2-5-2. Present situation of terminal facilities

The present situation of railway terminal facilities and means of transportation, as of the first field survey for the Basic Design in October 1985, is mentioned below.

(1) *Fuel loading facilities*

Fuel oil is loaded at oil company facilities in Port Sudan. Marshalling of empty of loaded wagons is carried out at New South Station near the oil companies. When loading is finished, wagons are assembled and taken to Town Station where a Manama and Brake Van are added to make up a fuel train (see Fig. 2-6). New south Station has five tracks of 326 – 535 m in length and plans are under way to add five more tracks. The tracks use 75 lb/yd rails with a permissible axle load of 16.5 t. Relevant data on fuel loading facilities owned by AGIP, which supplies 70% of NEC's fuel requirements, is as follows :

· Shipping capacity (maximum)	Tank wagon : 900 t/day Tank truck : 500 – 700 t/day
· Filling point	2 for 1,500 sec. 1 for 3,500 sec. Two more points will be added in 1986.
· Oil pump	2 units (40 t/hour each)
· Storage tank	1 unit (850 t, 1,500 sec.) 1 unit (950 t, 3,500 sec.) Installation of a new tank is planned.
· Heating facilities	Installation is planned (schedule not decided). There is no loading problem, since fuel oil from the refineries is loaded before being cooled. Loading time of 3,500 sec. fuel oil during the winter takes twice as long as that in the other seasons.
· Shunting	Manual shunting (using wires and winches)

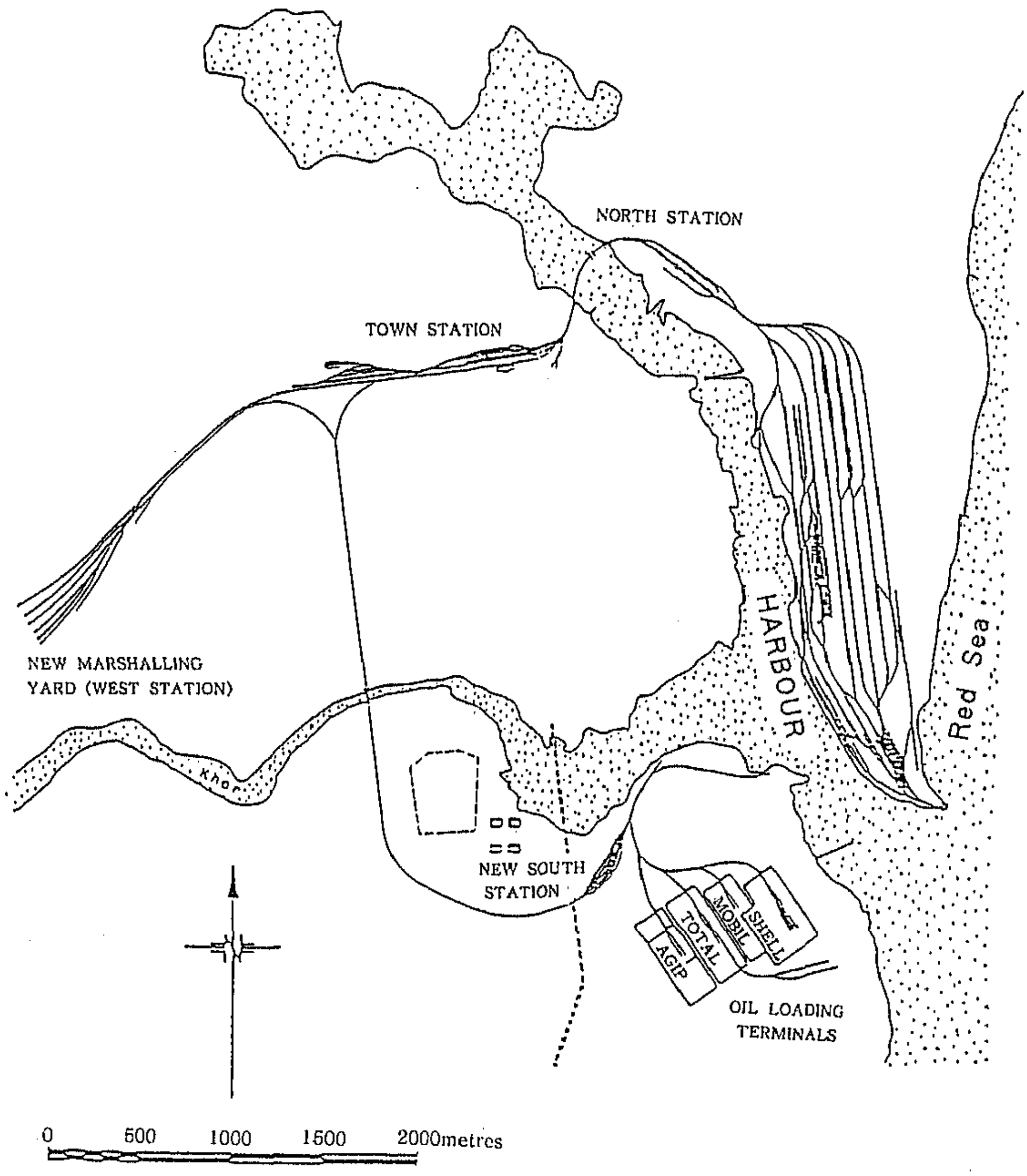


Fig. 2-6 Terminal facilities in Port Sudan

According to the FTS Report, other oil companies own similar facilities, with storage capacities as follows :

Total	1,350 t
Mobil	910 t
Shell	3,210 t

Also, SHELL has a steam heating plant and the best equipped loading facilities.

(2) Fuel unloading facilities

Tank wagons hauled to the Khartoum North Power Station are to be detached at the Khartoum North Station and those to the Burri Power Station are to be channeled through Khartoum Station. Track layout in Khartoum is shown in Fig. 2-7.

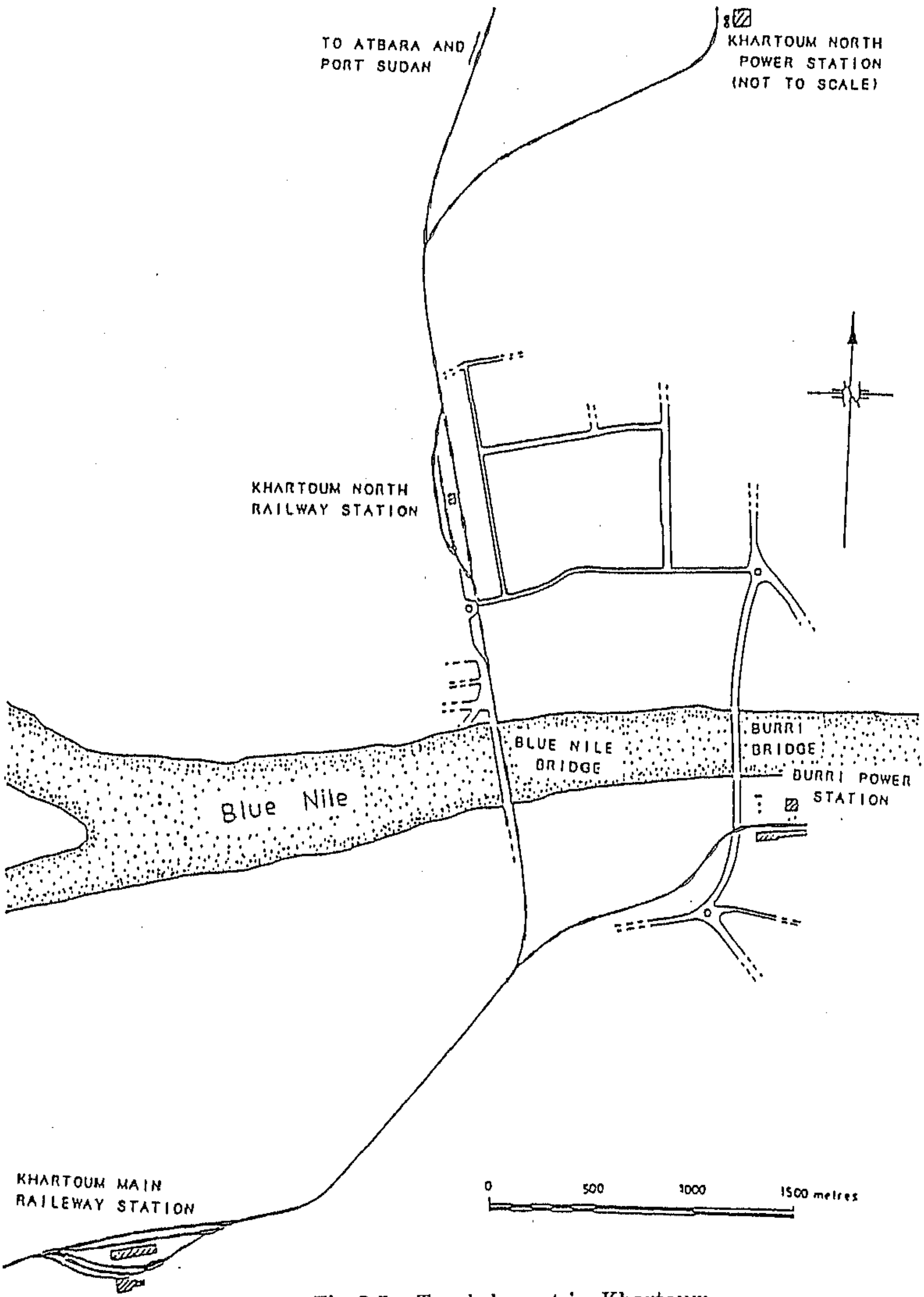


Fig. 2-7 Track layout in Khartoum

Khartoum North Power Station was recently constructed and has new unloading facilities. On the other hand, Burri Power Station is old and is being renewed. The unloading facilities are old and polluted with oil spillage at Burri Station but sidings for unloading and storage tanks were recently added. Track layouts at the power stations are shown in Fig. 2-8 and their unloading facilities summarized in Table 2-32.

