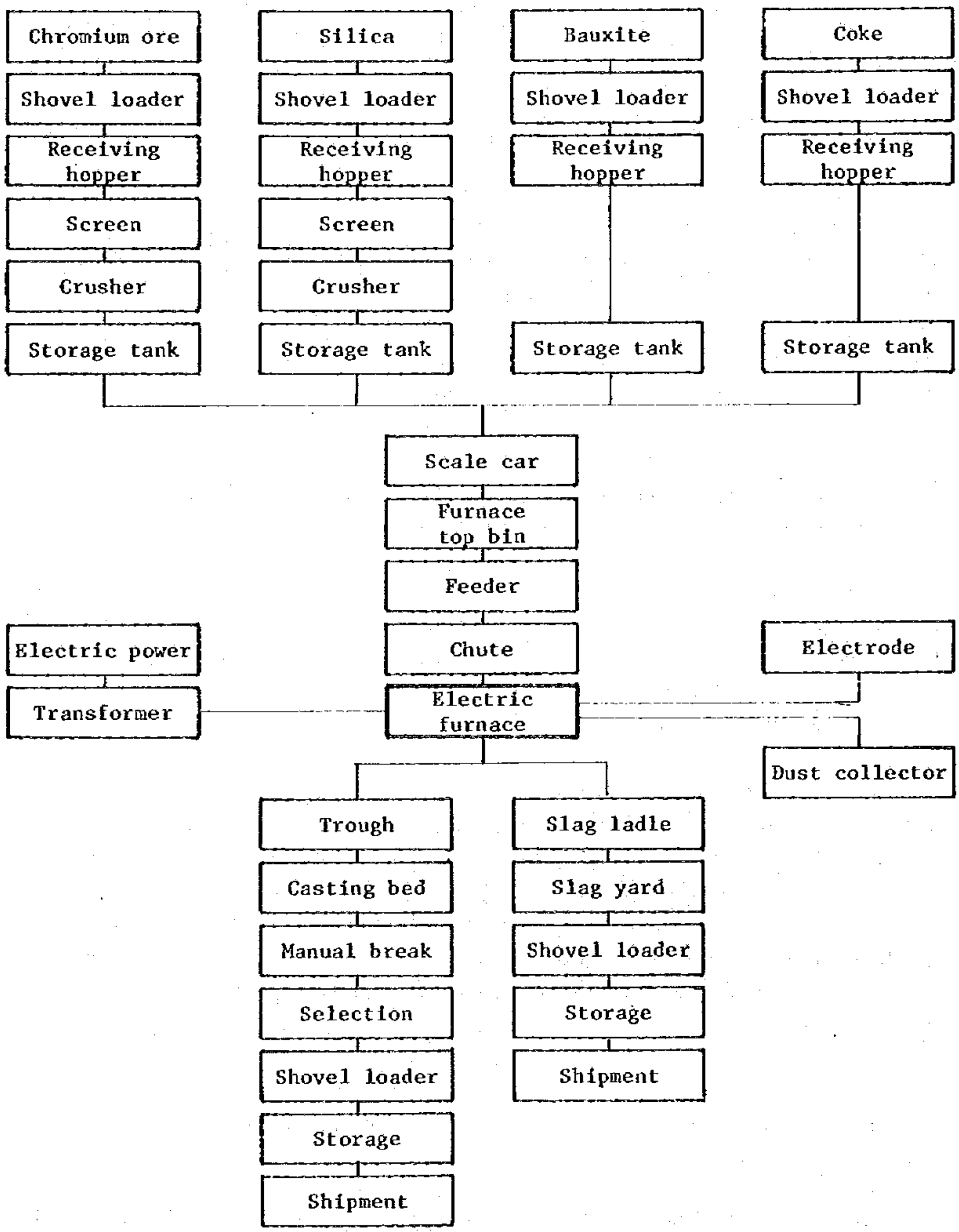
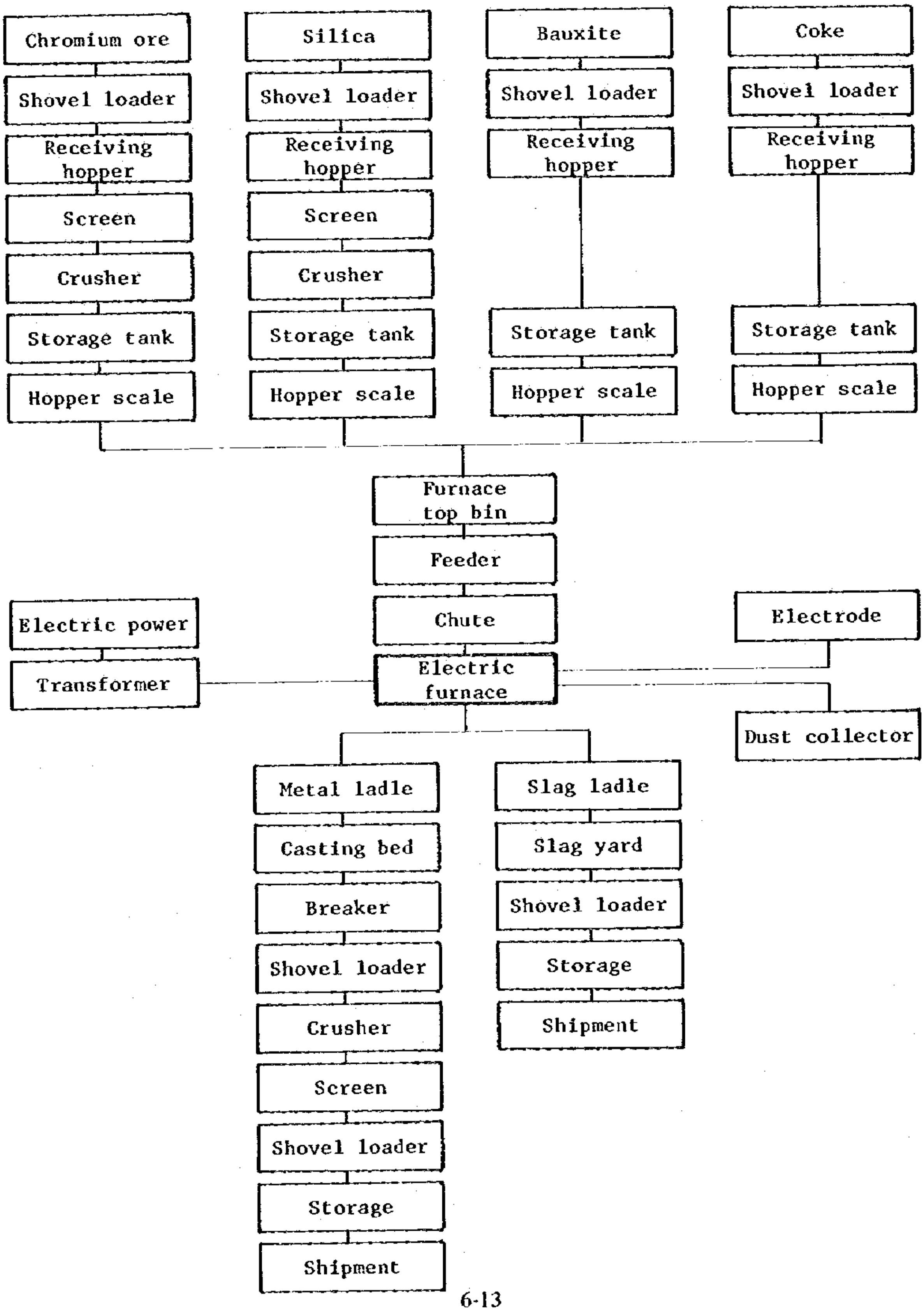


Fig. 6-8 High-Carbon Ferrochrome Manufacturing Flow Sheet
(Case B)



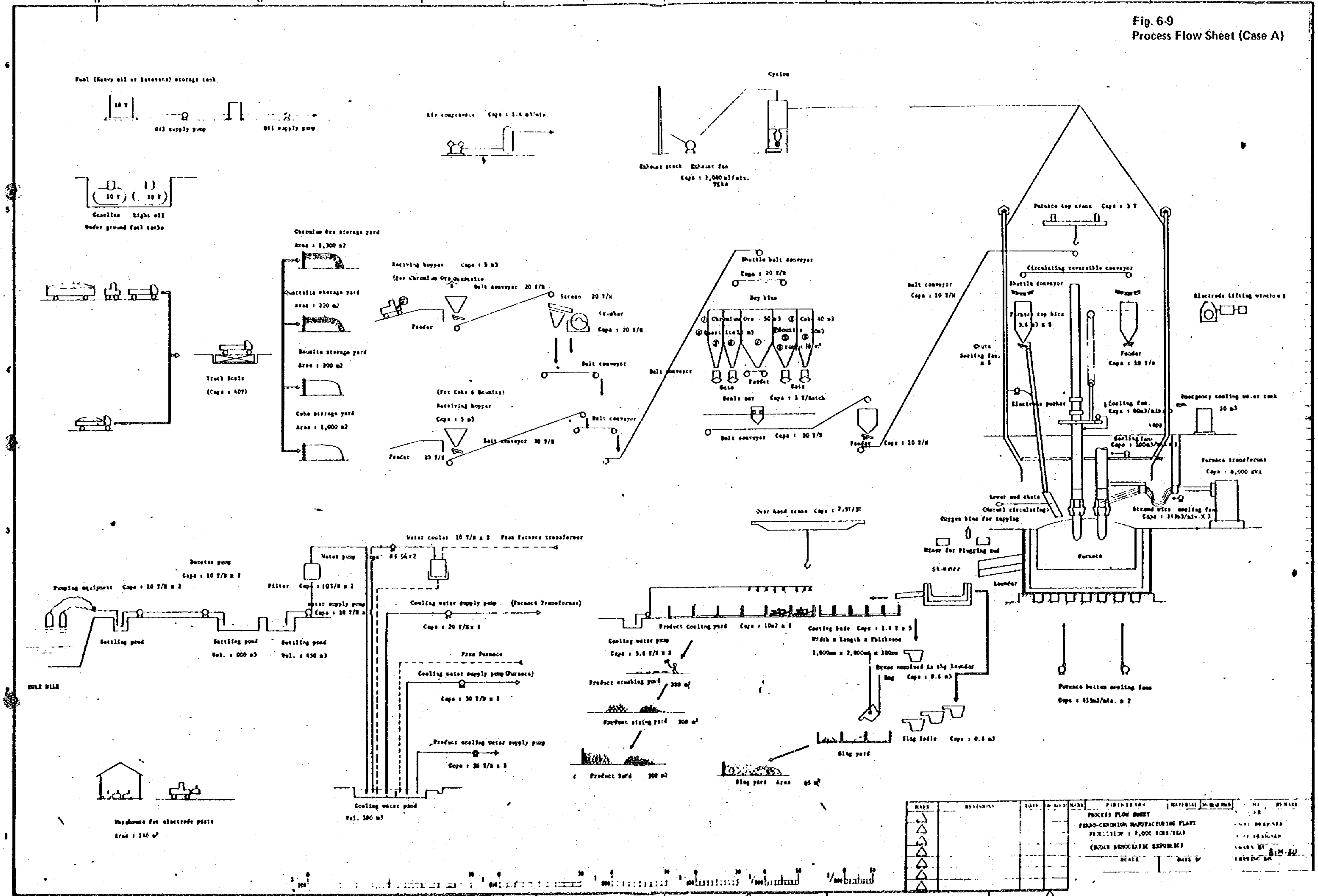
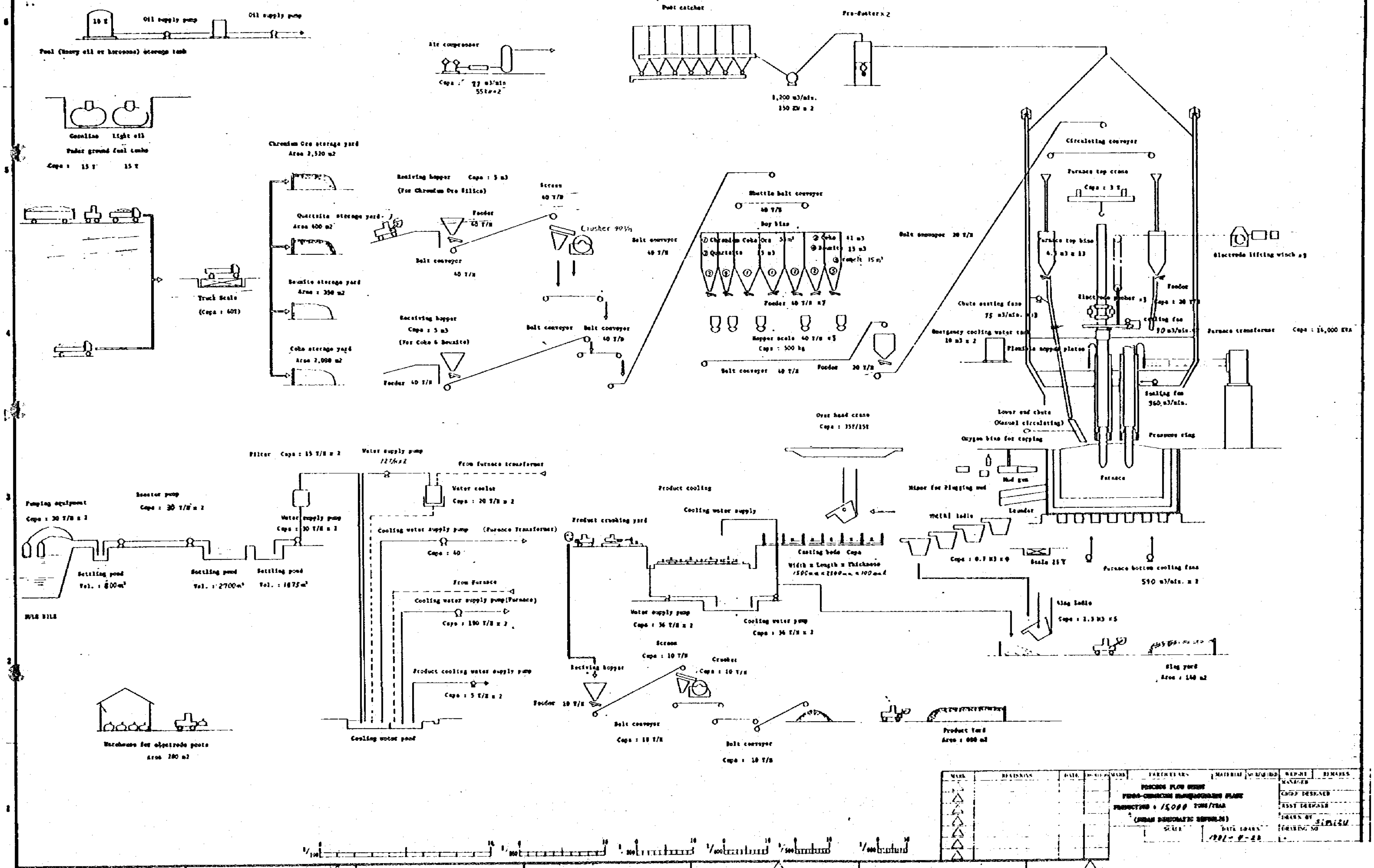


Fig. 6-9
Process Flow Sheet (Case A)

Fig. 6-10
Process Flow Sheet (Case B)



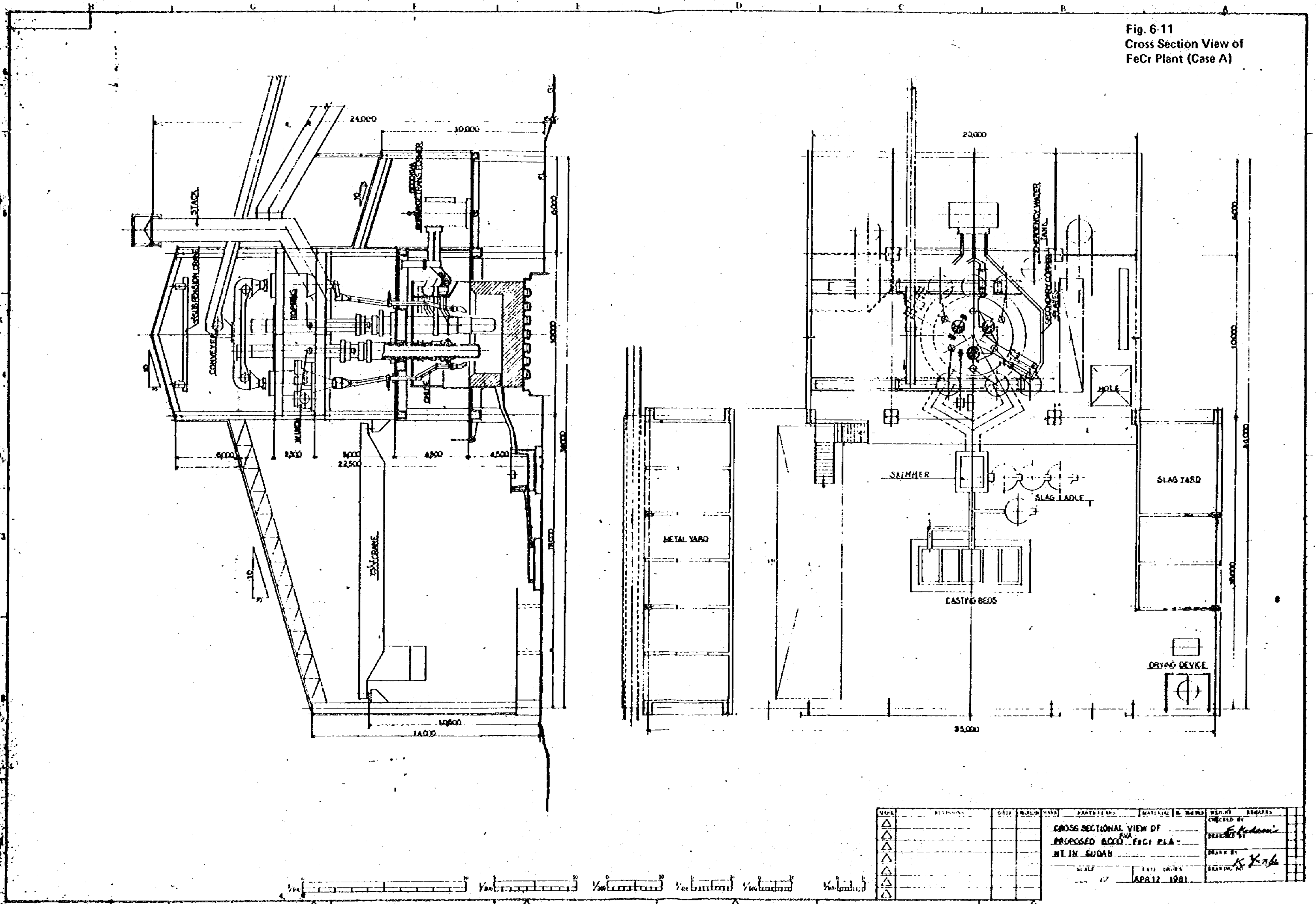


Fig. 6-11
Cross Section View of
FeCr Plant (Case A)

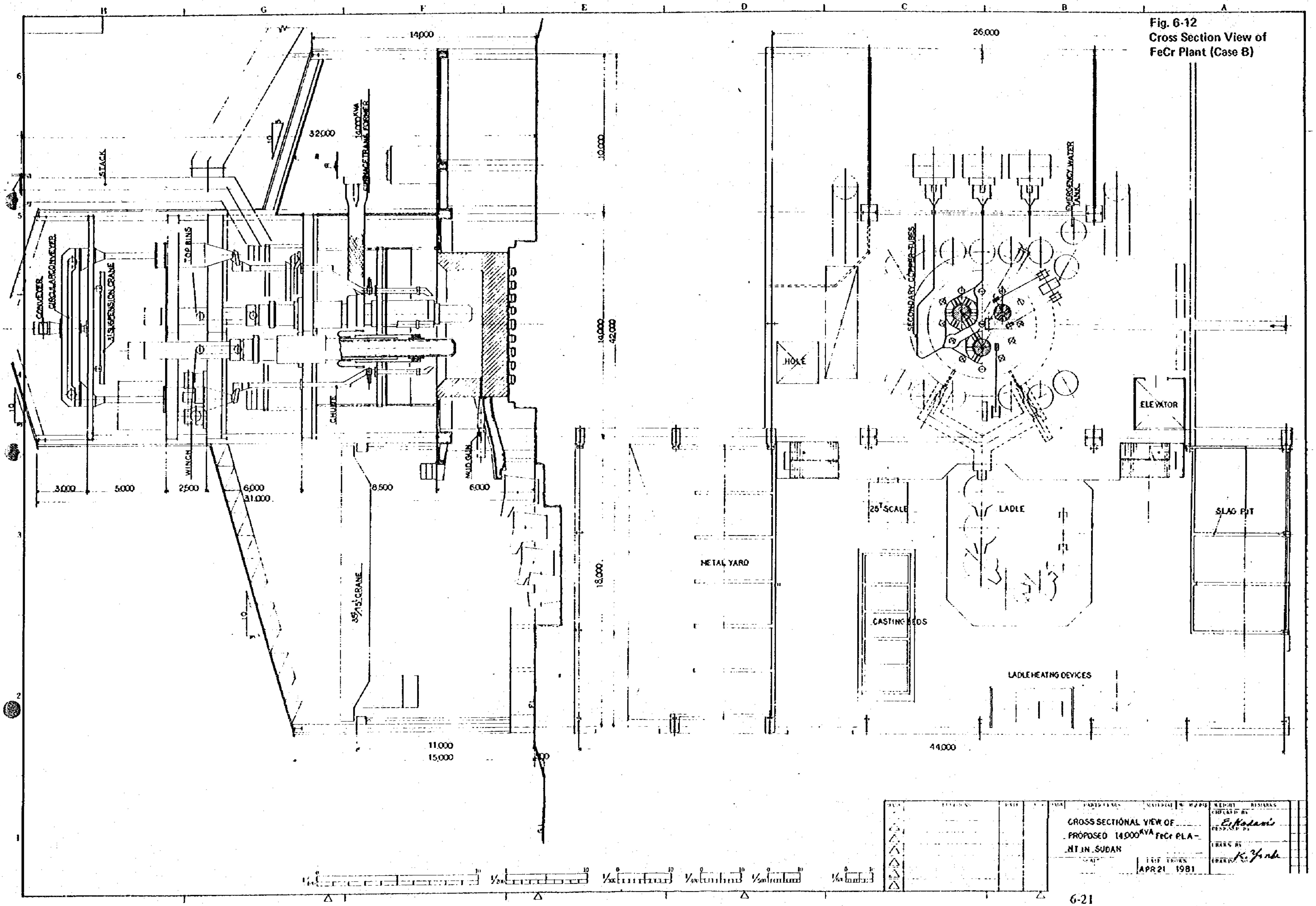


Fig. 6-12
Cross Section View of
FeCr Plant (Case B)

material tank. Then, they will be charged onto a scale car for cumulative measurement. One dosage will be 1,000 kg of chromium ore. The blended raw material will be transported to the 4th floor of an electric furnace building by way of tilting conveyor, passing through reversible conveyor and shuttle conveyor to be charged into the furnace top bin ($3.6\ m^3 \times 6$ units). Below the furnace top bin is installed a vibration feeder. Raw materials will be properly fed through a remote-control operation and charged into the furnace via 6 pieces of raw material input chute, according to necessity in electric furnace operation.

With regard to Case B, raw materials which are taken out from a vibration feeder located under each raw material tank will be measured by means of a scale arranged for each raw material. The discharge timing is considered so that after the completion of all the measurements, the blending may be made by a lower belt conveyor. The blending is based on a 50 kg of chromium ore and is automatically operated throughout. The blended raw materials will be carried out onto the 5th floor of an electric furnace building by means of tilting conveyor, and charged into the furnace top bin ($4.5\ m^3 \times 12$, $5\ m^3 \times 1$) through the rotary conveyor. The charging mechanism into the electric furnace is the same as Case A. However, the raw material input chutes total 13, of which one is arranged so that it can be introduced into the center of the furnace.

Electrode paste will be loaded on a carriage pallet at an indoor storage warehouse, carried into an electric furnace building with the assistance of forklift, brought up by means of 3t suspension crane installed at the upper of the building, taken out manually from the pallet and charged into the carbon case. This operation applies to both Case A and Case B.

(3) Electric furnace process

The electric furnace is of such type as called "submerged arc furnace". Raw materials are continuously charged into this furnace from the top through the raw material input chute. The electrode is buried type into the raw material layer. Reduction reaction is accelerated by electric heat and ferrochrome metal and slag are produced at the bottom of the furnace and taken out from the tap hole every 4 hours by opening a hole with oxygen gas.

Because of the passage of electricity through the electric furnace's electrode, the electrode is consumed so that it will be replenished by properly pushing it down.

Electric furnace facilities are composed of a winch supporting an electrode, an electrode lifting device such as wire rope, etc., a push-down device replenishing the lost portion of an electrode, an electric power supply device transmitting electricity from the transformer to the electrode, a hood and a smoke stack collecting an exhaust gas caused by CO gas combustion, a furnace body producing metal and slag through input raw material reaction, etc.

Due to high temperature inside the furnace, it is necessary to supply cooling water for cooling purpose so that the facilities may be kept up in good condition.

The main specifications of the electric furnace are as shown in Table 6-2.

Table 6-2 Main Specifications of Electric Furnace

Description	Unit	Case A	Case B
Transformer			
Capacity	KVA	6,000 x 1	4,667 x 3
Primary voltage	V	11,000	33,000
Furnace Body			
Electrode diameter	cm	80	105
Electrode cross-section	cm^2	5,024	8,655
Furnace shell diameter	cm	650	900
furnace shell height	cm	330	430
Electrode lifting distance	cm	90	100
No. of tap holes		2	2
Operation			
Load	KW	4,500	10,000
Operating secondary voltage	V	100	152
Power factor	%	84.6	72.6
Frequency of tapping	tap/day	6	6

(4) Finished product treatment process

Metal taken out from the electric furnace's tap hole is separated from slag by a skimmer and metal is tapped into a mold while slag is flown into a slag pan. (Case A.)

Metal is separated from slag in the laddle and is poured into a ladle which is lifted by an overhead crane after slag is overflown into a slag ladle (Case B.)

After spontaneous cooling and solidity, the metal is carried into the cooling yard by means of an overhead crane and then is forcibly cooled by water spray.

Slag, in the slag ladle, is cast into the slag yard. After completion of cooling, it is carried out into the outdoor slag yard by loader.

The metal cooling water is circulated through the closed circulation system so it is not exhausted. Metal after completion of cooling is roughly broken and then finely broken under Case A. The 10 to 200 mm sizes are selected at the selection yard and the over 200 mm sizes are again crushed. The under 10 mm sizes are returned to the raw material receiving hopper and stored in a raw material tank for use as raw material for the electric furnace again. This crushing process is entirely carried out manually. As to Case B, the metal is roughly broken by a giant breaker and then introduced into the finished product breaking process. It is received into the receiving hopper, passing through the breaking section and a screen. The crushed metal is sorted out into the over 200 mm, the 10 to 200 mm sizes and the under 10 mm sizes. The over 200 mm sizes are again put into the crusher. The under 10 mm sizes apply to the same manner as Case A. The finished product (10 to 200 mm) is stored into the outdoor concrete-floored stockyard.

(5) Dust collection process

CO gas generated through interfurnace reduction reaction is burnt on the surface of the raw material layer. This exhaust gas is collected through the hood and sucked into the blower by way of a duct. After this process, it enters the dust collector.

It is considered that this exhaust gas contains the about 0.8 g/Nm^3. Dust equivalent to approximately 90% is collected by the dust collector and purge to atmosphere at 0.1 g/Nm^3.

Collected dust is gathered by the hopper located at the lower part of the dust collector and discharged by the rotary valve. For dust treatment, dust is carried by a screw conveyor into a kneader. Simultaneously, water and cement are dumped into the said machine. After kneading, the product is taken out, poured onto the iron plate, levelled off in a 50 mm thickness and finally is cured.

The cured dust cake is manually broken into a dust cake under 50 mm in thickness. It is recycled as raw material for smelting ferrochrome.

The dust collector is of the cyclone type for Case A and of bag filter type for Case B.

In Sudan, no regulations on pollution control are now in force. However, because of the existence of a Dairy and Poultry Farm adjacent to the projected ferrochrome smelting plant site, the establishment of this dust collector is planned upon the Sudanese request.

The dust collection process is shown in Fig. 6-13 and Fig. 6-14 for Case A and Case B respectively.

Fig. 6-13 Dust Collecting Facility Flow Sheet (Case A)

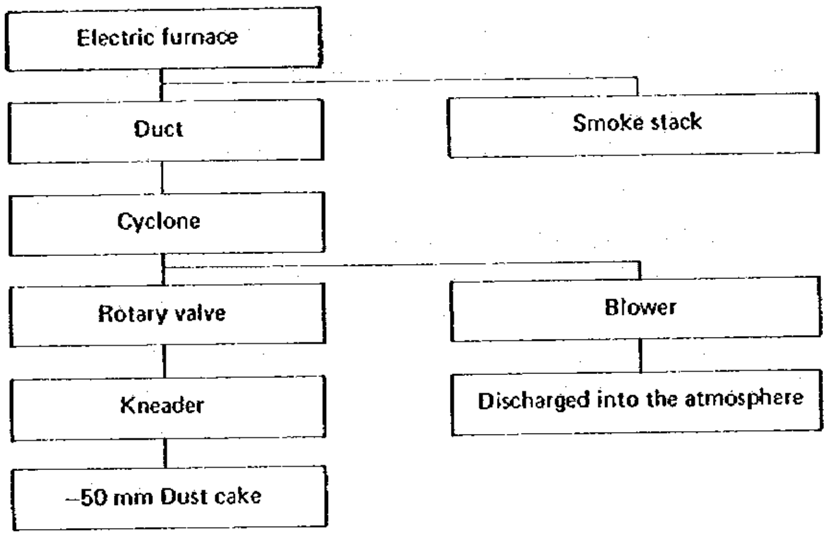
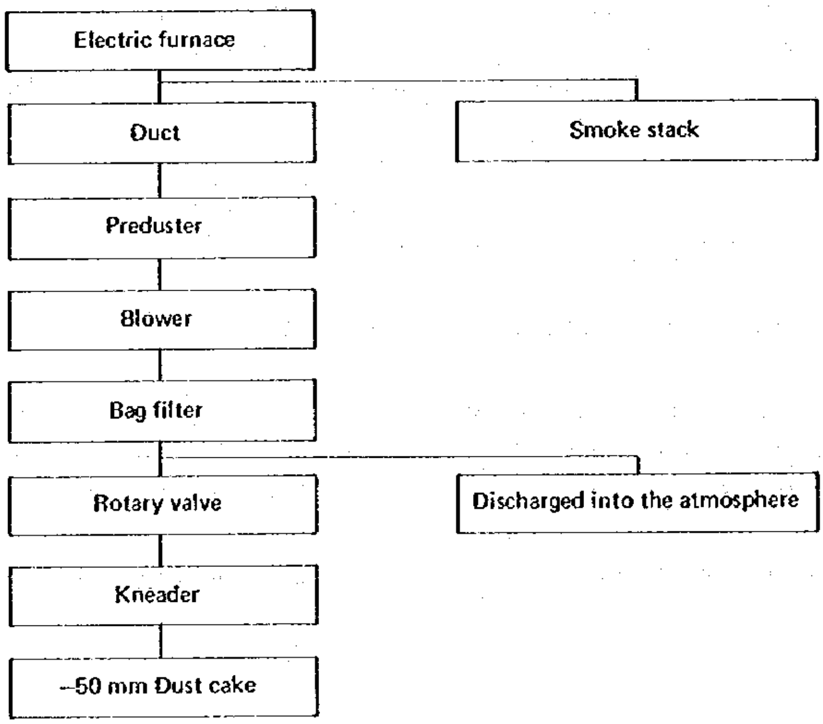


Fig. 6-14 Dust Collecting Facility Flow Sheet (Case B)



(6) Electric power receiving/substation facilities

As mentioned in Chapter 5 "Infrastructure", Clause "Electric Power", this plant will receive electric power at 11 KV for Case A and at 33 KV for Case B from the Er Roseires Power station (refer to Fig. 5.4 and Fig. 5.5).