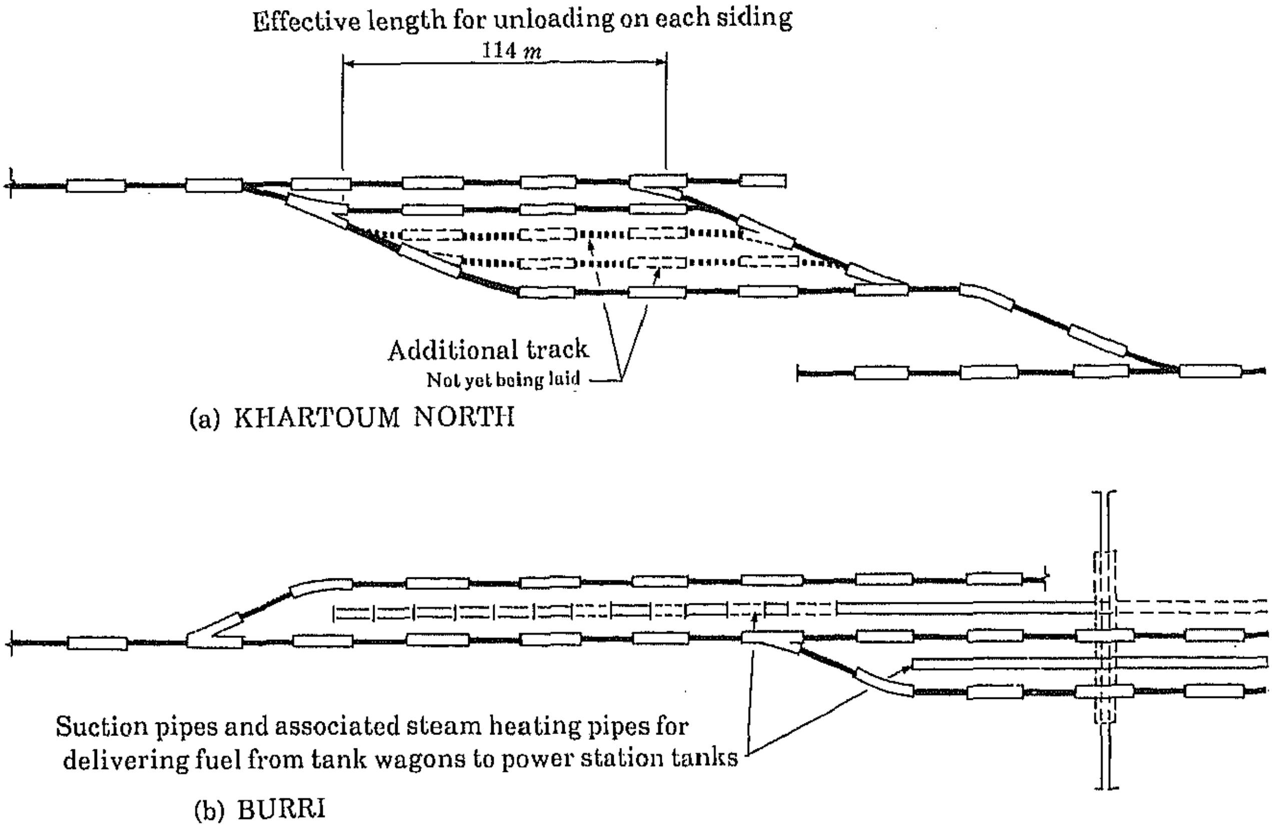


Fig. 2-8 Conception of track layouts at power stations

Table 2-32 Unloading facilities at power stations in Khartoum

Items	Burri	Khartoum North
Unloading point	5 wagons × 2 tracks 9 wagons × 2 tracks	10 wagons × 2 tracks
Unloading pump	54 m^3/h × 4	120 m^3/h × 2
Storage tank	1,500 t × 4 2,700 t × 4	20,000 t × 2

(200 t × 4 ---- for gas oil)

Khartoum North Power Station plans to add two storage tanks (20,000 t each) and has already reserved the land for them. Also, power stations intend to install steam heating facilities to heat tank wagons.

Shunting work at power stations is not carried out efficiently, since shunting locomotives owned by SRC are not always ready when needed.

2-5-3. Truck transportation

Truck transportation, which tentatively started in 1984/85, was initially conducted by a public transportation company (Petro Trans Company) and a private company (Trans National Company), both of which somewhat lacked quantitative reliability because of indefinite arrival times resulting from congestion on the roads (also from an unstable supply of truck fuel oil), as well as qualitative reliability (inclusion of impurities in fuel oil due to defective cleaning of the inside of the tank).

Due to the above, control has been concentrated at present (November 1986) by selecting only one company (Petro Trans Company) for transportation. NEC, however, desires to switch over to more reliable railway transportation, while Petro Trans is looking forward to curtailing the transportation of NEC fuel since which is not so profitable for them.

Also, the World Bank has felt, from the beginning, that fuel oil transportation by truck, which is too low in energy efficiency, is out of the question. Reported below are the results of the investigations conducted on the general situation of tank truck fuel transportation at the Petro Trans public transportation company.

Many of the trucks used by Petro Trans Company for transporting GPC and NEC fuel have a 35-ton capacity (weight of loaded truck 50 t), some a 50-ton capacity (weight of loaded truck 65 t). According to a statement of the Company, the use of the latter is prohibited as its excessive axle load damages roads, however, this restriction is not actually enforced and private transportation companies are using them. Therefore, Petro Trans is compelled to follow suit.

Approximately 70% of the tank trucks now in use are reproducted vehicles and only 30% are new. The fuel consumption rate of a truck is approximately 2.0 km/ℓ, about 320 gallons (1,210 ℓ) are consumed over a distance of 2,400 km. (The fuel consumption of a Japanese 12-ton capacity tank truck is 3.0 to 4.0 m/ℓ.) The price of gas oil at the project site (Khartoum) is 3.5 LS/gallon (as of Nov. 1986.)

Further, because the supply of gas oil in Kassala and other places on the way is undependable, and also because it is desirable to use the low-priced gas oil of Port Sudan, many of the tank trucks are equipped with 3 fuel tanks of 400 ℓ each, so as to enable them to make a Port Sudan – Khartoum round-trip without stopping for fuel. One round-trip of a tank truck from Port Sudan to Khartoum and vice versa takes 5 to 6 days.

2-6. Background of the request and its contents

In order to reinforce electric power generating facilities, the Republic of the Sudan has implemented, since 1961, the Power I and II Projects, focusing mainly on hydraulic power generation, and the Power III Project, which concentrated on reinforcing hydraulic and thermal power generation capacity to about the same extent.

In spite of this, as of this date, power generation capacity per capita and the generated energy per capita in the Republic of the Sudan are 23 W and 54 KWH, respectively. These figures are some of the lowest in the world. The electrified areas consist of Khartoum, the capital, and 15 major regional cities, but electric power networks and consistent supplies of electricity exist in only 2 regions including Khartoum, the rest have small isolated diesel generators.

In order to improve and develop power supply as well as to cope with the future increases in power demand, a power reinforcing scheme using mainly thermal generation became necessary for which the Power IV Project was drawn up at the end of 1983. In December 1983, a conference of the countries concerned in the Power IV Project was held in Paris, wherein an arrangement was reached as regards the broad aspects of the project, as shown in Table 2-33.

Table 2-33 Power IV Project

Unit: US$ million

Summary of the project	Local	Foreign	Total
Part A. Extension of facilities on the BNG (Total)	72.3	240.1	312.4
① Roseires unit No. 7	1.1	10.7	11.8
② Khartoum North Power Station units No.3 and 4	21.1	128.1	149.2
③ BNG transmission	5.4	23.4	28.8
④ Khartoum subtransmission and distribution	32.9	55.9	88.8
⑤ BNG distribution outside Khartoum	11.8	22.0	33.8
Part B. Expansion of facilities on the EG (Total)	5.3	19.7	25.0
① Khashm el Girba, 3 × 5 MW diesel station	4.4	16.8	21.2
② Transmission in EG	0.9	2.9	3.8
Part C. Rehabilitation and spare parts (Total)	6.5	18.3	24.8
① Rehabilitation (Roseires, Khashm el Girba)	6.4	14.8	21.2
② Provision for spare parts	0.1	3.5	3.6
Part D. Improvement of supply on the BNG	8.6	29.0	37.6
Part E. Fuel oil transportation equipment	15.0	35.9	50.9
① Investments by SRC	13.4	21.2	34.6
② Investments by NEC	1.6	14.7	16.3
Part F. Technical assistance and studies	0.9	6.0	6.9
Total —— Investments by NEC Investments by SRC	95.2 14.6	332.8 26.2	428.0 40.8
Grand Total	108.6	348.0	457.6

Source: from the request issued to Japan in Feb. 26, 1984

[Note] BNG : Blue Nile Grid

EG : Eastern Grid

Since the Power I Project, the World Bank has mainly been financing the electric power projects of the Sudan. For this Power IV Project also, the World Bank has decided to finance a loan for the urgent measures pursuant to the Power Rehab. (IDA) Project (1985 - 1988) ; furthermore, as a longterm measure, it is studying (and evaluating) the Power IV (IDA) Project. However, since the Power IV Project requires an extremely large amount of money and there is a limit to the financing capacity of the World Bank, co-financing with ADB is being studied.