1) Case A

Under Case A, two units of substation facilities capable of 3ϕ 11/0.415 KV, 30 KVA will be installed halfway in a 11 KV power transmission line as a power supply for the pump. The electric power will be transformed by each unit of electric furnace transformer and power transformer capable of 3ϕ 33/11/0.415 KV, 750 KVA via a commercial meter after arrival of the electric power at the plant. After transformation, the electric power will be distributed to each equipment. The specifications of electric furnace transformer are as shown in Table 6-3.

Table 6-3 Specifications of Electric Furnace Transformer (Case A)
(3ϕ 6,000 KVA Furnace Transformer)

Tap No.	Primary			Secondary			Capacity (KVA)
	Volt. (V)	Phase Cur. (A)	Line Cur. (A)	Volt. (V)	Phase Cur. (A)	Line Cur. (A)	
1	11,000	147.0	245.5	80	20,207	35,000	4,850
2		154.3	267.3	84			5,092
3		161.7	280.0	88			5,335
4		169.0	292.7	92			5,577
5		176.4	305.5	96			5,820
6		181.8	314.9	100	20,000	34,641	6,000
7				104	19,230	33,309	
8				108	18,519	32,075	
9				112	17,857	30,929	
10				116	17,241	29,863	
11				120	16,667	28,868	
12				124	16,129	27,936	
13				128	15,625	27,063	
14				132	15,155	26,243	
15				136	14,706	25,471	
16				140	14,286	24,744	
17				144	13,889	24,056	

2) Case B

Under Case B, the electric power at 33 KV will be transformed by each unit of electric furnace transformer and power transformer capable of 3ϕ 33/11/0.415KV, 1,500/300/1,200 KVA via commercial meter after arrival of the electric power at the plant. After transformation, the electric power will be distributed to each equipment. The specificcation of electric furnace transformer are as shown in **Table 6-4.** Each unit of condenser for power factor improvement capable of 2,000 Kvar and 3,000 Kvar will be installed.

(7) Utility process

1) Industrial water

The ferrochrome manufacturing electric furnace is operated at high temperature so that it is necessary to supply cooling water for equipment protection.

The portions of the furnace requiring cooling are an electrode holder, a cylinder, the secondary electric power supply device, a hanging frame, etc. A considerable quantity of cooling water is required for metal and slag.

For this reason, the projected plant will take in water at a point approximately 4 km downstream from the Er Roseires Dam with a subtank to be established near the river connected to a settlement tank for supplying water through an approximately 3 km long pipe line leading to the plant site.

The turbidity of river water during the rainy season is as high as 4,000 to 7,000 ppm. The used cooling water which is discharged is conducted into the sotrage pit after its temperature was reduced by the cooling tower. This water then will be used for cooling the electrode, metal and slag. After cooling the used water is returned to the storage tank through the intermediately of a cooling tower. The service water is used as cooling water. However, the drained water treatment facilities are not required.

Under the present project, a water treatment device is required because of very high turbidity. In order to minimize the facilities scale as far as circumstances allow, the recycling method will be adopted and it is desired that the water intake from the Blue Nile River be limited to a quantity to serve the settlement pond, storage tank and cooling tower as supplement of evaporation water and for use as make-up water for cooling metal and slag.

Table 6-4 Specifications of Electric Furnace Transformer (Case B)
(1ϕ, 4,667 KVA x 3 Furnace Transformer)

Tap No.	Primary			Secondary			Capacity (KVA) 1ϕ/3ϕ
	Volt. (V)	Phase Cur. (A)	Line Cur. (A)	Volt. (V)	Phase cur. (A)	Line Cur. (A)	
1	33,000	109.2	189.0	104	34,641	60,000	3,603/10,808
2		112.3	194.5	107			3,707/11,120
3		115.5	200.0	110			3,811/11,432
4		118.6	205.5	113			3,914/11,743
5		121.8	211.1	116			4,018/12,055
6		124.9	216.4	119			4,122/12,367
7		128.1	221.8	122			4,226/12,679
8		131.2	227.3	125			4,330/12,990
9		134 4	232.7	128			4,434/13,302
10		137.5	238.2	131			4,538/13,614
11		140.7	243.6	134			4,641/13,926
12		141.4	245.0	137	34,063	58,999	4,667/14,000
13				140	33,333	57,735	
14				143	32,634	56,524	
15				146	31,963	55,362	
16				149	31,320	54,528	
17				152	30,702	53,177	
18				155	30,108	52,148	
19				158	29,536	51,158	
20				161	28,986	50,204	
21				164	28,455	49,286	
22				167	27,944	48,401	
23				170	27,451	47,546	
24				173	26,976	46,722	
25				176	26,515	45,926	
26				179	26,071	45,156	
27				182	25,641	44,412	
28				185	25,225	43,691	
29				188	24,823	42,994	
30				191	24,433	42,319	
31				194	24,055	41,664	
32				197	23,689	41,030	
33				200	23,333	40,415	

The intake and consumption of water for Case A and Case B are as follows:

	Case A	Case B
Intake	10 t/hr.	30 t/hr.
Recycle	70 t/hr.	175 t/hr.

The service water facilities flow sheet is indicated in Fig. 6-15 and Fig. 6-16 for Case A and Case B.

2) Fuel

The types of oil to be used are heavy oil (kerosene), light oil and gasoline. The heavy oil will be used for heating of the trough and ladle, the light oil for transport vehicle and the gasoline for the car. The storage will be made in the on-the-ground tankage for heavy oil (kerosene) and in the underground tankage for light oil and gasoline.

In the Damazin area, it is difficult to obtain oil and therefore the fuel facilities will be based on considerations over the consumption of fuel at the time of construction work.

3) Compressed air

In the compressor room, a compressor and a receiver tank are installed and an air pipe line will be arranged where the dust collector is used inside the electric furnace building. The air will be used for the furnace top damper, drying burner, instrumentation and dust collector.

1–5 Details of Facilities

As to the details of the projected ferrochrome smelting plant, the specifications of the principal equipment are shown in Table 6-5 for Case A and Case B according to the itemization of facilities such as raw material receiving, raw material processing, electric furnace, finished product treatment, dust collection, electric power receiving/distribution, utilities and attachments.

Fig. 6-15 Water Purification System (Case A)

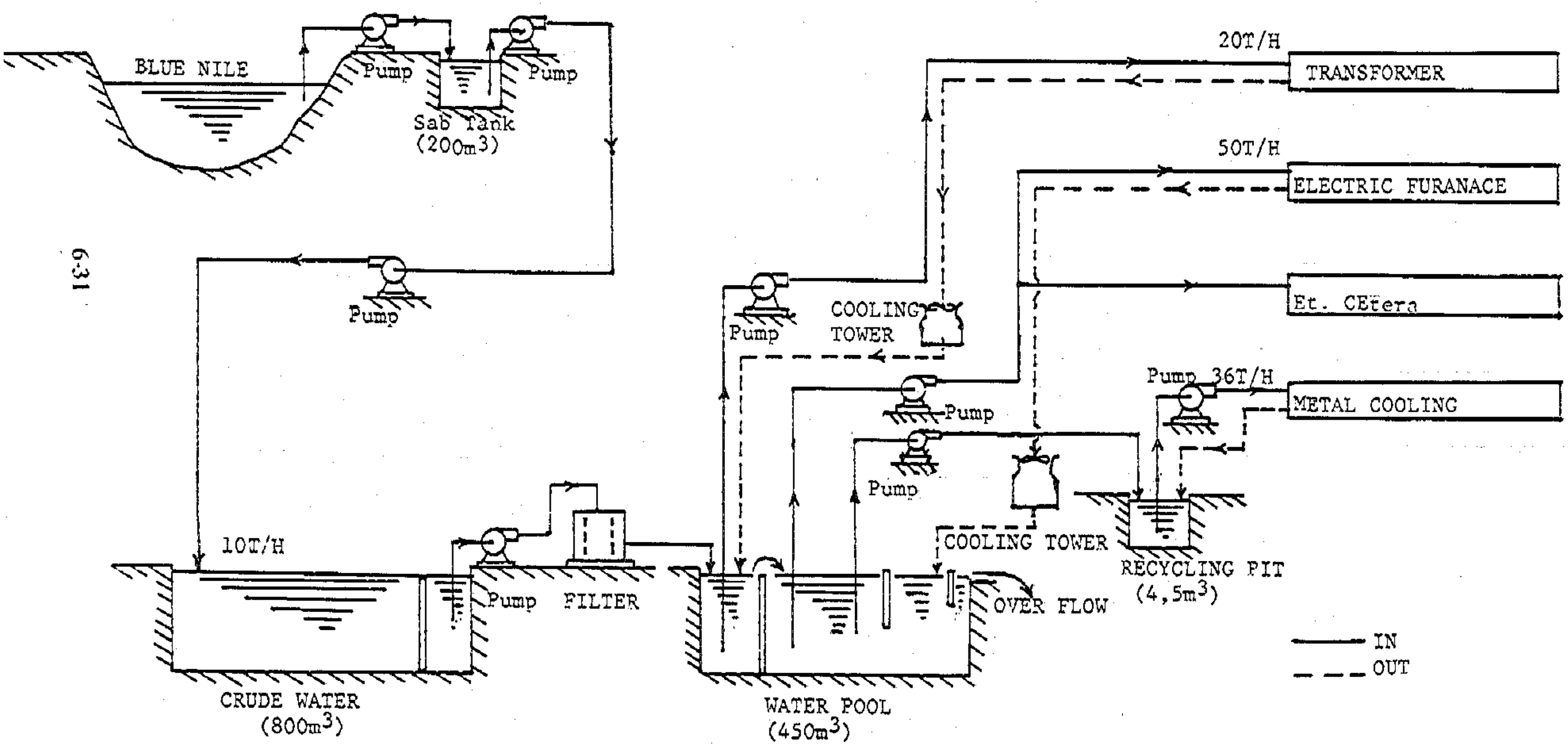


Fig. 6-16 Water Purification System (Case B)

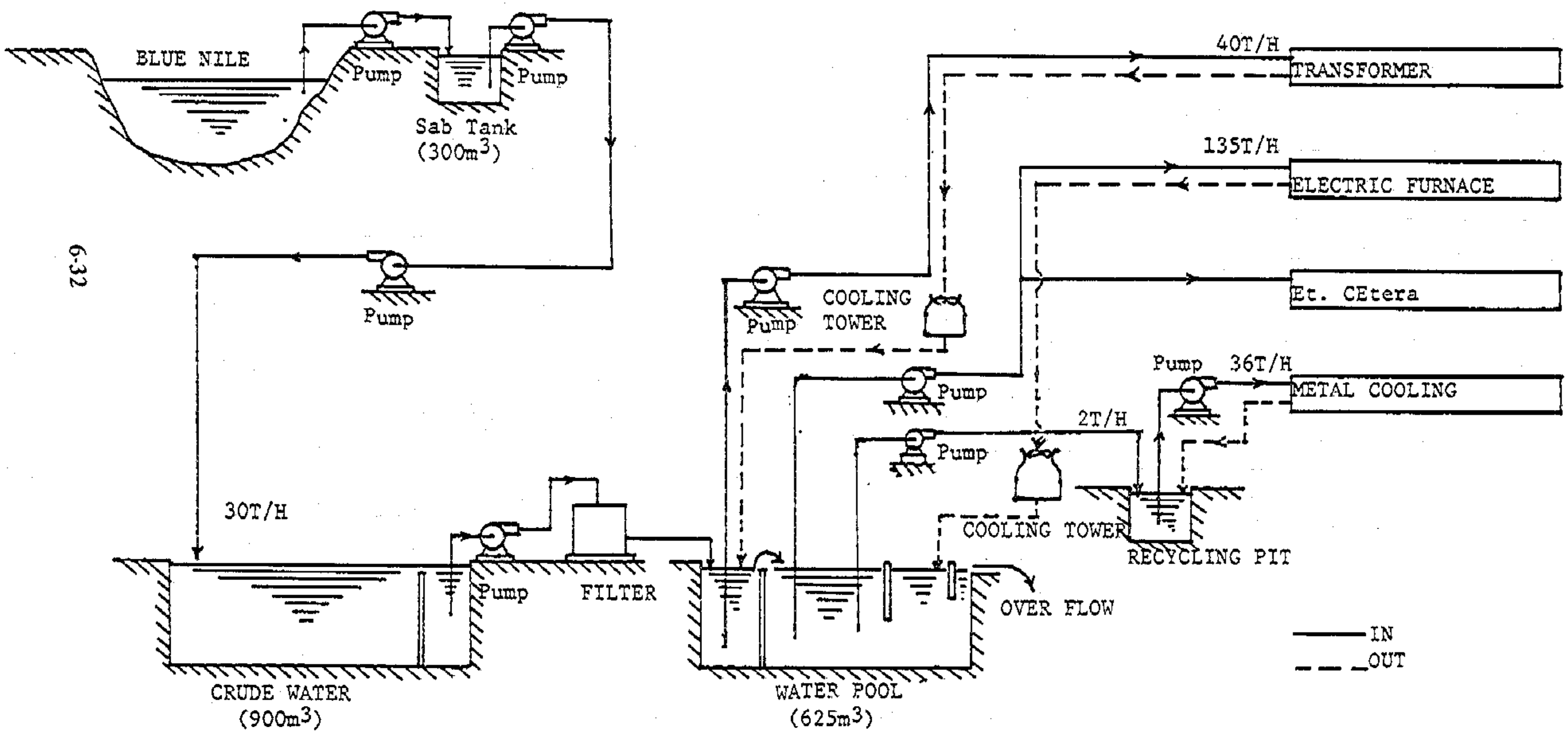


Table 6-5 Equipment List

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
Raw Material Receiving Facility	Chromium ore yard	Concrete floor	1,250 m^2	Chromium ore yard	Concrete floor	2,520 m^2
	Silica stone yard	Concrete floor	200 m^2	Silica stone yard	Concrete floor	400 m^2
	Coke yard	Concrete floor	1,000 m^2	Coke yard	Concrete floor	2,000 m^2
	Bauxite yard	Concrete floor	150 m^2	Bauxite yard	Concrete floor	350 m^2
	Carbon paste yard	Indoor	140 m^2	Carbon paste yard	Indoor	300 m^2
Raw Material Processing Facility	Receiving hopper	5 m^3 with vibrator	2 units	Receiving hopper	7 m^3 with vibrator	2 units
	Feeder	20 t/hr.	2 units	Feeder	40 t/hr.	2 units
	Belt conveyor	20 t/hr.	1 unit	Belt conveyor	40 t/hr.	1 unit
	Vibration sieve	20 t/hr.	1 unit	Vibration sieve	40 t/hr.	1 unit
	Crusher	20 t/hr.	1 unit	Crusher	40 t/hr.	1 unit
	Belt conveyor	20 t/hr.	4 units	Belt conveyor	40 t/hr.	4 units
	Shuttle conveyor	20 t/hr.	1 unit	Shuttle conveyor	40 t/hr.	1 unit
	Tank			Tank		
	Chromium ore	50 m^3	1 unit	Chromium ore	55 m^3	2 units
	Silica	10 m^3	1 unit	Silica	15 m^3	1 unit
	Coke	40 m^3	1 unit	Coke	41 m^3	2 units
	Bauxite	10 m^3	1 unit	Bauxite	15 m^3	1 unit

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Remelt	10 m^3	1 unit	Remelt	10 m^3	1 unit
	Feeder	20 t/hr.	5 units	Feeder	40 t/hr.	7 units
	Scale car	1,000 Kg/batch	1 unit	Hopper scale	500 Kg/batch	5 units
	Belt conveyor	10 t/hr.	1 unit	Belt conveyor	20 t/hr.	1 unit
	Cushion tank	3 m^3	1 unit	Cushion tank	6 m^3	1 unit
	Feeder	10 t/hr.	1 unit	Feeder	20 t/hr.	1 unit
	Belt conveyor	10 t/hr.	1 unit	Rotary conveyor	20 t/hr.	1 set.
	Reversible conveyor	10 t/hr.	1 unit	Hopper	0.2 m^3	13 units
	Shuttle conveyor	10 t/hr.	1 unit	Chute	20 t/hr.	1 unit
	Furnace-top-bin	3.6 m^3	6 units	Furnace-top-bin	4.5m^3 x 12.5m^3x1	13 units
	Feeder	10 t/hr.	6 units	Feeder	20 t/hr.	1 set
	Paste container		1 set	Paste container		1 set
Electric Furnace Facility	Electrode lifting device	Winch	3 sets	Electrode lifting device	Winch	3 sets
	Electrode cylinder	Water-cooling for lower part	3 sets	Electrode cylinder	Water-cooling for lower part	3 sets
	Electrode pushdown device	Electric type	3 sets	Electrode pushdown device	Air	3 sets
	Terminal hanging frame	Water-cooling	3 sets			

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Carbon case	Steel structure, 800ϕ	3 sets	Carbon case	Steel structure, 1,050ϕ	3 sets
	Secondary power supply device	Copper tube, copper plate	3 sets	Secondary power supply device	Copper tube, copper plate	3 sets
	Electrode holder	Water-cooling, 6 pcs./set, set bolt	3 sets	Electrode holder	Water-cooling, 6 pcs./set	3 sets
				Pressure ring	Air	3 sets
	Furnace body	6.5 mϕ x 3.3 mH	1 unit	Furnace body	9.0 mϕ x 5.5 mH	1 unit
	Furnace body lining	223.5 t	1 set	Furnace body lining	521.8 t	1 set
	Slag ladle	0.6 m^3	5 units	Slag ladle	1.3 m^3	5 units
				Metal ladle	0.7 m^3	4 units
	Trough		1 set	Trough		1 set
	Skimmer		1 set			
	Emergency water tank	10 m^3	1 unit	Emergency water tank	10 m^3	2 units
	Air-cooling blower for cylinder	80 m^3/min.	3 pcs.	Air-cooling blower for cylinder	90 m^3/min.	3 pcs.
	Air-cooling blower for furnace bottom	415 m^3/min.	2 pcs.	Air-cooling blower for furnace bottom	590 m^3/min.	2 pcs.
	Air-cooling blower for strand	142 m^3/min.	3 pcs.			

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Chute blower	60 m^3/min.	6 pcs.	Chute blower	75 m^3/min.	13 pcs.
	3 Fℓ blower	100 m^3/min.	3 pcs.	3FL blower	120 m^3/min.	3 pcs.
	Suspension crane	3 t	1 unit	Suspension crane	3 t	1 unit
	Electric welder		2 pcs.	Spot welder		1 set
				Elevator for personnel/cargo	1,000 Kg	
Finished Product Treatment	Bed for finished product	1m x 2m x 0.3 m	5 pcs.	Bed for finished product	1.5m x 2.5m x 0.3m	5 pcs.
	Finished product cooling yard	Concrete floor	60 m^2	Finished product cooling yard	Concrete floor	70 m^2
	Slag cooling yard	Concrete floor	30 m^2	Slag cooling yard	Concrete floor	65 m^2
	Cooling water service pit	Concrete floor	4.5 m^2	Cooling water service pit	Concrete floor	
	Cooling water pump	0.6 m^3/min.	2 units	Cooling water pump		2 units
	Sprinkler		1 set	Sprinkler		1 set
	Kneader	Clay kneading	1 unit	Kneader	Clay	1 unit
	Mixer	Sand	1 unit	Mixer	Sand	1 unit
	Finished product fine breaking yard	Concrete floor	200 m^2	Breaking yard	Concrete floor	250 m^2
				Giant breaker		1 unit
	Finished product selection yard	Concrete floor	200 m^2	Receiving hopper	3 m^3	1 unit

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
				Feeder	10t/hr.	1 unit
				Vibration sieve	10 t/hr.	1 unit
				Crusher	10 t/hr.	1 unit
				Belt conveyor	10 t/hr.	1 unit
				Rotary conveyor	10 t/hr.	1 unit
	Platform scale	20 t	1 unit	Platform scale	25 t	1 unit
	Overhead crane	7.5t/3.5t	2 units	Overhead crane	35t/15t	2 units
	Finished product yard	Concrete floor	300 m^2	Finished product yard	Concrete floor	600 m^2
	Slag yard	Concrete floor	65 m^2	Slag yard	Concrete floor	140 m^2
Dust Collector	Exhaust tower		2 pcs.	Exhaust tower		2 pcs.
	Furnace-top damper		2 sets	Furnace-top damper		2 sets
	Cyclone	3mϕ x 5.5 mH	1 unit			
	Rotary valve		1 unit			
	Exhaust smoke stack	1.25 mϕ x 15 mH	1 unit			
				Pre-duster	3.2 mϕ x 6 mH	2 units
				Rotary valve		2 units

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
				Bag filter	Bag 144 x 7	1 set
				Rotary valve		7 units
				Screen conveyor		1 unit
	Blower	1,080 m^3/min., 75 KW	1 unit	Blower	1,200 m^3/min., 150 KW x 2	1 unit
	Mixer		1 unit	Mixer		1 unit
	Pallet		1 set	Pallet		1 set
Electric Power Receiving/ Distribution Facility						
— Electric Furnace Equipment	Furnace transformer	6,000 KVA	1 unit	Furnace transformer	4,667 KVA	3 units
	Raw material input control panel		1 set	Raw material input control panel	Graphic	1 set
				Weighing control panel		1 set
				Automatic discharge control panel		1 set
	Transformer control panel		1 set	Transformer control panel		1 set
	Electrode lifting control panel		1 set	Electrode lifting control panel		1 set

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Electrode lifting operation panel		1 set	Electrode lifting operation panel		1 set
	Push-down operation panel		3 sets	Push-down operation panel		1 set
	Blower operation panel		2 sets	Blower operation panel		1 set
	Finished product cooling pump operation panel		1 set	Finished product cooling pump operation panel		1 set
	Dust collector operation panel		1 set	Dust collector operation panel		1 set
– Main Electric Power Receiving Facility	Switch cubicle for power receiving		1 set	Instrument transformer		1 set
	Switch cubicle for furnace		1 set	Instrument converter		1 set
				11 KV Switch cubicle		1 set
				0.415 KV Switch cubicle		1 set
	Power transformer	750 KV	1 unit	Power trnasformer	1 500 KVA	1 unit
	Electric power control panel		1 set	Electric power control panel		1 set
	Power transformer control panel		1 set	Power transformer control panel		1 set

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
				Condenser	33 KV, 2,000 KVA; 33 KV, 3,000 KVA	1 set 1 set
				Series reactor	13%, 260 KVA 13%, 390 KVA	1 unit 1 unit
				Condenser control panel		1 set
– Electric Power Receiving Equipment for Pump Startup	11 KV Switch cubicle Power transformer	200 KVA	1 set 1 unit	11 KV Switch cubicle Power transformer	300 KVA	1 set 1 unit
Utilities Equipment						
– River Water Transmission Device	Submerged pump	0.17 m^3/min.	2 units	Submerged pump	0.5 m^3/min.	
	Sub-tank	Made of concrete	200 m^3	Sub-tank	Made of concrete	300 m^3
	Pressure pump					
	First stage	0.17 m^3/min.	2 units	First stage	0.5 m^3/min.	2 units
	Second stage	0.17 m^3/min.	2 units	Second stage	0.5 m^3/min.	2 units
– River Water Supply	Settlement pond	Made of concrete	800 m^3	Settlement pond	Made of concrete	900 m^3
	Reservoir	Made of concrete	450 m^3	Reservoir	Made of concrete	625 m^3
	Filter pump	0.17 m^3/min.	2 units	Filter pump	0.5 m^3/min.	2 units
	Filter	0.17 m^3/min.	2 units	Filter	0.5 m^3/min.	2 units
	Pool	Made of concrete	180 m^3	Pool	Made of concrete	200 m^3

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Transformer cooling pump	0.33 m^3/min.	2 units	Transformer cooling pump	0.67 m^3/min.	2 units
	Electric furnace cooling pump	0.83 m^3/min.	2 units	Electric furnace cooling pump	3.0 m^3/min.	2 units
	Cooling tower	10 t/hr.	2 units	Cooling tower	70 t/hr.	2 units
	Cooling tower circulation pump	0.2 m3/min.	2 units	Cooling tower circulation pump	0.4 m^3/min.	2 units
	Finished product cooling makeup pump	0.06 m^3/min.	2 units	Finished product cooling makeup pump	0.006 m^3/min.	2 units
– Air Device	Compressor	1.4 m^3/min.	2 units	Compressor	7.7 m^3/min.	2 units
	Receiver tank	3 m^3	1 unit	Receiver tank	5 m^3	1 unit
				After cooler		1 unit
– Fuel Oil Device	Heavy oil tank	10 t	1 unit	Heavy oil tank	10 t	1 unit
				Ladle dryer burner		1 unit
	Mobile burner	250 ℓ/day	2 units	Mobile burner	250 ℓ/day	2 units
	Gasoline tank	10t, underground type	1 unit	Gasoline tank	15t, underground type	1 unit
	LGO tank	10 t, underground type	1 unit	LGO tank	15 t, underground type	1 unit

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Service tank	0.4 m^3	2 units	Service tank	3 m^3	1 unit
– Transport Vehicle	Shovel loader	3 t	3 pcs.	Shovel loader	3 t	4 pcs.
	Dump truck	10 t	3 pcs.	Dump truck	10 t	3 pcs.
	Forklift	2 t	2 pcs.	Forklift	3 t x 1, 2 t x 1	2 pcs.
	Truck scale	40 t	1 pc.	Truck scale	40 t	1 pc.
	Commutation bus	50 seaters	1 pc.	Commutation bus	50 seaters x 1, 25 seaters x 1	2 pcs.
– Instrumentation	Intake pump control panel		1 set	Intake pump control panel		1 set
	Pressure pump control panel		2 sets	Pressure pump control panel		2 sets
	Filter control panel		1 set	Filter control panel		1 set
	Cooling water pump control panel		1 set	Cooling water pump control panel		1 set
	Cooling tower control panel		1 set	Cooling tower control panel		1 set
	Compressor control panel		2 sets	Compressor control panel		2 sets
	Heavy oil pump control panel		1 set	Heavy oil pump control panel		1 set

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
— Communication Device	Telephone for exchange line	2 of office, 1 of operation room	3 circuits	Telephone for exchange line	2 of office, 1 of operation room	3 circuits
	Telephone for extension	20 circuits	1 set	Telephone for extension	20 circuits	1 set
	Wireless telephone	Khartoum 1 circuit Mine 1 circuit	1 set	Wireless telephone	Khartoum 1 circuit Mine 1 circuit	1 set
Auxiliary						
—Analysis Device	Automatic chemical scale		1 pc.	Automatic chemical scale		1 pc.
	Sample melting furnace		1 pc.	Sample melting furnace		1 pc.
	Dryer		1 pc.	Dryer		1 pc.
	Pure water device		1 pc.	Pure water device		1 pc.
	Burning furnace		1 pc.	Burning furnace		1 pc.
	Jaw crusher		2 pcs.	Jaw crusher		2 pcs.
	Top grinder		1 pc.	Top grinder		1 pc.
—Machine Tools	Shear		1 unit	Shear		1 unit
	Lathe		1 unit	Lathe		1 unit

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
	Drilling machine		2 units	Drilling machine		2 units
	Grinder		1 unit	Grinder		1 unit
	Bending roller		1 unit	Bending roller		1 unit
	Forming lathe		1 unit	Forming lathe		1 unit
	Bending machine		1 unit	Bending machine		1 unit
	Electric winch		1 unit	Electric winch		1 unit
	Suspension crane	3 t	1 unit	Suspension crane	3 t	1 unit
Building related						
– Raw Material Processing Building	Receiving hopper shed		100 m^2	Receiving hopper shed		100 m^2
	Raw material breaking room		152 m^2	Raw material breaking room		154 m^2
	Raw material blending room		130 m^2	Raw material blending room		165 m^2
–Electric Furnace Building	Electric furnace shed		320 m^2	Electric furnace shed		624 m^2
	Finished product treatment shed		675 m^2	Finished product treatment shed		792 m^2
	Paste warehouse		150 m^2	Paste warehouse		300 m^2

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
— Finished Product Breaking Building				Finished product breaking room		180 m^2
				Finished product receiving hopper shed		60 m^2
—Maintenance Plant	Electrode case fabrication plant		225 m^2	Electrode case fabrication plant		225 m^2
	Repair shop		450 m^2	Repair shop		450 m^2
— Analysis Room	Analysis room		112.5	Analysis room		112.5
—Commodity Warehouse	Spare parts house		225 m^2	Spare parts house		225 m^2
	Warehouse for consumer goods		225 m^2	Warehouse for consumer goods		225 m^2
—Office	Office		330 m^2	Office		330 m^2
—Pump Blower Room	Water intake room		20 m^2	Water intake room		20 m^2
	Pressure pump room		10 m^2	Pressure pump room		10 m^2
	Cooling water pump room		81 m^2	Cooling water pump room		108 m^2
	Blower room		30 m^2	Blower room		98 m^2

Name of Equipment	Case A			Case B		
	Item	Specifications	Quantity	Item	Specifications	Quantity
–Welfare, Others	Recreation facilities		621.5 m^2	Recreation facilities		621.5 m^2
	Guard station		21 m^2	Guard station		21 m^2
	Chapel		25 m^2	Chapel		22.5 m^2
	Garage	Roof only	270 m^2	Garage		270 m^2
	Watching station	4m^2 x 4 stations	16 m^2	Watching station	4 m^2 x 4 stations	16 m^2
	Weighing room		30 m^2	Weighing room		30 m^2

2. Construction Work

2–1 Status Quo of the Construction Industry in Sudan

(1) Service agency for construction work

The development of private houses and public buildings is financed almost entirely by the foreign countries. For developments depending mostly on imported materials, the finance companies such as Sudan Kuwait Building and Construction Company undertake the job with their foreign exchange appropriated for financing purposes.

Partly because of the insufficiency of the private sector growth, the government plays an important role in every field of the construction department. The Ministry of Construction & Public Works, the Public Corporation for Building and Construction, the Road & Bridge Corporation and the Civil Aviation Department are cited as the government agencies.

1) Ministry of Construction & Public Works
The Ministry has under its jurisdiction mainly the operations such as construction or repairs of the central government-related buildings. Transportation facilities and housing projects belong to the other Ministry.

Construction work sometimes is undertaken by this Ministry. In most cases, however, it is carried out on a contractual basis. Under this method, an order is placed with the local private contractors depending on the case. But the job is preferentially given to the Public Corporation for Building and Construction, a public consultant.

2) Public Corporation for Building and Construction
Due to the technical level of private contractors, this entity was established in July, 1978. It performs the work on an independent profitability basis. In almost all the cases, this corporation obtains the orders through negotiation and undertakes an order through the bid concerning project items under international tender.

3) Private Contractors
The local private contractors are extremely weak in terms of financing capability and technical level. They have almost no experience in civil engineering. Even as to is construction work, there is no fulfiledged private contractor because the important items are wrought exclusively by the Public Corporation for Building and Construction.

4) Foreign Contractors

As to the maintenance of infrastructure of large-size buildings through construction buildings, transportation system, communications, network, etc., foreign consultants are relied on in all the stages ranging from the preparation to the execution of development projects.

Before, almost all the public undertakings were directly carried out by the government agency. Recently, however, due to the insufficient capability of the government agency to deal with development projects which become more and more active on a larger scale than ever, or the relationship with financiers, etc., most of the construction works are performed on a contractual basis. In addition, on account of the unavailability of the local private contractors experienced in civil engineering, there are many contracts of construction that foreign contractors perform.

The foreign countries which are eager to deal with construction works in Sudan are Italy, West Germany, Yugoslavia, etc.

(2) Local procurement

1) Construction materials

Except for some, almost all consturction materials are not manufactured in Sudan. For this reason, the Sudanese contractors are depending on the imported ones.

The items which can be procured in Sudan are aggregate, structural iron, steel pipe (1/2 to 2.0"), red brick, galvanized iron sheet (No. 24 to 26), a small quantity of cement, etc. These items are produced in small quantities. Therefore, in the case of a project like this time's ferrochrome smelting plant construction which calls for a large quantity of materials in a brief period of time, it is considered appropriate to make plans on a precondition that all the required materials be imported.