On the other hand, the Republic of the Sudan has already lost the capability of repaying normal loans and is in no condition to consider any financing conditions other than those of the World Bank (IDA) loans, which offer long-term credit with no interest (50-year loan). Under these circumstances, in the Power IV Project, the sharing of the financing has been determined in such a way that the World Bank (and ADB) finances a loan for the portion of the project that shows the highest investment effect, and grants be requested from interested countries for the other portions where the investment effect would be lower.

As indicated in Table 2-33, the Power IV Project covers equipment and materials for fuel transportation (Fuel Transportation Project), for which the Government of the Sudan, in its letter of Feb. 26, 1984, requested the Government of Japan for aid, in accordance with the agreement reached at the above mentioned conference.

The concrete details of the request are described in the following :

① Diesel electric locomotives

Diesel electric locomotive with axle load about 16 tons and 1600 - 1700 HP ----- 10 units

② Communications equipment

· Wireless installations for communication, independent of existing communications networks, between the cities of Khartoum, Atbara and Port Sudan, as well as for the concerned organizations within the cities, for fuel transportation.

· Concerning wireless installations for communication between trains and their nearest stations, on-board wireless equipment is to be mounted in the locomotives mentioned in item ①.

Upon receipt of this request, the Government of Japan decided to conduct a basic engineering study for the Fuel Transportation Project and the Japan International Cooperation Agency (JICA) dispatched a study team from September 26 to October 17, 1985. The main object of this team was to study the feasibility of the Fuel Transportation Project.

Then, it was revealed that power demand was lower in than the initial Power IV Project, and it was reviewed and modified by NEC.

In the middle of 1986, in relation to the appraisal of the Power IV Project by the World Bank, it became necessary to review and evaluate the Fuel Transportation Project in relation to the entire Power IV Project, and at the request of the Government of the Sudan, the Government of Japan decided to again carry out a basic engineering study and to ascertain the approach and intention of the World Bank regarding the Power IV Project.

CHAPATER 3. DESCRIPTION OF THE PROJECT

CHAPATER 3. DESCRIPTION OF THE PROJECT

3-1. Contents of the Power IV Project

3-1-1. Power generation plan

(1) Background leading to establishment of the Power IV Project

The Long Term Power Plan, after the completion of the Power III Project, was done by English consultants (Sir Alexander Gibb & Partners, and Merz and Mclellan), who presented the final report to the Government of the Sudan in June 1983. The report, estimating the demand for the 15 year period of 1985/86 to 2000/01, proposed an outline for the electric power development program on the basis of the estimates for the growth rate of electric power demand (8.2%/year) and electric energy demand (8.3%/year).

At the same time, the said consultants conducted a feasibility study on a power reinforcement plan succeeding the Power III Project, based on the demand forecasts in the Long Term Power Plan, and presented the final report in July 1983. This is the plan on which the Government of the Sudan based its Power IV Project. The power reinforcement project according to the above plan is as indicated in Table 3-1.

Table 3-1 **Initial Power IV Project**

(From Feasibility Study report of English Consultant)

Fiscal Year (FY)	Main forecast		Low forecast		Power reinforcement program (Power IV Project only)
	Power generation	Installed capacity	Power generation	Installed capacity	
1982/83	920 GWh	235 MW	999 GWh	188 MW	
83/84	1,134	263	1,089	205	Kilo × 30 MW gas turbine
84/85	1,329	294	1,187	223	Roseires # 7 40 MW water turbine
85/86	1,544	323	1,294	243	
86/87	1,760	352	1,410	265	Khartoum North 60 MW × 2 steam turbine
87/88	1,974	384	1,540	289	Khartoum North 60 MW × 1 steam turbine
88/89	2,148	419	1,680	315	Sennar 30 MW water turbine extention
89/90	2,413	456	1,830	343	

The actual power demand of NEC in 1982/83, 1983/84 and 1984/85 was 934 GWh, 1,010 GWh and 1,233 GWh, respectively, figures lower than the initial demand forecast (Table 3-1).
The Government of the Sudan reexamined the power reinforcement project prepared by the afore-mentioned consultant and drew up the present Power IV Project (Table 3-2), placing emphasis on the reinforcement of the thermal power stations, the rehabilitation of the hydroelectric power station, and the reinforcement and expansion of transmission and transformation facilities and distribution lines (rehabilitation, procurement of spare parts and extension).

(2) Description of the Power IV Project
Power generating facilities to be reinforced in the Power IV Project, based on the revised demand forecast, is outlined in Table 3-2.

Table 3-2 Outline of the Power IV Project

Fiscal Year	Load forecast		Power reinforcement of the Power IV Project - 1986/87 ~ 1990/91 -
	Energy generation (GWh)	Installed capacity (MW)	
1986/87	1,593	303	Khartoum North 20 MW × 2, gas turbine (under construction)
87/88	1,714	326	Burri Extension 10 MW × 2, diesel (under construction) Roseires #7 Extension 40 MW Hydro plant 10 units of Diesel Locomotive for Fuel Transportation
88/89	1,839	356	Eastern Grid Extension 5 MW × 3, diesel
89/90	1,961	373	Khartoum North 45 MW × 2, steam turbine
90/91	2,095	385	Regional Cities Electrification Total 10.5 MW diesel
91/92	2,232	425	

The power source to be reinforced under the Power IV Project in BNG amounts to 190 MW, of which thermal power generation accounts for 150 MW. Upon completion of this Project, BNG will have an installed capacity of 632.3 MW, consisting of 267 MW of hydropower and 365.3 MW of thermal power, forming a composition of a "thermal main and hydraulic auxiliary". The present Power IV Project is two years behind the initial schedule. The reason seems to be that the Power III Project was completed two years behind schedule. (Khartoum North Power Station Unit No. 2 had been originally scheduled to be commissioned in August 1983, however, this was realized in only June 1985.)
The Power IV Project is characterized by reinforcement of power generation capacity with priority given to thermal power, and consists of the Khartoum North and Burri Thermal Power Stations. Fuel oil for these new and existing thermal power stations has to be transported to

Khartoum from Port Sudan. The actual records of fuel consumption and transportation for the past 5 years, according to NEC, are as shown in Table 3-3.

Table 3-3 Fuel transportation

(10^3 t)

Fiscal Year	1981/82	1982/83	1983/84	1984/85	1985/86
Consumption	33.9	41.0	61.6	91.8	127.7
By Rail	33.9	41.0	61.6	36.7	63.9
By Road				55.1	63.9

As shown in the Table, a shortage in SRC's railway transportation capacity became evident in 1984/85, and truck transportation was introduced.

Fuel for the Power IV Project is indispensable and the Sudanese Government decided to obtain diesel locomotives and fuel tank wagons to be used exclusively for fuel transportation, under the Power IV Project. This is one of the characteristics of the Power IV Project, not found in the Power I – III Projects. The Power IV Project includes not only power reinforcement, but also a general plan aiming at reinforcing all facilities necessary for power supply such as the extension of transmission lines, substations and distribution lines. A detailed description of the Power IV Project is shown in Table 3-4.

Table 3-4 Components and financial condition of Power IV Project

Unit: US$ million

Components of project	Cost	Financial condition
(BNG): Blue Nile Grid (1) Improvement of Khartoum North Thermal Power Station 40 MW (20 MW × 2, gas turbine)	6.5	Italian grant
(2) Improvement of Burri Thermal Power Station 20 MW (10 MW × 2, diesel)		
(3) Rehabilitation of Roseires Hydro Power Station	39.6	IDA: 30.0 soft loan (Power Rehab. Project, IDA)
(4) Procurement of spare parts for Sennar Hydro Power Station		
(5) Improvement of Roseires Hydro Power Station No. 7 unit (40 MW)	13.0	EIB 12.0 soft load
(6) Equipment for fuel transportation: 10 mainline diesel locomotives and communications equipment	20.0	Requesting Japan
(7) Improvement of Khartoum North region 110/33/11 kV lines at Khartoum North Substation 110 kV sending line and 33 kV supply line Supply line of Khartoum region	112.0	Kuwait fund: 35.0 OPEC: 10.0 for several parts a soft loan
(8) Improvement of Khartoum North Thermal Power Station (45 MW × 2, steam turbine)	76.0	IDA: 38.0, ADB: 38.0 } soft loan appraisal
(9) Investments for Blue Nile Grid 220 kV lines: rehabilitation 220 kV, 110 kV Substation: rehabilitation Rehabilitation of 220/110 kV transformer Rehabilitation of 110/33 kV transformer	36.0	———
(EG): Eastern Grid (10) Improvements at Eastern Grid Substation (66 kV substation)	24.0	Finnish 16.0 grant
(11) Improvements at Khashm el Girba Thermal Power Staton (5 MW × 3, diesel)	14.3	Dutch 12.5 grant
(ID) (12) *Electrification of loacal cities*	24.5	
El Obeid (1.5 MW × 3, diesel)	6.5	Dutch 6.0 grant
Shendi (1.2 MW × 1, diesel) El fashar (1.0 MW × 1, diesel) Atbara (4.0 MW × 1, diesel) Dongla: Distribution lines	18.0	Danish 17.6 grant
(13) Electrification of White Nile Region	82.4	
Total cost	472.8	

(3) Power IV Project and financing

As shown in Table 3-4, the Power IV Project is a comprehensive power development project that includes reinforcement of existing facilities from generation to distribution, electrification of regional cities, and construction of fuel transportation facilities. The scale of the Power IV Project is an ambitious program for the Sudan, as compared with former projects which consisted mainly of power reinforcement.