2) Construction equipment

Around the metropolital Khartoum area, brisk construction activities such as erecting roads, buildings and houses are noticed, and construction equipment which is considered acceptable anyhow by our standard are of foreign origin. The machines of the type such as the main contractors possess can be obtained under a lease contract. Nevertheless, these machines are not fully utilized because of their high rental. Truck cranes, bulldozers, trucks, etc. can be procured locally, but their available type and number are insufficient. It is impossible to locally procure small-size machines such as belt conveyor, electric welder, iron bar working machine, rammer, chain block and other equipment related to electric installations, etc. This situation necessitates our own supply of such equipment at the time of construction.

Concerning light oil, gasoline, lubricants, etc. which are used for these construction machines, their quantities available on the local market are extremely small and besides are difficult to obtain. For these reasons, it is recommended that these supplies be brought in together with the machinery.

3) Contractors

In the Damazin area where the plant site construction is scheduled, no contractors are found. However, in the capital Khartoum, many of them are available, and they are handling almost all the small and medium-size construction works. When it comes to the large-scale construction work, special type building work, etc., foreign enterprises or foreign financed construction companies perform such works with the dispatch of foreign engineers and technicians whenever they are started. Consequently, for this time's plant construction, the building for electric furnace body, mechanical and electrical facilities, etc. of the special construction type will be fabricated and assembled temporarily abroad and brought into the site. Then, they will be installed by the foreign technical staff. In the meantime, other auxiliary buildings for geological survey, pile driving, foundation work, office, storage, etc. could be designed and installed by the local contractors under a collective order.

4) Construction laborers

Due to the fact that specialized artisans of different professions are not available in the Damazin area, they will be sent from Khartoum. Consequently, their accommodation quarters will have to be arranged at the time of construction so that the labor cost will be higher than the Khartoum market rate by 10 to 20%. As to the procurement of labor in the Damazin area, only construction laborers, odd-job men or laborers working under each artisan are required. Therefore, many such laborers will be hired with comparative ease.

2–2 Site Preparation

(1) Topographical survey

As mentioned earlier, the approximate location of the plant site has already been determined as a result of the site survey. However, for preparing the site, it is necessary to carry out an accurate survey covering the ground level, flora, drainage system, roads, buildings, etc. in the neighborhood of the site. For this purpose, it is required to set a reference point, clearly plot coordinates and levels for the reference point and at the same time illustrate all land marks on the plot.

(2) Ground survey

First, the outline of geological structure and nature, underground water level, etc. inside the site will be grasped and then a building arrangement planned. At the same time, it will be determined what type of foundation structure is required for the buildings and which stratigraphic section should be used for supporting the buildings. Data thus obtained will serve as one for working out a policy for establishment of the method, extent, etc. of the following full-scale survey. Normally, in the preliminary survey, boring and standard intrusion test will be performed in the main. The results of boring survey by load agency are shown in Table 6-6.

Table 6-6 Plant Site Geology

Dimension		Symbol	Name	Features
m/m	m/m			
1,000	750 1,300		Black clay	Cotton soil, cracked.
2,000 3,000	3,000		Brown clay	Carbonates, mottled.
4,000 5,000	5,000		Middle grain sand	Quartz including mica, circular grain to half-angular size (contains moisture).
6,000 7,000 8,000	8,100		Coarse grain	Quartz, feldspar and half-angular grain (high percentage of moisture content).
			Sand clay	Plastic, contains pebble.

1) Basic formation

The Blue Nile River has a rock formation of gneiss, schist and marble and in its area, new granite or super-basic silt (new one the same as the annular composite rock formation in Ingessana Hills) has interpenetrated. At a point 10 km west of the scheduled smelting plant site, there are exposed super-basic rock (J. Gargado), new granite (J. Abu Garin) and marble. Gneiss and marble are exposed near the Damazin Dam site. Rocks have sent in materials which are helpful in forming a soil layer. It is considered that there should possibly be marble at the bottom of the scheduled smelting plant site.

2) Planning

Based on the above-mentioned field survey report, it is presumed that at the more than 8 m depth, coarse granular sand should have been replaced by pebble way deep into the rock bottom. However, at this moment, the layer thickness and the stratum at the more than 8 m depth cannot be identified. Therefore, the Study Team have to wait for this report so that a definite ground bearing capacity may be grasped. This time, The Study Team have worked out the equipment plan on an assumption that a single pile (up to 12 m long) could reach the support layer.

3. Construction Schedule

The construction schedule referred to here is a period from the effective date of a contract through the date of commencing the operation. As explained in the separate Man-Hour Table, the estimated period is 36 months for Case A and 48 months for Case B. It is considered that during this period, the engineers and technicians concerned with the construction project will have to undergo training. Throughout the entire period, 320 man-month and 540 man-month are estimated for Case A and Case B respectively.

The construction schedules for Case A and Case B are idicated in **Fig. 6-17** and **Fig. 6-18.**

4. Estimation of Consturction Cost

4–1 Basic Idea on Estimation of Construction Cost

(1) Classification of import and local procurement

The undermentioned criteria are used in principle.

– Purchased equipment:	Import
– Installation work:	Local procurement

– Construction materials: Local procurement as far as circumstances allow.

Considering the results of the site survey, The Study Team have arranged so that the ratio of local procurement may be sufficiently high.

(2) Estimation criterion

1) Timing of estimation

– Import portion:	International market price of March, 1981
– Local procurement portion :	Domestic market price in Sudan of March, 1981

2) Used currency & exchange rate

– Import portion:	US dollar
– Local procurement portion:	Conversion from S£ to US dollars
– Exchange rate:	One US dollar = S£ 0.79 (March, 1981)

Considering the results of the site survey, The Study Team have arranged so that the ratio of local procurement may be sufficiently high.

(3) Impact of price fluctuation

Under this study, the construction cost is based on an estimate at the current market price as of March, 1981 but is not based on an estimated price at the time of an actual construction. The impact of price fluctuation does not occur at the same rate in product selling price, raw material purchasing price (including energy price) or construction cost. The project's profitability would be significantly influenced by the absolute linkage of the increase rate of the abovementioned prices and cost instead of the absolute level of the said increase rate. Consequently, in this study, the price fluctuation is not involved throughout it in accordance with the general rule of studies of this type so that an uncertain estimation may be eliminated.

(4) Taxation on imported equipment

Under this study, the estimation is made on an assumption that a tax exemption would apply to imported machines under the Encouragement Investment Act 1981.

4–2 Required Construction Cost

(1) Construction cost

The construction cost applicable to Case A and Case B is as follows:

Gross Construction Cost

(Unit: X10^3 US$)

	Import	Local Procurement	Total
Case A	12,355	5,395	17,750
Case B	21,720	8,395	30,615

For details, refer to Table 6-6.

(2) Ratio of local procurement

As mentioned above, as a result of the site survey meant for increasing the ratio of local procurement, the said ratio has been increased to a considerably high 30% or so, most of which accounts for civil engineering-related items.

Ratio of Import/Local Procurement

	Import	Local Procurement	Total
Case A	69.6	30.4	100.0
Case B	70.9	29.1	100.0

Table 6-6 Estimated Construction Costs

(Unit: 10^3 US$)

Item	Case A			Case B			Detailed Cost Element
	Imports	Domestic	Total	Imports	Domestic	Total	
Raw Material conveying and Blending facilities	685	290	975	910	610	1,520	Raw material receiving and storage facilities, blending equipment.
Electric Furnace Facilities	2,245	380	2,625	5,500	490	5,990	Electric furnace, trnasformer for furnace, dust collector and other equipment.
Product Handling Facilities	5	50	55	555	65	620	Product crushing equipment, storage yards for products and slag.
Power Receiving and Transforming Facilities	310	575	885	930	1,065	1,995	Power receiver and distributor, power receiving equipment for pumps, power transmission equipment.
Utilities Facilities	960	350	1,310	1,200	905	2,105	Water pumping and transporting equipment, water supply equipment, air compressor, equipment for fuels, vehicles and others.
Subsidiary equipment	415	10	425	375	80	455	Office equipment, workshop machinery and Laboratory equipment.
Buildings	865	1,640	2,505	1,405	2,315	3,720	Building for electric furnace, product handling room, buildings for welfare facilities and other auxiliary buildings.
External Structure	120	595	715	175	830	1,005	Paved service roads in the plant site, ditches, fences, lighting and others.
Construction Materials and Machinery	665	795	1,460	670	800	1,470	Road from the railway station to the plant site, trucks, cranes, buldozers, stagings and temporary facilities.
Materials for Operation	160	30	190	310	60	370	Consumables necessary for plant operation such as oxygen.
Spare Parts	355	–	355	640	–	640	Spare parts for machinery.
Sub-Total	6,785	4,715	11,500	12,670	7,220	19,890	
Various Charges	680	–	680	1,270	–	1,270	
Packing and Inland Transportation	970	–	970	1,615	–	1,615	
Ocean Freight	1,630	–	1,630	2,540	–	2,540	
Unloading and Overland Transportation	150	680	830	270	1,175	1,445	
Supervision	2,140	–	2,140	3,355	–	3,355	
Sub-Total	5,570	680	6,250	9,050	1,175	10,225	
TOTAL	12,355	5,395	17,750	21,720	8,395	30,115	

Fig. 6-17 Construction Schedule (Case A)

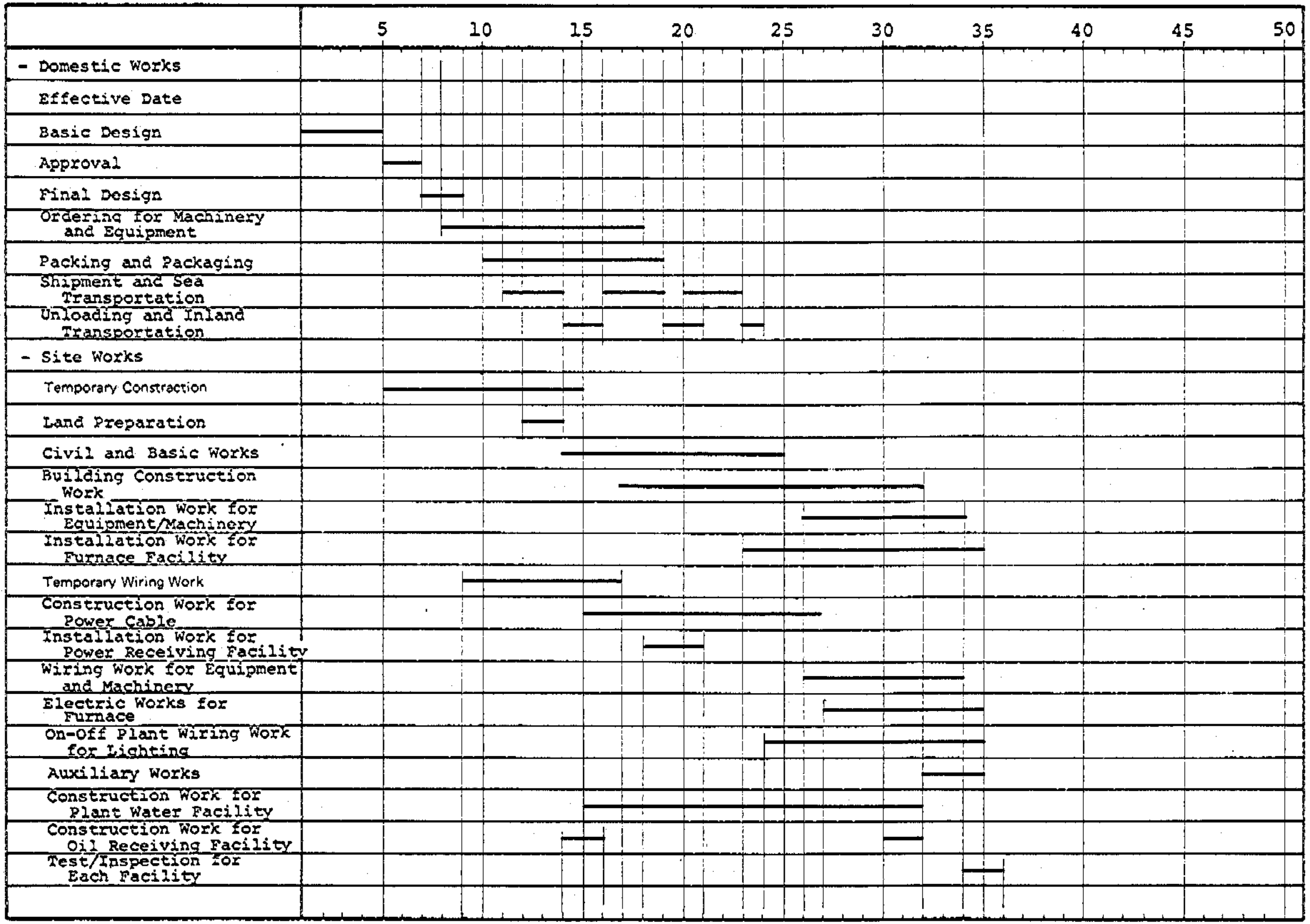
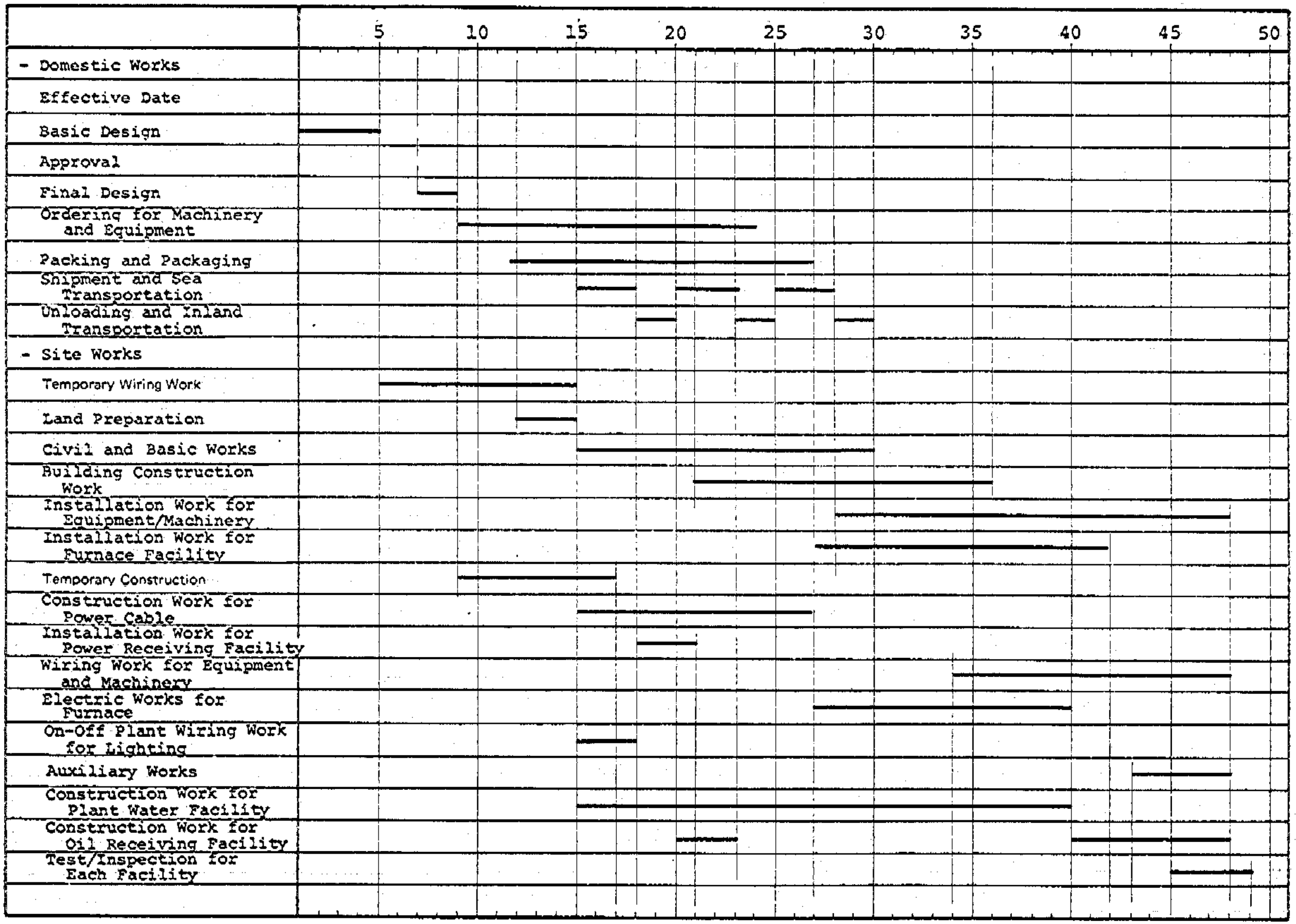


Fig. 6-18 Construction Schedule (Case B)



CHAPTER 7

ORGANIZATION AND MANPOWER PLANNING

1. Organization and Management

1–1 Overall Organization

A proper organization has to be established for efficient implementation of The Project. Functions to be fulfilled by the organization include supervision of construction works, procurement of materials and equipment, marketing of products, management of production processes, accounting and administrative affairs.

There should be two separate contracts covering works in Khartoum and in Damazin as specified subsequently. First, the Head Office would be set up in Khartoum to handle administrative affairs, overall planning, procurement and marketing as well as matters associated with the central government. Secondly, the ferrochrome plant in Damazin would deal with matters directly related to plant operation and management of production facilities.

1–2 Head Office

The head office in Khartoum would be organized in the form given in Fig. 7-1. The same form of organization is assumed for both Case A and Case B.

1–3 Ferrochrome Plant

A possible form of organization of the ferrochrome plant is presented in Fig. 7-1. Major functions of the director and each department or division are listed below.

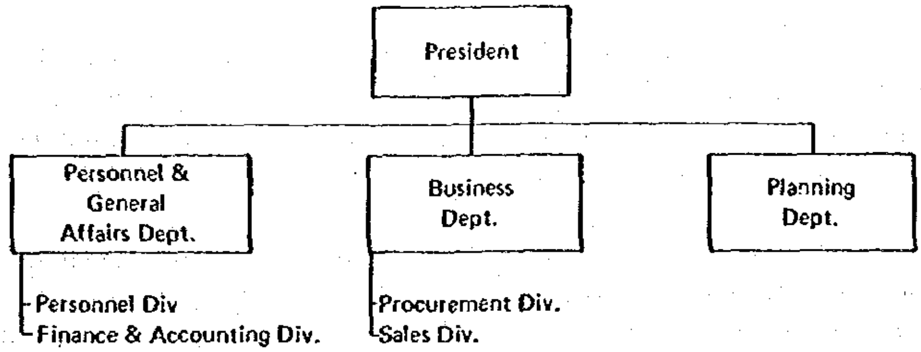
Director - - - - - Overall management of plant operation.

(1) Personnel & General Affairs Department - - - - - General and administrative affairs.
    Personnel Division - - - - - Formulation of recruitment and training programs, welfare services for employees.
    Finance and Accounting Division - - - - - Financing and repayment of loans, accounting.

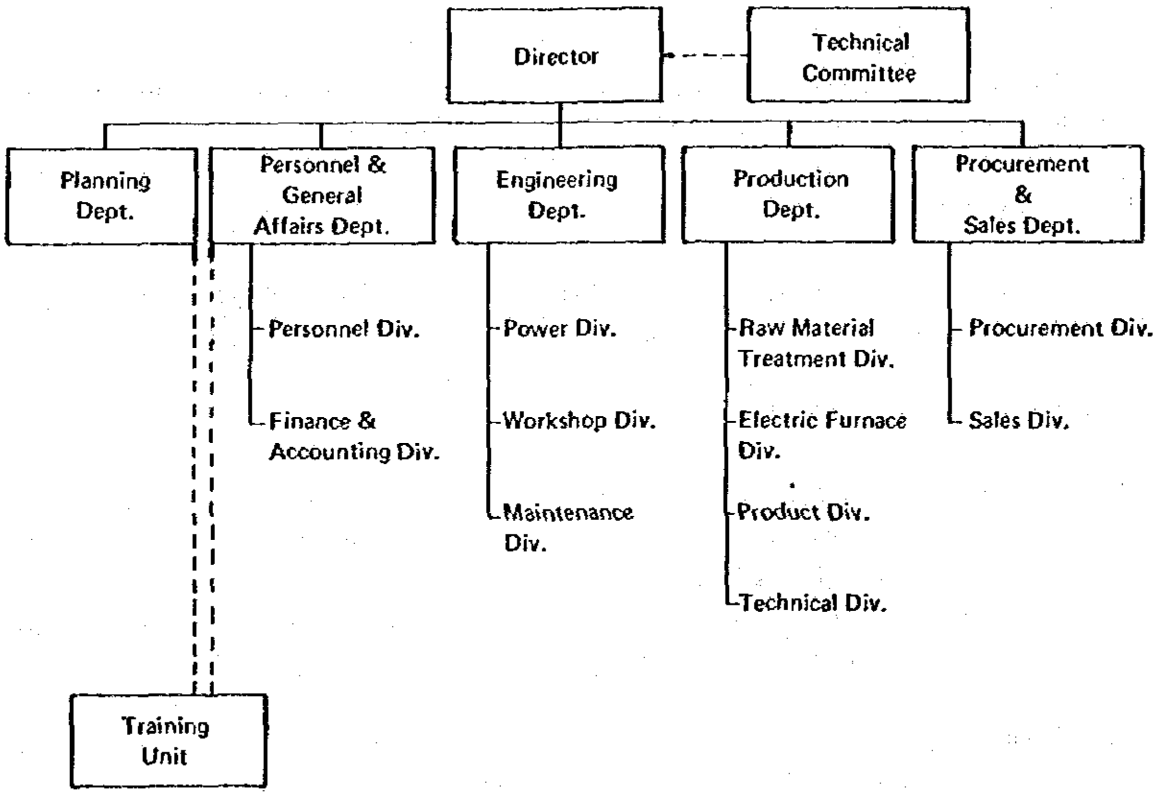
(2) Engineering Department - - - - - Design and Supervision of construction works, management and maintenance of workshops and a repair house.
    Power Division - - - - - Management and control of power receiving facilities.
    Workshop Division - - - - - Management of workshop operation.
    Maintenance Division - - - - - Maintenance of plant facilities.

Fig. 7-1 Organization Charts

(a) Head Office in Khartoum



(b) Ferrochrome plant in Damazin



(3) Production Department ----- Management of production processes.

Raw Material Treatment Division ----- Management and operation of raw material blending and treatment processes.

Electric Furnace Division ----- Management and operation of electric furnaces.

Product Division ----- Management of final processing of products.

Technical Division ----- Analysis of technical materials, quality control.

(4) Procurement and Sales Department

Procurement Division ----- Procurement of materials and equipment, inventory management.

Sales Division ----- Control and marketing of products.

(5) Planning Department ----- Formulation of annual production schedule and overall budget plans, cost estimates, monitoring and evaluation of production performance.

In addition to these departments listed above, some supporting units will also be required for the orgnization to function properly. A technical committee will assist the director in fulfilling its roles of supervision and coordination. A training unit should be established under a separate program, but its operation has to be well coordinated with the implementation of The Project and on-the-job training. The coordination is made by the technical committee and Planning Department as well as Personnel and General Affairs Department.

2. Manpower Planning

2-1 Requirements

(1) Head office

Manpower requirements for the head office in Khartoum are summarized in Table 7-1.

(2) Ferrochrome plant

Labor force required to operate the ferrochrome plant in accordance with the organization presented above is summarized in Table 7-2 for the alternative plant scales. This plan has been drafted taking into account the severe working conditions mainly attributable to the local climate of the area, relatively low skill levels available and lack of experience in modern technology industry. For those workshops that need to be operated continuously, 20% is added to the total number of workers under foremen as supplementary workers. Most of managerial and supervising positions would be assumed by expatriates, and some engineers

Talbe 7-1 Manpower Requirements of Head Office

	Head	Chief	Clerk	Workers	Subtotal
President	1				1
Personnel & General Affairs Dept.	1				1
Personnel Div.		1	1	1	3
Finance & Accounting Div	-	1	1	1	3
Business Dept.	1				1
Procurement Div.		1	1	1	3
Sales Div.		1	1	1	3
Planning Dept.	1	1	1	1	4
TOTAL	4	5	5	5	19

and technicians may also have to be sent from abroad. Other engineers and technicians as well as skilled workers will be recruited in the Sudan, but some vocational training would be indispensable. On-the-job training would be effective and realistic, but a separate program would also be necessary. Such a program should be initiated soon after a final decision is made on the implementation of The Project.

2–2 Availability: Macroscopic Pictures

According to the latest census taken in 1973 (the second in the nation), the total population of the Sudan was approximately 14.8 million and that of Blue Nile Province and the town of Damazin was respectively 3.8 million and 12 thousand as shown in Table 7-3. The annual growth rate between the first and the second census (1955 – 73) was higher in urban areas as indicated by the figures in Table 7-2. The population growth is estimated to be higher for the period after the second census, and a rough estimate of total population in 1981 is about 22 million for the Sudan and 21.5 thousand for the Damazin area.

Distribution of labor force by sector in 1973 is given in Table 7-4 for both the Sudan as a whole and Blue Nile Province. The agricultural sector is clearly dominant, but the mining and quarrying sector as well as manufacturing sector have grown considerably since the time of the latest census.

Distribution of labor force by occupation shown in Table 7-5 for Blue Nile Province gives some ideas on types of skills available in this locality. Most of professional and technical

Table 7-2 Distribution of Labor Force Required for Ferrochrome Plant

(a) Case A (7,000 t/yr. ferrochrome production)

Director	1					1
	Head	Chief Clerk	Chief	Clerk	Worker	Sub-Total
Personnel & General Affairs Dept.	1					1
Personnel Div.		1	2	2	5	10
Finance & Accounting Div.		1	2	2	–	5
Procurement & Sales Dept.	1					1
Procurement Div.		1	1	2	5	9
Sales Div.		1	1	1	3	6
Planning Dept.	1	1	1	5	2	10
	Head	Chief Clerk	Foreman	Skilled worker	Unskilled worker	Sub-Total
Engineering Dept.	1					1
Power Div.		1	3	3	3	10
Workshop Div.		1	2	7	2	12
Maintenance Div.		1	2	5	2	10
Production Dept.	1					1
Raw Material Treatment Div.		1	3	6	5	15
Electric Furnace Div.		1	3	18	10	32
Product Div.		1	1	10	10	22
Technical Div.		1	2	2	–	5
TOTAL	6	12	23	63	47	151

(b) Case B (15,000 t/yr. ferrochrome production)

Director	1					1
	Head	Chief Clerk	Chief	Clerk	Worker	Sub-Total
Personnel & General Affairs Dept.	1					1
Personnel Div		1	2	3	7	13
Finance & Accounting Div.		1	2	3	–	6
Procurement & Sales Dept.	1					1
Procurement Div.		1	2	3	7	13
Sales Div.		1	2	3	5	11
Planning Dept.	1	1	2	7	4	15
	Head	Chief	Fore-man	Skilled Worker	Unskilled Worker	Sub-Total
Engineering Dept.	1					1
Power Div.		1	3	6	5	15
Workshop Div.		1	3	10	4	18
Maintenance Div.		1	3	7	5	16
Production Dept.	1					1
Raw Material Treatment Div.		1	3	9	7	20
Electric Furnace Div.		1	3	21	15	40
Product Div.		1	2	15	15	33
Technical Div.		1	2	3	–	6
TOTAL	6	12	29	90	74	207

Table 7-3 Population of the Sudan

(Unit: person)

	1973	Annual Growth Rate 1955 – 73 %	Rough Estimate 1981
Sudan	14,819,000	2.14	22,000,000
Khartoum (Province)	1,150,000	4.85	–
Blue Nile (Province)	3,804,000	3.50	–
Damazin (Town)	12,233	–	21,500

Table 7-4 Distribution of Labor Force by Sector (the Sudan, Blue Nile Province)

(Unit: %)

Sector	the Sudan	Blue Nile Province
Agriculture, Hunting, Forestry & Fishing	65.2	62.7
Mining & Quarrying	0.1	0.0
Manufacturing	3.9	4.3
Electricity, Gas & Water	1.0	2.4
Construction	2.0	2.6
Commercial	5.4	5.9
Transport, Storage & Communication	3.7	4.5
Financing, Insurance, Real Estate, etc.	0.1	0.0
Community Social & Personal Services	11.0	8.2
Activities not adequately defined	7.5	9.2
TOTAL	100.0	100.0
Unemployed	6.0	4.9

Source: Second Population Census 1973: Sudan.

Table 7-5 Distribution of Labor Force by Occupation (Blue Nile Province)

Occupation	Total Economically Active	Employer	Own Account Worker	Employee	Unpaid Family Worker	Other Unpaid Worker	Unemployed
Professional & Technical	21,800	324	604	20,728	24	77	47
Administrative & Managerial	749	207	204	333	2	–	3
Clerical	7,381	15	104	7,225	13	3	21
Sales	32,131	1,618	27,710	2,028	706	23	46
Service	38,635	884	5,276	32,034	237	84	120
Agricultural, Animal Husbandry, Forestry, Fishing & Hunting	415,541	36,747	246,574	108,121	23,582	86	431
Production, Transport & Labor	91,769	1,510	36,157	52,636	574	258	734
Others	77,980	195	10,610	33,944	705	105	32,421
TOTAL	685,990	41,500	327,239	256,949	25,843	636	33,823

Source: Second Population Census 1973: Blue Nie Province.

workers were employed, and the same is true with clerical workers. Among workers not classified by occupation, however, a large slack exists, and it is considered that they are mostly unskilled workers. These conditions are consistent with the expectation expressed in the latest "Six Year Plan of Economic and Social Development, 1977/78 – 1982/83" that managers, technicians and skilled workers are generally in short supply in the Sudan in the near future, while unskilled workers are relatively abundant.

2–3 Recruitment

Population of the Damazin area is approximately 21,500 as given in Table 7-3, of which about 50% are engaged in agriculture and the rest are making living on governmental, commercial and other activities. Population of surrounding areas is estimated to be about 48,000, most of which are engaged in agricultural and related activities. There seems to be little problem in obtaining unskilled workers except that consideration has to be given to seasonal variations in availability of workers. In particular, many temporary workers may return to their farms during rainy seasons.

The Damazin High School has about 450 students of ages 17 through 21, who are receiving general education in various subjects including mathematics, science (biology, chemistry and physics), languages, geography, history and arts. About 20 to 30 students go to higher education every year after graduation. It is judged that these graduates have sufficient educational background to be trained as skilled workers.

3. Labor Costs

3–1 Wages

Wage levels of different classes of workers have been determined as given in Table 7-6, with reference to data for some existing firms in the Sudan and other relevant documents including "Minimum Wage Law, 1974" and "The Employers and Employed Persons Ordinance, 1948 as amended in 1969/73". These wages include allowances for housing, commuting, shift, family and others as well as employer's share of social insurance. Total annual payments for wages will be S£244,200 or S£298,740 for the plant scale of 7,000 tons or 15,000 tons, respectively, as calculated in Table 7-6..

3–2 Costs of Vocational Training

Ferrochrome production techniques belong to one of the more sophisticated among ferroalloy technology, for which no experience exists in the Sudan. It is, therefore, indispensable to recruit workers of higher educational background and to train them at existing ferrochrome plants in a developed country in order for them to acquire necessary skills and experience.

Number of workers to be sent abroad for training and their period of stay would be as follows:

	Number	Period
Technicians	5	6 months
Foremen	10	6 months

These workers, in turn, will serve for training other Sudanese workers after their return to the country.

Table 7-6 Annual Labor Costs

Worker Class	Wage Level (S₵/year/capita)	Case A		Case B	
		Number of Worker	Payment for Wages (S₵/year)	Number of Worker	Payment for Wages (S₵/year)
Director	5,400	1	5,400	1	5,400
Dept. Head	4,200	5	21,000	5	21,000
Div. Chief	3,240	12	38,880	12	38,880
Foreman (Chief)	1,800	23	41,400	29	52,200
Skilled Worker (Clerk)	1,080	63	68,040	90	97,200
Unskilled Worker	540	47	25,380	74	39,960
TOTAL		151	200,100 1)	211	254,640 2)

Notes: 1) Equivalent to US $253,190/year.
2) Equivalent to US $322,228/year.

CHAPTER 8

OPERATION PLANNING

1. Operation Results

As described in detail in Chapter 3, it is expected to study plans covered by both Case A of 7,000 tons/year and Case B of 15,000 tons/year with regard to the production scale of a ferrochrome smelting plant.