The financial requirements of the Power IV Project are estimated to require some 470 million US dollars, excluding interest during construction. This is almost double the cost of the Power III Project (US$244.74 million including contingencies and escalation, but excluding interest during construction, according to the IDA report)

The Government of the Sudan requested financing for the Power IV Project from donor countries as well as from international financial institutions (A meeting for donor countries was held in Paris on December 15, 1983). Financing for the Power IV Project is shown in Table 3-4. Financing for BNG in the Power IV Project for fuel transportation locomotives and facility reinforcement remains pending, but other items have been decided. As shown in Table 3-4, some are under implementation and others under evaluation, that is, IDA provided a soft loan of 30 million dollars for items (2) – (4) in Table 3-4, completing the project appraisal in June 1985. This project is called the "Power Rehabilitation Project" and is scheduled to be completed in 1988. As of November 1986, IDA has been appraising an expansion (90 MW) of Khartoum North Power Station (item (8) in Table 3-4). IDA and ADB committed a soft loan of 38 million dollars each. IDA calls this project the "Power IV Project", and an appraisal report is scheduled to be submitted to the Board of Directors in March 1987. Therefore, it is desirable that financing be decided at the earliest for the locomotives, which are indispensable for power reinforcement. Financing for BNG and ID, except item (13), "White Nile Electrification", has been committed and they are under implementation. Financial assistance for the Power IV Project is being provided from 8 countries (including Japan) and 4 international financial institutions including IDA. Thus the Power IV Project is really an international cooperation project for the Sudan. Especially, fuel transportation is a vital element for the completion of the Power IV Project, thus the role of Japan for the financing of the locomotives is important.

(4) Evaluation of the Power IV Project

In this section, a study of the thermal power facilities to be reinforced in the Power IV Project in relation to the estimated fuel consumption (by NEC) will be made in order to technically justify the Power IV Project from the standpoint of the balance of demand/supply and fuel consumption rate. Then, the ratio of the fuel transportation costs to the electricity rate is compared with that in Japan. Also the financial condition of NEC will be studied from its financial statements.

① Balance between power demand and power reinforcement project

Table 3-5 shows the assumed installed capacity of BNG, including existing and planned power plants in the Power IV Project, and the actual and estimated sent out capacity for the 8 years from 1986/87 to 1993/94. In this table, the increase in existing hydropower is attributable to the rehabilitation of Roseires Power Station, while the decrease in thermal power is attributable to the retirement of power plants as they reached the end of their serviceable life.

This table shows that the maximum generating capacity of BNG will exceed 400 MW in 1986/87, and reach 570 MW in 1990/91 with the completion of the Power IV Project. This capacity is for average hydrological conditions on the Blue Nile, and in case of adverse hydrological conditions and releases of water for irrigation, the generating capacity of Roseires Power Station is estimated to decrease to 140 MW (before rehabilitation) and 155 MW (after rehabilitation).

Table 3-5 Estimation of installed and actual sent-out capacity (BNG)

Unit: MW

Power source		Capacity	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
Existing	Hydro	Installed	227	227	227	227	227	227	227	227
		Actual sentout	194	225	225	225	225	225	225	225
	Steam	Installed	86	86	86	86	86	60	60	60
		Actual sentout	76	76	76	76	76	60	60	60
	Diesel	Installed	77.3	55	55	55	55	55	55	55
		Actual sentout	48.4	46.5	45.5	45.5	45.5	45.5	45.5	45.5
	Gas Turbine	Installed	52	52	52	38	38	38	38	38
		Actual sentout	47	47	47	34	34	34	34	34
	Total	Installed	442.3	420	420	406	406	380	380	380
		Actual sentout	365.4	393.5	393.5	380.5	380.5	364.5	364.5	364.5
Power IV	Hydro	Installed		40	40	40	40	40	40	40
	Steam	Installed				90	90	90	90	90
	Diesel	Installed		20	20	20	20	20	20	20
	Gas Turbine	Installed	40	40	40	40	40	40	40	40
Grand Total		Installed	482.3	520	520	596	596	570	570	570
		Actual sentout	405.4	493.5	493.5	570.5	570.5	554.5	554.5	554.5

[Note] In Power IV Project,
Hydro : Roseires unit No. 7
Steam : Khartoum North 90 MW
Diesel : Burri 20 MW
Gas turbine : Khartoum North 40 MW

Accordingly, by taking into account adverse hydrological conditions or the releases of water for irrigation, the minimum generating capacity of BNG is assumed to be 70 MW less than the maximum capacity, as shown in Table 3-6.

Table 3-6 Estimate of minimum capacity (BNG)

FY	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
Minimum capacity (MW)	351	423	432	500	500	484	484	484

BNG's balance of supply at maximum power demand is shown in Table 3-7, based on minimum capacity.

Table 3-7 Demand-supply balance at maximum demand (BNG)

Item \ FY	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
(1) Maximum capacity(MW)	351	423	432	500	500	484	484	484
(2) Load forecast (MW)	303	326	356	373	385	425	454	486
(3) Required capacity (MW)	363.5	388.6	421.6	455.3	468.5	512.5	544.4	579.6
(4) (Max. unit : KRTN)(MW)	(30)	(30)	(30)	(45)	(45)	(45)	(45)	(45)
(5) Cold reserve (MW)	△12.5	34.4	1.4	44.7	31.5	△28.5	△60.4	△95.6
(6) Cold reserve rate (%)	△4.1	10.6	0	12.0	8.2	△6.7	△13.3	△19.7

[Note] (1) : From Table 3-6
(2) : Estimate by NEC
(3) : Load Forecast (2) × 1.1 + Max. unit (4)
(4) : Steam Turbine Unit as Khartoum North
(5) : (1) – (3)
(6) : (5) / (3) × 100

Item (3), "Required Capacity", of Table 3-7 shows a capacity that consists of a reserve of 10% of the power demand and an additional reserve equivalent to the capacity of the largest unit in the power system. This means that should the largest unit in the system go down, the system can be operated with this 10% reserve, which is an ideal pattern for power system operation.

Judging from this operation pattern, BNG will have a shortage in cold reserve (standby generating capacity not connected to the system) in 1986/87, but will be fine up to 1990/91 when the Power IV Project is completed. After 1991/92, it will be necessary to implement another power reinforcement plan, because the shortage in cold reserve will become even larger then.

Thus, the power demand-supply balance at minimum generating capacity is stable during the Power IV Project, except for 1986/87. Also, there will be no problem in supply capability under average hydrological conditions, so the power reinforcement plan in the Power IV Project is considered reasonable.

② Power generation plan and fuel consumption

The estimated fuel consumption by NEC is shown in Table 3-8.

Table 3-8 Load forecast, generation plan and fuel consumption (BNG)
(1986/87 ~ 1995/96 : NEC)

FY	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96
Power ration (GWh)	1,593	1,714	1,839	1,961	2,095	2,232	2,386	2,554	2,736	2,938
Hydro(1) (GWh)	1,016	1,106	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Thermal (GWh)	487	608	639	761	895	1,030	1,186	1,354	1,536	1,738
Fuel consumption(2) (10^3 t)	134	167	176	209	246	284	327	373	423	479

86/87: Khartoum North (20 MW × 2)
87/88: Burri (10 MW × 2)
88/89: Roseires #7 (40 MW)
89/90: Khartoum North (45 MW × 2)

[Note] (1): Average hydrological conditions
(2): Average specific fuel consumption (SFC) = 275 t/GWh

According to the table, an average fuel consumption rate of 275 t/GWh is used. Assuming that the average heat value of heavy and light oils is 10,000 – 11,000 kcal/kg, and that the average thermal efficiency of Burri's 20 MW and Khartoum North's 90 MW, which are installed in the Power IV Project, are estimated to be 28.5%, the fuel consumption rate becomes 274 t/GWh – 307 t/GWh. However the actual fuel consumption rate is considered to be a little larger than these values, due to the condition of old thermal plants in the grid. The forecast by NEC is judged to be reasonable considering what the optimum operation of a power system should be by utilizing new facilities in priority.

The power generation capacities of the Roseires and Sennar hydropower stations have great influence on fuel consumption. Therefore, an estimation should be made for fuel consumption required when hydropower generation capacity is decreased. Decreases are observed during adverse hydrological conditions on the Blue Nile River. The Phase I mission found that capacity decreases to approximately 85% of that during average hydrological conditions. Fuel consumption estimates for these two cases are shown in Table 3-9 and Figure 3-1. As seen in the table, hydropower generation is 1,200 GWh in a year with average hydrological conditions and 1,020 GWh in a year with adverse hydrological conditions, after commissioning of Roseires Unit No. 7. Therefore, power demand that cannot be supplied by hydro must be augmented by thermal power generation. Therefore, it is possible that more fuel will be consumed than estimated by NEC, depending upon hydrological conditions.