In order to accomplish this production scale, The Study Team examined the operation conditions. The results are as follows:

1–1 No. of Annual Operating Days

From a viewpoint of the electric furnace's characteristics, it is desirable to continue operation on a long-term basis at the ferrochrome smelting plant as far as circumstances allow. As mentioned in Chapter 5, Clause 1-2, judging from the electric supply demand condition in Sudan, it is considered inevitable to shut down the furnaces for approximately two months when the said condition should be the tightest. In the meantime, during this shutdown period, the repair of various equipment will be carried out.

It is considered most appropriate to schedule the said shutdown for July/August when the power generation of the Er Roseires Power Station is reduced.

Considering these various conditions, the number of operating days per year will be 300 days in both Cases A and B. The furnace shutdown period will be from June 28 through August 31.

1–2 Operating Results

In order to estimate the expected operation results when ferrochrome is manufactured using the Ingessana Hills chromium ore, we worked out the material balance and the heat balance.

(1) Preconditions

As explained in Chapter 4, the composition of main and subsidiary raw materials are as shown in Table 8-1.

(2) Ferrochrome manufacturing method

High-carbon ferrochrome manufacturing method is to reduce chromium, iron and

Table 8-1 Raw Material Composition Table (%)

	Cr_2O_3 (Cr)	FeO (Fe)	SiO_2	MgO	$A\ell_2O_3$	Cr/Fe	C
Chromium ore (A)	48 (32.8)	13 (10.1)	10.0	18	5	3.2	
Chromium ore (B)	45 (30.8)	14 (10.9)	10.0	18	7	2.9	
Silica stone			95.0				
Bauxite		5.0 (3.9)	18.4		59.0		
Coke			5.0				85.0
Electrode Paste							80.0

silicon contained in the ore with the assistance of reducing agent (coke) and at the same time, separate SiO_2, $A\ell_2O_3$, MgO, etc. of gangue in the ore. In this case, the important chemical reactions are as follows:

$$7Cr_2O_3 + 27C = 2Cr_7C_3 + 21CO$$
$$Cr_7C_3 + Cr_2O_3 = 9Cr + 3CO$$
$$FeO + C = Fe + CO$$
$$SiO_2 + 2C = Si + 2CO$$

For the commercial production of ferrochrome, it is necessary to charge chromium ore, coke and flux into the electric furnace, and heat and melt the charge at approximately 1,600 to 1,800°C with the electric current applied through the electrode. Thus, the aforementioned reaction can be performed.

At that time, one of the points to which attention should be paid is that the composition of slag should be adjusted to the range of 1.0 to 1.3 for MgO/SiO_2 and 1.2 to 1.6 for $MgO/A\ell_2O_3$. The slag of this composition has a melting point at approximately 1,650°C and its fluidity is satisfactory. In addition, its extraction from the electric furnace is efficient.

Another point of attention is the proper grain size distribution of the charge for the improvement of the electric furnace's thermal efficiency. That is, as mentioned earlier, in the electric furnace, a large quantity of carbon monoxide gas is generated by chemical reaction. Therefore, it is important to discharge the gas smoothly through the raw materials layer. In case a large quantity of fine particle exists in the raw materials, the aforementioned carbon monoxide will not be discharged, resulting in a blowing due to its temporary escape. This will significantly deteriorate the electric furnace's thermal efficiency and in turn, the unit electric consumption. For this reason, various raw material pretreatment methods are available at present. Ferrochrome and slag manufactured in the electric furnace are extracted from the electric furnace at a certain time interval. After ferrochrome and slag were separated by means of specific gravity difference, the former is cast into the mould. The solidified cast ferrochrome is taken out of the mould and is sized to the prearranged dimensions. After this process, it is shipped out.

In the meantime, the slag is thrown into the yard and used as material for road foundation, etc. after solidification.

(3) Material balance

The results of calculating the mateiral input/output when coke and flux are blended with chromium ore for the manufacture of ferrochrome are as shown in Table 8-2.

Based on this material balance, the required quantities of raw materials involved for the manufacture of one ton of ferrochrome are worked out.

(4) Heat balance

The theoretical required calorie calculated for the manufacture of ferrochrome based on the aforementioned material balance are indicated in Table 8-3 covering the heat balance.

Generally, the thermal efficiency of the electric furnace for the manufacture of ferrochrome is 60 to 65%. Therefore, the value obtained after dividing the above theoretical required calorie by 0.6 to 0.65 represents an actually required calorie. The main heat loss of 40 to 35% is represented by a loss in the electric circuit cooling water (holder, transformer) a radiant heat from the furnace body, etc.

(5) Estimation of manufacturing performance

Based on the combined results of the abovementioned mateiral balance and the heat balance, the manufacturing performance per case was obtained after calculation as shown in Table 8-6.

Table 8-2 Material Balance (Case A)

(Based on 1,000 Kg of metal; Unit: Kg)

Item	Unit Consumption	Cr	Fe	SiO_2	Al_2O_3	MgO	C	H_2O
Input								
Chromium ore (A)	2,182	715.7	220.4	218.2	109.1	392.8		21.8
Silica	127			122.8				2.5
Bauxite	296		11.6	54.3	171.5			55.1
Coke	495			24.8			420.9	74.3
Electrode	19						15.3	
Total	3,119	715.7	232.0	420.1	280.6	392.8	436.2	153.7
Output								
Metal	1,000	665.5	225.0	64.3			75.0	
Slag	1,142	38.8	6.8	352.1	280.4	386.9		
Dust	30	11.4	0.2	3.7	0.2	5.9	0.4	
Gas	947						360.8	153.7
Total	3,119	715.7	232.0	420.1	280.4	392.8	436.2	153.7

(a) Gas Volume

$360.8 \times 22.4/12 \div 0.95 = 709$ Nm^3/t ($CO + CO_2 = 95\%$)

(b) FC quantity

Cr portion	665.6 x 36/104	= 230.4 Kg/t-Metal
Fe portion	225.0 x 12/56	= 48.2 Kg/t-Metal
Si portion	30.0 x 24/28	= 25.7 Kg/t-Metal
C portion	75.0 x 1.0	= 75.0 Kg/t-Metal

TOTAL ....379.3 Kg/t-Metal

Suppose the excess rate of FC is 15%: 436.2 Kg/t-Metal

Table 8-3 Material Balance (Case B)

(Based on 1,000 Kg of metal; Unit: Kg)

Item	Unit Consumption	Cr	Fe	SiO_2	Al_2O_3	MgO	C	H_2O
Input								
Chromium ore (B)	2,248	692.4	245.0	224.8	157.4	406.6		21.5
Silica	144			139.4				2.9
Bauxite	227		8.8	41.8	131.7			42.2
Coke	491			24.6			417.6	73.7
Electrode	19						15.3	
Total	3,129	692.4	253.8	430.6	289.1	404.6	432.9	140.3
Output								
Metal	1,000	643.8	246.2	64.3			75.0	
Slag	1,174	38.2	7.4	362.7	288.9	398.6		
Dust	30	10.4	0.2	3.6	0.2	6.0	0.4	
Gas	925						357.5	140.3
Total	3,129	692.4	253.8	430.6	289.1	404.6	432.5	140.3

(a) Gas Volume

$357.5 \times 22.4/12 \div 0.95 = 702$ Nm^3/t ($CO + CO_2 = 95\%$)

(b) FC quantity

Cr portion	643.8 x 36/104	=	222.8 Kg/t-Metal
Fe portion	246.2 x 12/56	=	52.8 Kg/t-Metal
Si portion	30.0 x 24/28	=	25.7 Kg/t-Metal
C portion	75.0 x 1.0	=	75.0 Kg/t-Metal

TOTAL .... 376.4 Kg/t-Metal

Suppose the excess rate of FC is 15%: 432.9 Kg/t-Metal

Table 8-4 Estimation of Unit Electric Power Consumption from Viewpoint of Heat Balance (Case A)

(Based on 1,000 Kg of metal)

Item	Calculation Base	Quantity (Kg)	Calorie ($\times 10^3$ Kcal)
Sensible Heat			
Of metal	(1,650 → 25°C) CP 0.19	1,000	309
Of slag	(1,650 → 25°C) CP 0.24	1,142	445
Of dust	(400 → 25°C) CP 0.20	30	2
Of vapor	(400 → 25°C) CP 0.47	158	28
Of gas	(400 → 25°C) Cp 0.31	947	110
Sub-Total			894
Reaction & Evaporation Heat			
$Cr_2O_3 \rightarrow 2Cr + 3/2O_2$	2,600 Kcal/Kg-Cr	666	1,732
$FeO \rightarrow Fe + 1/2O_2$	1,130 Kcal/Kg-Fe	225	254
$SiO_2 \rightarrow Si + O_2$	7,480 Kcal/Kg-Si	30	224
$C + 1/2O_2 \rightarrow CO$	(–) 2,200 Kcal/Kg-C	361	(–) 794
$7Cr + 3C \rightarrow Cr_7C_3$	(–) 117 Kcal/Kg-Cr	666	(–) 78
$2MgO + SiO_2 \rightarrow 2MgO{\cdot}SiO_2$	(–) 252 Kcal/Kg-SiO_2	123	(–) 31
$FeO{\cdot}Cr_2O_3 \rightarrow FeO + Cr_2O_3$	119 Kcal/Kg-Cr	716	85
$H_2O(\ell) \rightarrow H_2O(g)$	584 Kcal/Kg-H_2O	154	90
Sub-Total			1,482
TOTAL			2,376

Thermal efficiency of electric furnace : 65%

Required heat input : $(2,376 \times 10^3)/0.65 = 3,655 \times 10^3$ Kcal/t

Unit electric power consumption : $(3,655 \times 10^3)/860 = 4,250$ KWH/t

Table 8-5 Estimation of Unit Electric Power Consumption from Viewpoint of Heat Balance (Case B)

(Based on 1,000 Kg of metal)

Item	Calculation Base	Quantity (Kg)	Calorie ($\times 10^3$ Kcal)
Sensible Heat			
Of metal	(1,650 → 25°C) Cp 0.19	1,000	309
Of slag	(1,650 → 25°C) Cp 0.24	1,174	458
Of dust	(400 → 25°C) Cp 0.20	30	2
Of vapor	(400 → 25°C) Cp 0.47	144	25
Of gas	(400 → 25°C) Cp 0.31	925	108
Sub-Total			902
Reaction & Evaporation Heat			
$Cr_2O_3 \rightarrow 2Cr + 3/2O_2$	2,600 Kcal/Kg-Cr	644	1,674
$FeO \rightarrow Fe + 1/2O_2$	1,130 Kcal/Kg-Fe	246	278
$SiO_2 \rightarrow Si + O_2$	7,480 Kcal/Kg-Si	30	224
$C + 1/2O_2 \rightarrow CO$	(–) 2,200 Kcal/Kg-C	358	(–) 788
$7Cr + 3C \rightarrow Cr_7C_3$	(–) 117 Kcal/Kg-Cr	644	(–) 75
$2MgO + SiO_2 \rightarrow 2MgO{\cdot}SiO_2$	(–) 252 Kcal/Kg-SiO_2	139	(–) 35
$FeO{\cdot}Cr_2O_3 \rightarrow FeO + Cr_2O_3$	119 Kcal/Kg-Cr	692	82
$H_2O\,(\ell) \rightarrow H_2O\,(g)$	584 Kcal/Kg-H_2O	140	82
Sub-Total			1,442
TOTAL			2,344

Thermal efficiency of electric furnace : 65%

Required heat input : $(2,344 \times 10^3)/0.65 = 3,606 \times 10^3$ Kcal/t

Unit electric power consumption : $(3,606 \times 10^3)/860 = 4,193$ KWH/t

Table 8-6 Estimated Ferrochrome Manufacturing Performance

Item	Unit	Case A	Case B
Quality of Finished Product	%		
Cr		66.6	64.4
Si		3.0	3.0
C		7.5	7.5
Cr Yield	%	93.0	93.0
Unit Electric Power Consumption	KWH/t	4,250	4,193
Unit Raw Material Consumption	Kg/t		
Cr ore		2,182	2,248
Bauxite		296	227
Silica		127	144
Coke		495	491
Electrode paste		19	19
Slag composition	%		
Cr_2O		5.0	4.7
FeO		0.8	0.8
SiO_2		30.8	30.9
Al_2O_3		24.5	24.6
MgO		33.8	33.9
Slag Production	Kg/t	1,142	1,174

1–3 Startup & Repair

(1) Startup

With regard to the startup of the projected ferrochrome smelting plant, employees will be given technical training in the advanced countries. In addition, the technical instructors of the advanced countries will extend technical guidance to the trainees. However, this will be the first plant ever of its category in Sudan and as such the careful startup will be necessary. For this reason, considering the past experiences and special characteristics of this projected plant, The Study Team have worked out the startup plan as shown in Table 8-7.

It is assumed that both Case A and Case B would reach the level of normal operation in six months' time.

Table 8-7 Startup Plan

Description	Unit	1st month	2nd month	3rd month	4th month	5th month	6th month
Case A							
Electric furnace load	KW	2,000	2,500	3,000	3,500	4,000	4,000
Unit power consumption	KWH/t	6,000	5,000	4,500	4,300	4,250	4,250
Production	t/m	240	360	480	600	680	680
Case B							
Electric furnace load	KW	4,000	5,000	6,000	7,000	8,000	9,000
Unit power consumption	KWH/t	6,000	5,000	4,500	4,300	4,200	4,200
Production	t/m	480	720	960	1,200	1,370	1,540

(2) Repair

Operation of the ferrochrome electric furnace normally should be continuous (24 hours/day, 365 days/year). It is usually possible to operate electric furnace lining for 3 to 4 years without repair. Under this project, however, it will be required to shut down the furnace for two months per year according to the electric supply condition as mentioned above. In such case, in order to smooth the next startup, it will be necessary to dig out the matter remaining inside the furnace, and the lining may need to be partially repaired.

If there are other equipment parts requiring repair in addition to electric furnace, such repair should be carried out.

1–4 Operating Guidance

Extension of the technical training to the Sudanese trainees at the ferrochrome smelting plant in the advanced country prior to the startup of this plant is as described in the preceding Clause. However, it is desirable that when this plant is started up, the qualified technical people be dispatched to the site for a prearranged period to guide the Sudanese workers in the operation.

The recommendable number of instructors and the training period are as follows:

	No. of Instructors	Period	Total
Technician	3	6 months	18 person-months
Foreman	6	6	36
TOTAL			54

In extending operating guidance, the Operation Manual should be prepared so that it may be efficient.

1–5 Operation Plan

Annual operation plan of the plant set forth are as follows: (Annual operation days: 300 days; after startup period of furnace stoppage: 10 days)

	Unit	Case A	Case B	Remarks
Ave. Furnace Load	KW	4,300 (4,600)	9,000 (9,500)	( ) shows max. load.
Unit Electric Power Consumption	KWH/t	4,250	4,193	
Daily Output	t/d	24.3	51.5	
Annual Operation Days	days	290	290	Excluding 10 days after startup.
Annual Output	t	7,047	14,940	

2. Production Cost

2-1 Cost Structural Elements

The cost structural elements of ferrochrome are classified into the following two categories:

- Variable portion: Raw material cost, Electric power cost and Subsidiary material cost
- *Fixed portion : Labor cost, Equipment depreciation cost, General & administrative cost and Paid Interest*

That is, the variable portion represents a portion directly influenced by manufacturing performance (unit consumption per metal), while the fixed portion accounts for a portion requiring a *fixed amount of spending regardless of a rate of operation (production).*

2-2 Variable Manufacturing Cost

(1) Unit consumption per metal

Each case uses the value of the preceding Clause as a unit consumption per metal. However, as to consumable materials cost and auxiliary section cost, the actual figures of JMC's ferrochrome plant were used as a reference for the entry.

(2) Base for establishing the unit price

The unit costs of raw materials and electric power are based on those set in Chapters 4 and 5. However, as to imported raw materials, on precondition that they be bonded, no import duty was added. As for the estimation of unit costs of items, they were corrected on the basis of unit costs of items, they were corrected on the basis of knowledge and experience obtained by the survey team, referring to field survey results.