All fuel for thermal power generation in BNG is now transported from Port Sudan to Khartoum by railway and road. However, the latter has several problems so it is necessary to arrange railway transportation for securing a stable supply of fuel at a low cost. It is therefore considered reasonable that the Power IV Project include a fuel transportation program by upgrading the railway system.

Table 3-9 Thermal power generation and fuel consumption

(Actual and estimated)

FY	Power demand (GWh)	Hydro (GWh)		Thermal (GWh)		Fuel consumption (10^3 t)		Transportation (10^3 t)	
		Average	Adverse	Average hydro	Adverse hydro	Average hydro	Adverse hydro	Rail	Road
1981/82	873	746		127		33.9		33.9	
82/83	934	773		161		41.0		41.0	
83/84	1,014	781		233		61.6		61.6	
84/85	1,233	949		284		91.8		36.7	55.1
85/86	1,218	(825)		(393)		127.8		63.9	63.9
86/87	1,593	1,106	940	487	653	134	180	*1	
87/88	1,714	1,106	940	608	774	167	213		
88/89	1,839	1,200	1,020	639	819	176	225		
89/90	1,961	1,200	1,020	761	941	209	259		
90/91	2,095	1,200	1,020	895	1,075	246	296		
91/92	2,232	1,200	1,020	1,030	1,212	284	334		
92/93	2,386	1,200	1,020	1,186	1,366	327	376		
93/94	2,554	1,200	1,020	1,354	1,534	373	423		
94/95	2,736	1,200	1,020	1,536	1,716	423	473		
95/96	2,938	1,200	1,020	1,738	1,918	479	528		

*1 100% by upgrading railway

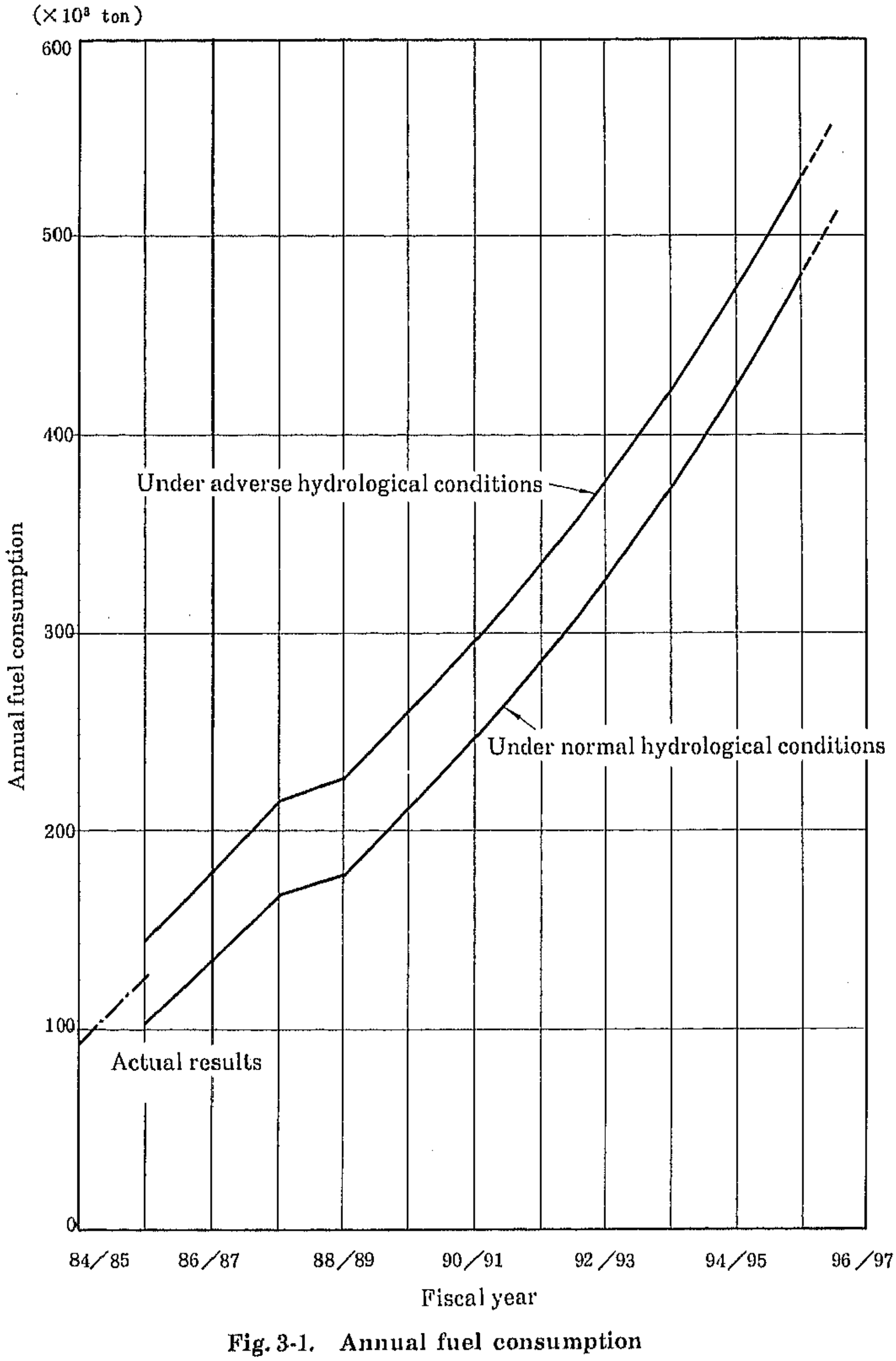


Fig. 3-1. Annual fuel consumption

③ Fuel transportation cost and electricity fees

(a) Present status of fuel cost per kWh

NEC's energy generation for hydro and thermal from 1978/79 to 1984/85 is shown in Table 3-10 (Source : 1984/85 NEC Annual Report).

Table 3-10 Power generation of NEC

FY	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Hydro (GWh)	622	724	732	746	773	781	949
Index	100	116	118	120	124	126	153
Thermal (GWh)	102	98	102	127	161	233	284
Index	100	96	100	125	158	228	278
Total (GWh)	724	822	833	873	934	1,014	1,233
Index	100	114	115	121	129	140	170

The fuels NEC uses for power generation are 1,500 sec and 3,500 sec heavy oil, diesel oil (light oil) and gas oil. Most of the fuels used are however heavy oils. In 1984/85, the fuel consumed was 87% heavy oil, 10.4% diesel oil, and 2.6% gas oil. According to the 1984/85 Annual Report, the ratio (%) of fuel costs to power generation costs are shown in Table 3-11, indicating that fuel costs exceeded by 40% NEC's power generation costs.

Table 3-11 NEC's expenditure in LS

FY	Wages & Salaries	Fuel & Power	Operation & Materials	Repair & Maintenance	Others	Total
1978/79	6,085,500	5,819,943	608,709	1,707,660	941,408	15,163,220
Percentage	40%	38%	4%	11%	7%	100%
1979/80	7,403,898	7,518,064	1,476,738	2,597,184	1,822,692	20,918,576
Percentage	36%	36%	7%	12%	9%	100%
1980/81	8,477,476	10,226,731	1,274,428	4,048,297	1,943,234	25,970,166
Percentage	33%	39%	5%	16%	7%	100%
1981/82	12,443,492	17,745,340	2,276,074	5,538,244	4,125,006	42,128,156
Percentage	30%	42%	5%	13%	10%	100%
1982/83	11,493,000	20,616,000	1,210,000	6,276,579	5,600,000	45,497,579
Percentage	25%	46%	3%	14%	12%	100%
1983/84	15,782,455	29,686,112	2,616,161	9,772,070	19,856,609	77,713,407
Percentage	20%	38%	3%	13%	26%	100%
1984/85	19,728,069	51,088,150	8,502,280	19,753,490	19,262,360	118,334,349
Percentage	17%	43%	7%	17%	16%	100%

The ratio of fuel costs increases with the rise in thermal power generation, so attention should be paid to this trend. Fig. 3-2 shows actual expenditures by fiscal year.

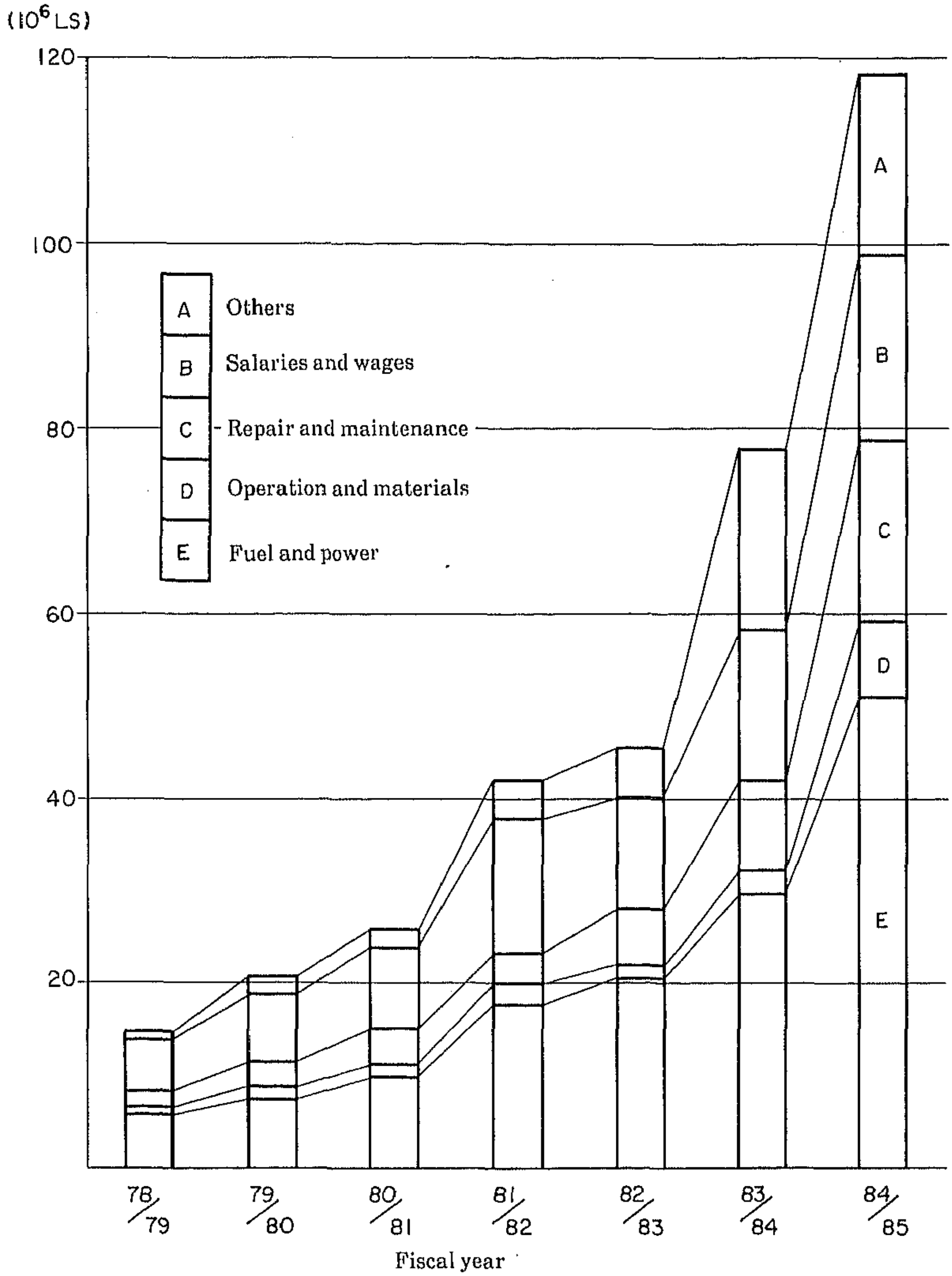


Fig. 3-2 Annual Expenditure of NEC

Fuel cost per kWh is next calculated to compare it with the average electricity rate. From the expenditure in Table 3-11 and power generation in Table 3-10, the fuel cost per kWh is obtained as shown in Table 3-12.

Table 3-12 Fuel cost per kWh

(LS/kWh)

FY	1978/79	79/80	80/81	81/82	82/83	83/84	84/85
Fuel cost for thermal generation	0.057	0.077	0.100	0.140	0.128	0.127	0.180
Fuel cost for total generation	0.008	0.009	0.012	0.020	0.022	0.029	0.041
Index	100	112.5	150	250	275	362.5	512.5
Average electricity rate	0.034	0.054	0.054	0.054	0.054	0.142	0.205
Index	100	158.8	158.8	158.8	158.8	417.6	602.9

As seen from the table, the annual rise in fuel cost per kWh is large. In the 6-year period from 1978/79 to 1984/85 the fuel cost per kWh for thermal power generation increased 3.16 times or at a rate of 21% annually, and the fuel cost per kWh for total power generation increased 5.1 times or 31% annually. During the said 6-year period the average electricity rate rose twice, in 1983/84 and 1984/85, increasing the rate by 6 fold, though it was frozen for a certain period. The rise in fuel cost was almost equal to the price hike for the average electricity rate.

The importance of thermal power generation will surely increase in the NEC system in the future. In 1990/91, when the Power IV Project is completed, it is estimated that hydropower generation will be approximately 26% greater than that of 1984/85 and thermal power generation approximately 215% (cf. Table 3-9). Assuming that expenditure is simply proportional to power generation, it is estimated that in 1990/91 the ratio of fuel cost to total expenditure would be about 60%, and the importance of fuel cost in the electricity rate is expected to increase more and more.

(b) Fuel cost per ton and transportation cost

NEC's average fuel cost per ton cannot be identified in its annual report. The figures in Table 3-13 are estimated from the prices of gas oil and heavy oil (1,500 sec and 3,500 sec) per ton, including transportation cost at Khartoum.

Table 3-13 **Fuel price per ton (LS/t)**

(Price at Khartoum including Transportation Cost)

FY	1979/80	80/81	81/82	82/83	83/84	84/85	85/86
Gas oil	197.6	245.9	289	401.5	562.1	674.5	792.7
Furnace oil (1,500 sec)	96.1	160.5	190	250	250	351.3	495.7
Furnace oil (3,500 sec)	51.1	84.0	100	140	140	241.3	283.0
Fuel Price of NEC (1)	119	141	193	209	311	386	456
Annual escalation rate (%)	55	18.5	37.1	8.3	49	24	19.3
Annual price index (%)		25.3	24.5	25.7	30.6	47.6	

Note: (1) is an estimated figure calculated from the weighed averages of various fuels used by NEC.

According to the table, NEC's unit price for fuel increased by 3.9 times or 25% annually in the 6 years from 1979/80 to 1985/86, which is almost equal to the 25% average increase in the commodity price index.

As for the transportation cost from Port Sudan to Khartoum, in fuel price units, the study team found that transportation by road was 100 LS/t, and by rail 101.3 LS/t and 151.9 LS/t, in 1984/85 and 1985/86. The averaged weight of the transported volume in these fiscal years was used to calculate the average transportation cost per ton, and the results are shown in Table 3-14. Gas oil, though transported by pipe line, is included in the calculation of the average transportation cost per unit. The volume of gas oil is small compared with the total amount of fuel transported, and the inclusion of gas oil results in slightly lowering the average transportation cost per unit.

Table 3-14 Average fuel transportation cost per unit for NEC

FY		1984/85	85/86
Road transportation	(%)	60	50
Rail transportation	(%)	40	50
Unit cost by road	(LS/t)	100	100
Unit cost by rail	(LS/t)	101.3	151.9
Average unit cost	(LS/t)	100.5	126.0
NEC's fuel unit cost	(LS/t)	386	456
Transportation cost	(%)	26.0	27.6

From Table 3-14, it is evident that 26% and 27.6% of NEC's fuel price per ton, shown in Table 3-13, were the transportation cost in 1984/85 and 1985/86, respectively.

(c) Fuel transportation cost and electricity rate

The relationship between the fuel cost and electricity rate from actual results is shown in Table 3-15.

Table 3-15 Proportion of fuel and transportation costs in the electricity rate

FY	1978/79	79/80	80/81	81/82	82/83	83/84	84/85
Fuel cost (× 10^3 LS)	5,820	7,518	10,227	17,745	20,618	29,686	51,088
Total power generated (GWh)	724	822	833	873	934	1,014	1,233
Power sold (GWh)	609	608	630	681	662	790	990
Fuel cost at generation end (LS/GWh)	0.008	0.009	0.012	0.020	0.022	0.029	0.041
Average electricity rate	0.034	0.054	0.054	0.054	0.054	0.142	0.205
Average electricity rate includes –							
Fuel cost (%)	23.5	16.7	22.2	37.0	40.7	20.4	20.0
Transportation Cost (%)	—	—				5.3	5.52

As seen from the table, the ratio of the fuel cost in the electric rate was approximately 20%, a little more than 5% occupied by the transportation costs, in the fiscal years of 1983/84 and 1984/85. They were however the results of 160% and 44% rises in the electric rate, respectively, made in the previous fiscal years. If the electric rate was not revised, abnormal results would have been obtained, i.e., the fuel cost would have exceeded 50% and the transportation cost would have been over 15% of the electric rate. The ratio of the transportation cost in the electric rate has a tendency to increase because of the contents of the Power IV Project which mainly consists of thermal power generation. It is therefore important to minimize the transportation cost.

④ Financial situation of NEC

The Income Statement and the Balance Sheet furnished by NEC are shown in Tables 3-16 and 3-17, respectively. On the basis of these financial statements, the operating efficiency (Table 3-18) and fund operation (Table 3-19) of NEC were analyzed.