2-3 Fixed Cost

(1) Plant fixed cost

1) Labor cost

Except for the special case, the plant-assigned employees are always in employ and paid wages. Therefore, the amount obtained by dividing the annual labor cost by a production represents a labor cost per ton of finished product.

2) Equipment depreciation

The annual depreciation when the construction cost is depreciated over 15 years is equivalent to 6% of construction cost. The amount obtained by dividing the annual depreciation by a production represents an equipment depreciation per ton of finished product.

3) Expenses

All general expenses such as plant office, welfare/recreation, etc. were entered and the amount obtained by dividing the total expenses by a production represents an expense per ton of finished product.

(2) Selling cost

Freight and charges involved in a shipment from the plant to port Sudan are entered as a selling cost.

(3) General & administrative cost

The amount equivalent to 3% of the plant cost is, in practice, entered as a head office cost.

(4) Paid Interest

The paid interest is estimated as 8% per annum on construction cost and 8% per annum on the five month's worth of plant cost as interest on operating funds. However, paid interest on construction cost is reduced proportional to a decrease in the outstanding loans. Therefore, it was entered on the basis of 4% per annum of the average interest for 10 years.

2–4 Cost Calculation

Breakdown costs are shown in Table 8-8.

Table 8-8 Calculation of Unit Costs

(Unit: US$/t)

Item	Unit Price	Case A			Case B		
		Unit Consumption	Amount	%	Unit Consumption	Amount	%
Chromium Ore (A)	69.0	2,182 Kg/t	150.6	15.9			
Chromium Ore (B)	63.3				2,248 Kg/t	142.3	16.6
Coke	210.6	495 Kg/t	104.2	11.0	491 Kg/t	103.4	12.1
Bauxite	102.3	296 Kg/t	30.3	3.2	227 Kg/t	23.2	2.7
Silica (A)	44.9	127 Kg/t	5.7	0.6			
Silica (B)	38.6				144 Kg/t	5.6	0.7
Electric Power	0.0433	4,650 KWH/t	201.4	21.3	4,593 KWH/t	198.9	23.2
Electrode	640.2	19 Kg/t	12.2	1.3	19 Kg/t	12.2	1.4
Consumables			20.0	2.1		20.0	2.3
Auxiliary Costs			15.0	1.6		15.0	1.7
Variable Production Costs			(539.4)	(57.0)		(520.6)	(60.7)
Labor Cost		$253,200/yr	36.2	3.8	$322,228/yr.	21.5	2.5
Depreciation		$17.750Mx6%	152.1	16.1	$30.115Mx6%	120.5	14.1
Expenses (for maintenance & repair)			30.0	3.1		30.0	3.5
Fixed Costs at the Plant			(218.3)	(23.0)		(172.0)	(20.1)
Total Accounting Costs at the Plant			(757.7)	(80.0)		(692.6)	(80.8)
Sales Cost			40.2	4.2		40.2	4.7
General Administration Cost		757.7x3%	22.7	2.4	692.6x3%	20.8	2.4
Interest Payment (Facility)		$17.750Mx4%	101.4	10.7	$30.115Mx4%	80.3	9.4
Interest Payment (Operation)		757.7x8%x$\frac{5}{12}$	25.3	2.7	692.6x8%x$\frac{5}{12}$	23.1	2.7
Fixed Costs at the Head Office			(189.6)	(20.0)		(164.4)	(19.2)
Total Unit Cost			947.3	100.0		857.0	100.0
Selling Price			602.1			587.5	
Profit/Loss			-345.2			-269.5	

CHAPTER 9

COMPREHENSIVE EVALUATION

1. Financial Analysis

1–1. Summary of Costs and Benefits

Investment costs

The initial investment costs necessary for constructing the ferrochrome plant were estimated by item in Chapter 6 with the results summarized in Table 9-1. The total construction costs are allocated to each year of the construction period according to the construction shcedule given in Figs. 6-17 and 6-18. Additional investment costs are required after the production is initiated for replacement of worn-out facilities and for other purposes. The working capital requirements estimated based on the practice usually followed in the ferrochrome industry are also given in Table 9-1.

The foreign currency portions of the investment costs as given in Table 9-1 have been estimated by identifying import materials and needs for expatriates mainly for supervision and technical assistance. Exact rates of custom duties applied to import materials differ among actual cases – particular projects and origins of imports. For instance, the custom duties imposed on cement imported in 1979 range from 0% to over 10% depending on exporting countries, and those on electrical equipment and supplies from virtually nil up to over 45%.[1)]

It is assumed herein that import duties on machines, equipment and materials necessary for the construction will be exempted in accordance with "The Encouragement of Investment Act, 1980", but 40% custom duties will be imposed on the additional investment costs including the working capital.

Production costs

A production schedule over initial operating months is given in Table 8-7 for each plant capacity. To allow for start-up problems, lower production figures have been assumed during initial operations.

The production costs consist of material costs, power and other utility costs, labor costs and others including sales and freight costs, loyalty, local taxes as well as overhead and administration costs. Each cost element has been estimated in Chapter 8, but a slight change is introduced. In view of the fact that the costs of cokes account for a significant fraction of the production costs as shown in Table 8-8. and also taking account of the intention of the Sudanese side for utilizing domestic charcoal, the assumption is made herein that one-third of requirements for reducing agents necessary for ferrochrome production are satisfied by the

1) *Ministry of National Planning, Foreign Trade Statistic 1979.*

charcoal. The costs of chromium ore have been estimated from its production costs just as done in Chapter 8. The production costs at full operation of the plant are summarized in Table 9-2. The foreign currency portions of the production costs as given in Table 9-2 have been estimated by each cost element in the same way as described above.

Revenues

The revenues of The Project are derived from exporting the products of the ferrochrome smeltery. The total revenues are computed based on the assumed production figures in Table 8-8 . and the estimated average FOB price of ferrochrome at Port Sudan. Considering the difference in quality of the products, the average FOB price of ferrochrome is taken to be 476 S£/ton or 461 S£/ton for the respective plant capacity of 7,000 tons/year or 15,000 tons/year ferrochrome production. A discount of 10%, 5% and 5% respectively has been applied to the production in the first three years to reflect possible problems associated with quality of the products during the start-up period.

1–2 Financial Rate of Return

The computation of the internal financial rate of return for the standard case is shown in Table 9-4, where the following assumptions are underlying.

(1) The net sales revenue is the gross sales revenue less the quality discount that is described above.

(2) The total investment and production costs are based on the data given in Table 9-1 and Table 9-2.

(3) In calculating the taxable income, depreciation has to be excluded from the operating profit. Calculation of depreciation follows "A Note for Foreign Investers" prepared by Ministry of Finance and National Economy. That is, the straight-line method is used, by which a fixed percentage of original costs is depreciated every year during the project life. The following values are used as the fixed percentage of respective facilities:

Transportation facilities, electrical facilities and buildings:	2.5%
Product handling facilities, power receiving equipment, utility and other facilities:	10%

(4) The salvage value is 50% of the original costs for those facilities listed in item (3) above having the annual depreciation of 2.5%.

Table 9-1 Summary of Investment Costs

(a) Case A (7,000 ton/year ferrochrome production)

(Unit: 10^3 S£)

	Local currency	Foreign currency	Total	Notes
Initial investment costs	4,262.1	9,760.5	14,022.6	Over three year construction period
Additional investment costs	1,116.3	1,915.3	3,031.6	In the 10th year of production
Increase in working capital				
1st year of production	845.1	370.8	1,215.9	
2nd year of production	182.0	79.8	261.8	
20th year of production	–1,027.1	–450.6	–1,477.7	

(b) Case B (15,000 ton/year ferrochrome production)

(Unit: 10^3 S£)

	Local currency	Foreign currency	Total	Notes
Initial investment costs	6,632.1	17,158.8	23,790.9	Over four year construction period
Additional investment costs	2,330.2	3,371.3	5,701.5	In the 10th year of production
Increase in working capital				
1st year of production	1,891.4	588.9	2,480.3	
2nd year of production	391.1	121.7	512.8	
20th year of production	–2,282.5	–710.6	–2,993.1	

Source: Table 6-6 of this report.

Table 9-2 Summary of Production Costs at Full Operation

(a) Case A (7,000 ton/year ferrochrome production)

(Unit: 10^3 S£)

	Local currency	Foreign currency	Notes
Variable costs Main row material	831.7	0	Average ore price = 54.5 S£/ton
Power	890.6	222.6	Electricity rate = 0.0342 S£/kwh
Subsidiary raw materials and other consumables	403.7	491.6	
Fixed costs Labor	244.2	0	
Others (overhead & administration, sales/freight, insurance, royalty, local taxes)	344.0	123.9	

(b) Case B (15,000 ton/year ferrochrome production)

(Unit: 10^3 S£)

	Local currency	Foreign currency	Notes
Variable costs Main raw material	1,687.5	0	Average ore price = 50.0 S£/ton
Power	1,885.0	471.2	Electricity rate = 0.0342 S£/kwh
Subsidiary raw materials and other consumables	832.5	991.5	
Fixed costs Labor	298.5	0	
Others (overhead & administration, sales/freight, insulance, royalty local taxes)	787.8	246.5	

Source: Table 8-8 and Table 8-9 of this report.

(5) The corporate income tax rates are given in Table 9-3 for different types of companies. The total corporate tax levied on private limited companies for the taxable profit (P) exceeding S£ 20,000 is calcualted by the following formula:

$$1{,}000 \times 0.25 + (10{,}000 - 1{,}000) \times 0.40 + (20{,}000 - 10{,}000) \times 0.50 + (P - 20{,}000) \times 0.60, \text{ or } P \times 0.60 - 3{,}150$$

In the analysis herein, the corporate income tax is exempted for the first five years of production in accordance with "The Encouragement of Investment Act, 1980," and the rate of 60% is applied to the sixth year of production and thereafter.

The financial rate of return calculated using the data in Table 9-1 and Table 9-2 is −11.0% or −10.1% for the respective plant capacity of 7,000 tons/year or 15,000 tons/year ferrochrome production (see Table 9-4 for computation). This means that the future stream of revenues has to be deflated rather than discounted at the respective rate of 11.0% or 10.1% to obtain the present value total revenue which is equal to the present value total costs. Thus The Project is infeasible at either plant scale as long as those conditions which constitute the standard case of financial analysis prevail.

1–3 *Sensitivity Analysis*

Since Case B, 15,000 ton/year ferrochrome production appears slightly more promising, sensitivity analysis is performed in this subsection to investigate various possibilities of this alternative.

Key parameters that to a varying degree affect financial viability of The Project include those representing the electricity rate, the price of chromium ore, the price of ferrochrome, the operating rate of the plant, the initial investment costs and custom duties. Of these parameters, the operating rate has been fixed at its maximum feasible corresponding to 300 days annual operation, and thus can not be varied to improve the financial rate of return. Also the price of chromium ore has been set at its minimum possible, estimated based on the production costs at existing mines. Values of the remaining four parameters are changed in the sensitivity analysis.

As shown in Table 9-5, the 30% decrease in the electricity rate, the 20% increase in ferrochrome price and exemption of all taxes and custom duties improve the computed values of financial rate of return, but all the values are still negative. Effects of exempting all taxes and customer duties are the smallest, since most of them were exempted already in the standard case.

Table 9-3 Business Profit and Land Rent Income Tax in the Sudan

(a) Resident individuals

	Income	Rate
On the first	400 S£	0%
On the next	100	15
On the next	500	20
On the next	3,000	30
On the next	6,000	40
On the next	20,000	50
On the balance		60

(b) Public limited companies

	Income	Rate
On the first	1,000 S£	25%
On the next	9,000	40
On the next	10,000	45
On the next	30,000	50
On the balance		60

(c) Private limited companies and foreign companies

	Income	Rate
On the first	1,000 S£	25%
On the next	9,000	40
On the next	10,000	50
On the balance		60

Source: Ministry of Finance and National Economy, A Note for the Foreign Investors.

Table 9-4 Calculation of Financial Rate of Return

(a) Case A -- 7,000 ton/year ferrochrome production

UNIT: 1000SL

	YEAR	NET SALES REVENUE	TOTAL INVESTMENT COSTS	TOTAL PRODUCTION COSTS	INCOME TAX	NET CASH FLOW
1.	1983	0.0	2804.5	67.7	0.0	-2872.2
2.	1984	0.0	6310.1	67.7	0.0	-6377.8
3.	1985	0.0	4907.9	67.7	0.0	-4975.6
4.	1986	2467.6	1215.9	2970.5	0.0	-1718.8
5.	1987	3165.4	261.8	3540.3	0.0	-636.7
6.	1988	3165.4	0.0	3540.3	0.0	-374.9
7.	1989	3332.0	0.0	3540.3	0.0	-208.3
8.	1990	3332.0	0.0	3540.3	0.0	-208.3
9.	1991	3332.0	0.0	3540.3	0.0	-208.3
10.	1992	3332.0	0.0	3540.3	0.0	-208.3
11.	1993	3332.0	0.0	3540.3	0.0	-208.3
12.	1994	3332.0	0.0	3540.3	0.0	-208.3
13.	1995	3332.0	3031.6	3540.3	0.0	-3239.9
14.	1996	3332.0	0.0	3540.3	0.0	-208.3
15.	1997	3332.0	0.0	3540.3	0.0	-208.3
16.	1998	3332.0	0.0	3540.3	0.0	-208.3
17.	1999	3332.0	0.0	3540.3	0.0	-208.3
18.	2000	3332.0	0.0	3540.3	0.0	-208.3
19.	2001	3332.0	0.0	3540.3	0.0	-208.3
20.	2002	3332.0	0.0	3540.3	0.0	-208.3
21.	2003	3332.0	0.0	3540.3	0.0	-208.3
22.	2004	3332.0	0.0	3540.3	0.0	-208.3
23.	2005	3332.0	-1477.7	3540.3	62.9	3900.4

INTERNAL RATE OF RETURN: -0.110

PRESENT VALUE NET BENEFIT: -17885.3 (DISCOUNT RATE=0.05)
-16240.1 (DISCOUNT RATE=0.10)
-14864.0 (DISCOUNT RATE=0.15)

(b) Case B -- 15,000 ton/year ferrochrome production

UNIT: 1000SL

	YEAR	NET SALES REVENUE	TOTAL INVESTMENT COSTS	TOTAL PRODUCTION COSTS	INCOME TAX	NET CASH FLOW
1.	1983	0.0	3568.6	50.8	0.0	-3619.4
2.	1984	0.0	8326.8	50.8	0.0	-8377.6
3.	1985	0.0	7137.2	50.8	0.0	-7188.0
4.	1986	0.0	4758.2	50.8	0.0	-4809.0
5.	1987	5157.2	2480.3	6021.0	0.0	-3344.1
6.	1988	6569.2	512.8	7204.1	0.0	-1147.6
7.	1989	6569.2	0.0	7204.1	0.0	-634.8
8.	1990	6915.0	0.0	7204.1	0.0	-289.1
9.	1991	6915.0	0.0	7204.1	0.0	-289.1
10.	1992	6915.0	0.0	7204.1	0.0	-289.1
11.	1993	6915.0	0.0	7204.1	0.0	-289.1
12.	1994	6915.0	0.0	7204.1	0.0	-289.1
13.	1995	6915.0	0.0	7204.1	0.0	-289.1
14.	1996	6915.0	5701.5	7204.1	0.0	-5990.6
15.	1997	6915.0	0.0	7204.1	0.0	-289.1
16.	1998	6915.0	0.0	7204.1	0.0	-289.1
17.	1999	6915.0	0.0	7204.1	0.0	-289.1
18.	2000	6915.0	0.0	7204.1	0.0	-289.1
19.	2001	6915.0	0.0	7204.1	0.0	-289.1
20.	2002	6915.0	0.0	7204.1	0.0	-289.1
21.	2003	6915.0	0.0	7204.1	0.0	-289.1
22.	2004	6915.0	0.0	7204.1	0.0	-289.1
23.	2005	6915.0	0.0	7204.1	0.0	-289.1
24.	2006	6915.0	-2993.1	7204.1	390.5	7146.3

INTERNAL RATE OF RETURN: -0.101

PRESENT VALUE NET BENEFIT: -29431.1 (DISCOUNT RATE=0.05)
-26274.1 (DISCOUNT RATE=0.10)
-23642.2 (DISCOUNT RATE=0.15)