Table 3-16 Income statement of NEC

(Unit: 10^6 LS)

FY	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
OPEPATING REVENUE								
Power sold GWh	659.1	789.8	931.5	1,139.2	1,307.4	1,484.1	1,542.6	1,551.1
Average price	0.068	0.137	0.158	0.212	0.272	0.321	0.388	0.407
Sales revenue	44.6	108.6	147.2	241.8	356.2	478.2	598.6	631.2
Other revenue	0.1	2.1	3.5	4.2	4.8	5.6	6.4	7.4
Operating revenue	44.7	110.7	150.7	246.0	361.0	483.8	605.0	638.6
OPERATING EXPENSES								
Salaries	11.5	15.8	16.3	25.2	28.4	31.2	33.9	36.5
Fuel	19.7	29.7	50.2	75.5	112.6	148.9	(193.6)	(251.6)
Materials	1.2	2.6	8.9	6.4	8.0	9.6	11.3	13.0
Repairs & Maintenance	6.3	9.8	23.3	25.5	31.9	38.3	44.9	51.7
Other	6.5	7.1	12.3	15.0	18.8	22.5	26.4	30.4
Depreciation	11.9	13.5	17.4	24.5	34.3	48.0	68.7	98.9
Operating expenses	57.1	78.5	128.4	172.1	233.8	298.4	(378.8)	(482.1)
OPERATING INCOME	−12.4	32.2	22.2	73.9	127.2	185.4	(226.2)	(156.5)
INTEREST ON EQUITY CAPITAL	13.2	8.8	9.5	19.6	28.5	45.0	61.7	85.2
NET INCOME BEFORE LOAN INTEREST	−25.6	23.4	12.7	54.3	98.7	140.4	(164.5)	(71.3)
INTEREST CHARGES	2.2	2.8	21.1	47.1	61.4	93.8	(165.4)	(252.0)
NET INCOME	−27.8	20.6	−8.4	7.1	37.3	46.7	(−0.9)	(−180.7)

Note: Prepared on May 7, 1986 (Estimated figures are used for after 1984/85)

Table 3-17 Balance sheet of NEC

(Unit : 10^6 LS)

FY	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
FIXED ASSETS								
Plant in operation	384.6	443.0	818.3	1,142.0	1,599.3	2,290.2	3,296.4	4,580.4
Depreciation	−115.2	−143.0	−197.3	−275.1	−378.1	−501.8	−658.3	−855.9
Works in progress	177.6	245.2	621.0	866.9	1,221.2	1,788.4	2,638.2	3,724.5
CURRENT ASSETS								
Cash and Banks	−6.5	−6.7	−6.5	−8.1	−19.6	−12.6	−36.5	−71.6
Accounts receivable	56.2	117.8	140.8	108.2	90.2	121.0	100.8	106.4
Inventories	27.4	42.2	24.5	34.3	48.0	68.7	98.9	137.4
Regional Power Corp.	57.1	79.6	50.0	40.0	30.0	20.0	10.0	0.0
Other	1.0	1.1	4.0	4.5	5.0	5.5	6.0	6.5
TOTAL CURRENT ASSETS	582.2	779.2	1,033.8	1,037.6	1,835.7	2,686.4	3,696.9	4,924.7
LIABILITIES & EQUITY								
Capital	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Retained earnings	−8.1	12.5	−0.5	6.6	43.9	90.5	158.5	101.6
Grants	57.8	75.8	90.8	95.8	95.8	95.8	115.8	115.8
Revaluation reserve	229.3	274.3	410.7	594.1	858.5	1,180.8	1,603.2	2,121.2
FIXED LIABILITIES	190.7	223.8	403.7	465.2	719.4	1,168.1	1,627.3	2,339.8
CURRENT LIABILITIES	101.3	181.6	117.4	134.8	106.9	139.9	180.9	235.1
TOTAL LIABILITIES	582.2	779.2	1,033.8	1,307.6	1,835.7	2,686.2	3,696.9	4,924.7

Note: Prepared on May 7, 1986 (Estimated figures are used for after 1984/85)

a) Break-even point

The break-even point constitutes a yardstick in the analysis of the operating efficiency of an enterprise. It is a marginal production level at which the operating income is equal to the operating expenses. It can be said that the lower this level is the higher the operating efficiency.

Table 3-18 shows the break-even point. From this table, the ratio of the break-even point to power sold was 66.8% in 1982/83, decreasing to 44.7% in 1987/88. But the ratio gradually increases thereafter to 44.7%, 45.1%, and 59.5%. Consequently, the operating efficiency is predicated to gradually deteriorate.

b) Current ratio

The current ratio is the ratio of current assets to current liabilities, and is considered to indicate the short-term solvency of an enterprise. An ideal ratio is generally regarded as being more than 200%. But, in view of the actual conditions of the enterprises at present such as shortages of capital, the average ratio is 110% to 120%. In the case of NEC, the ratio is constantly below 200%. Especially, after 1989, the value is to be less than 100%, indicating year by year a deterioration of solvency.

c) Fixed ratio

The fixed ratio is the ratio of fixed assets to capital and indicates how much capital has been invested in the fixed assets. An ideal ratio is less than 100%. In other words, a desirable situation is when capital, which has no terms of repayment, is more than sufficient to cover the fixed assets. In reality, however, it exceeds 150% in general.

In the case of NEC, the ratio shows a trend of gradually increasing from 1983/84 and reaching 202% in 1989/90. This means that borrowing the same amount of capital is necessary to finance investment in the fixed assets.

d) Ratio of fixed assets to long-term capital

In an enterprise like an electric utility, which requires huge fixed assets, the amount of capital is relatively small while the investment in equipment and installations is large. In such a case, the fixed ratio stated in the above item c) naturally deteriorates, but it is necessary to see which liabilities, the current or the fixed, are used to cover the shortage in capital. This is judged by the ratio of fixed assets to capital + fixed liabilities. If this ratio exceeds 100%, it means the amount of fixed liabilities is not sufficient to cover fixed assets and needs to be supplemented with short-term current liabilities, a situation which is unsound and lacks solvency. In the case of NEC, the ratio has been deteriorating since 1985, and will reach 100% in 1989.

e) Capital and liabilities ratio

On the basis of the conception that liabilities should be limited to the amount of capital, a capital and liabilities ratio higher than 100% is considered ideal. In the case of NEC, the ratio underwent fluctuations till 1986 and thereafter shows a decreasing trend, and may reach 91% in 1990.

From the study on all the above items, the financial situation of NEC is not considered sound, and there is the danger of its profitability deteriorating in the future. Net income after paying interest is extremely small, and only a fraction of the fund is required for new electric power development to cope with the growth of demand of about 11% per year.

In this connection, it has been tentatively calculated to set at what scale the power station can be constructed with the net profit of NEC, as follows :

The peak power demand in 1984/85 was 235 MW (refer to Table 2-6), while the energy sales (forecast) during the period of 1985 to 1990 show an annual growth of 11%, from 931.5 GWh to 1,551.1 GWh (cf. Table 3-16). In order to cope with this growth, it is necessary to reinforce power generating facilities by approximately 26 MW per year (235 MW × 11% = 25.85 MW). Then, assuming that all the net income of NEC is invested, the approximate scale of a thermal power station that can be constructed with its own funds is calculated as follows:

1. Net income in 1984 : US$5,150,000 (20,600,000 LS)
2. Average unit price for construction of thermal power station : US$700/kW

From the above, a thermal power station which NEC can construct will generate about 7 MW (5,150,000 ÷ 700 = 7,357 kW). That is to say, the construction fund for future electric power development to be carried out by NEC continues inevitably to depend on borrowing.

Furthermore, it is forecasted that net profit will become negative around 1990. Consequently, it is judged that investments which will increase the interest payment burden on NEC is unreasonable and that, as far as possible, international aid in the form of Grants Aid is desirable.

Table 3-18 Operating efficiency analysis

Item \ FY	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
(a) Power sales (GWh)	659.1	789.8	931.5	1,139.2	1,307.4	1,489.1	1,542.6	1,551.1
(b) Operating revenue ($\times 10^6$ LS)	44.7	110.7	150.7	246.0	361.0	483.8	605.0	638.6
(c) Variable cost ($\times 10^6$ LS)	19.7	29.7	50.2	75.5	112.6	148.9	NA (193.6)	NA (251.6)
(d) Fixed cost ($\times 10^6$ LS)	37.4	48.8	78.2	96.6	121.1	149.5	185.3	230.4
(e) Operating income Net income ($\times 10^6$ LS)	−12.4 −27.8	32.2 20.6	22.2 −8.4	73.9 7.1	127.2 37.3	185.4 46.7	(226.1) (−1.0)	(156.6) (−180.6)
(f) Operating revenue per KWh (a)/(b)	(piaster) 6.78	14.02	16.18	21.59	27.61	32.49	39.22	41.17
(g) Variable cost per KWh (a)/(b)	(piaster) 2.99	3.76	5.39	6.63	8.61	10.0	12.55	16.22
(h) Break-even point (d)/(f − g)	GWh 987	476	725	646	638	665	695	923

Note: 1 piaster = 0.01 LS

Table 3-19 Fund statement

(Unit: 10^6 LS)

Item \ FY	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
(a) Current assets	135.2	234.0	220.1	178.9	153.6	202.5	179.2	178.8
(b) Current liabilities	101.3	181.6	117.4	134.8	106.9	139.9	180.9	235.1
(c) Fixed assets	477.0	545.2	813.7	1,128.8	1,682.2	2,483.9	3,517.7	4,745.9
(d) Current liabilities	190.7	223.8	404.2	465.2	719.4	1,168.1	1,627.3	2,339.8
(e) Capital	290.2	373.8	512.1	707.6	1,009.4	1,378.3	1,888.7	2,344.8
(f) Current ratio (%) (a)/(b)	133	129	187	133	144	145	99	76
(g) Fixed ratio (%) (c)/(e)	164	146	159	160	167	180	186	202
(h) Fixed assets/Long-term capital (%) (c)/(e + d)	99	91	88	96	97	98	100	101
(i) Capital/Liabilities (%) (c)/(b + d)	99	92	98	118	122	105	104	91

⑥ Summary

The demand-supply balance of BNG in the Power IV Project supply capability is sufficient under average hydrological conditions. Except for 1986/87, cold reserve will not be adequate under adverse hydrological conditions, but stable power supply can be secured until 1990/91, the year the Power IV Project is completed. Therefore, the demand and supply balance of the Power IV Project is judged to be reasonable.

As for the quantity of fuel necessary to consume to accomplish the power generation, the estimate by NEC is also considered reasonable. The quantity of fuel required in adverse hydrological conditions is also estimated because thermal power generation has to complement hydropower generation, which is subject to hydrological conditions.

As for the relationship between fuel transportation costs and the electric rate, the fuel costs as well as fuel transportation costs occupy a rather large part in the electricity rate, because power stations are located inland. It is very important therefore to decrease transportation cost, considering that dependence on thermal power generation is increasing. Therefore, it is judged reasonable that a fuel transportation reinforcement program be included in the Power IV Project.

Investment for the Power IV Project is judged to be possible, according to the analysis of the financial condition of NEC. However, it would be difficult for NEC to continue investments which may burden it with more payments of interest.

3-1-2. Fuel Transportation project

The fuel Transportation Project formulated under the Power IV Project by the Government of the Sudan is as follows :

(1) Power generation plan and fuel consumption

As stated in the preceding section, the forecasts for power demand and fuel consumption in the Power IV Project are shown in Table 3-8. In addition, the forecast for adverse hydrological conditions is shown in Table 3-9 and Figure 3-1. These figures are calculated from the annual total consumption of fuel. After 1989/90, when the proposed diesel locomotives are delivered to the Sudan for fuel transportation, it will be necessary to have an annual transport capacity of 209,000 t (1989/90) and more than 479,000 t (1995/96) in order to transport the total fuel required by rail.

Fuel consumption varies according to the hydrological conditions on the Blue Nile River, irrigation conditions, and power demand. Fluctuation of BNG's power demand by month, according to NEC's Annual Report, is shown in Table 3-20.

For 1988/89, when BNG will have a maximum hydro generating capacity with the expansion of Roseires Unit No. 7, hydro and thermal power generation by month is estimated as shown in Figure 3-3.

Table 3-20 Monthly power demand (GWh)

Month	1982/83	1983/84	1984/85	%
7	84.9	90.5	107.3	8.96
8	66.3	53.8	114.5	7.43
9	74.3	67.0	100.2	7.65
10	87.2	89.2	105.2	8.92
11	78.4	86.2	97.9	8.32
12	81.9	84.5	88.2	8.07
1	68.2	84.8	104.0	8.14
2	65.7	83.2	79.0	7.22
3	77.1	91.0	99.9	8.49
4	75.5	86.0	98.7	8.24
5	87.5	89.1	109.1	9.05
6	86.9	108.4	105.0	9.51
Total	933.9	1,013.7	1,209.0	100

(Note) Percentage : Average value of monthly power demand/annual power demand

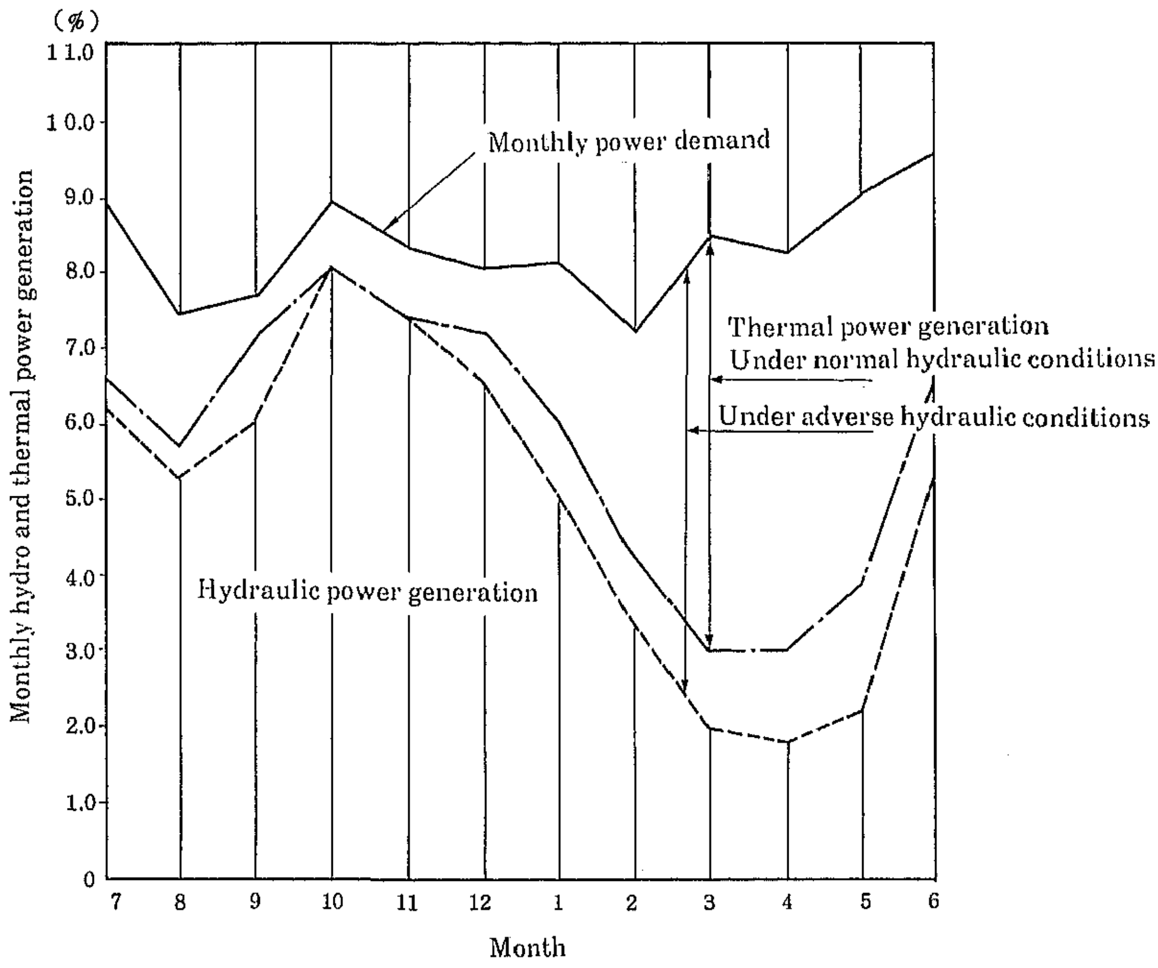


Fig. 3-3 The estimation of monthly power demand for hydraulic and thermal power generation

Figure 3-3 reveals that dependency on thermal power generation is great in the dry season from February to June. After 1988/89, all increments in electric power demand are to be supplied by thermal generation, resulting in a relative expansion of the band between hydro and thermal power in the figure.

The fuel consumption of thermal power generation by month in the period of the Power IV Project (1986/87 – 90/91) is estimated in Table 3-21. From this table, it is evident that a large volume of fuel is consumed from March through May.

Table 3-21 Fuel consumption estimate

(10^3 t)

FY	1986/87		1988/89		1989/90		1992/93		1995/96	
Month \ Hydro	Aver-age	Ad-verse	Aver-age	Ad-verse	Aver-age	Ad-verse	Aver-age	Ad-verse	Aver-age	Ad-verse
7	9.7	12.4	13.3	16.1	16.3	19.2	26.7	29.7	40.3	43.3
8	7.3	9.3	10.2	12.3	12.7	14.8	21.6	23.5	32.9	34.8
9	1.9	7.4	4.4	10.4	6.9	12.9	16.2	21.8	27.8	33.5
10	3.2	3.7	6.2	6.7	9.1	9.7	19.5	20.0	33.1	33.6
11	3.6	4.1	6.4	7.0	9.2	9.8	19.2	19.7	31.8	32.3
12	3.4	6.9	6.2	9.9	8.9	12.7	18.3	21.9	30.6	34.2
1	8.9	13.5	12.1	17.0	14.8	19.8	24.3	29.2	36.7	41.6
2	13.1	16.9	16.4	20.5	18.8	23.0	27.4	31.2	38.3	42.2
3	24.1	28.7	28.8	33.6	31.6	36.6	41.5	46.4	54.4	59.3
4	23.0	28.2	27.5	32.9	30.2	35.8	40.1	45.6	52.7	58.1
5	22.6	29.9	27.3	35.1	30.3	38.2	40.8	49.0	54.5	62.7
6	13.1	19.2	17.1	23.7	20.2	26.9	31.4	38.0	45.9	52.4
Total	134	180	176	225	209	259	327	376	479	528

(2) Transportation plan

Due to various reasons, power generation at thermal power stations and fuel consumption fluctuate seasonally. Therefore, power plants should be equipped with fuel storage tanks to handle fluctuations in consumption and equalize transportation rates as much as possible. The required monthly minimum transportation capacity would be the average of the annual fuel consumption, but if the monthly transportation is increased this will result in a decrease of the required capacity of the storage tanks. If the required transportation volume is based on approximately 260,000 t for 1989/90, which is assumed as an adverse hydrological year, the relationship between monthly transportation capacity and storage tank capacity is as shown in Fig. 3-4.

From the above result, a storage tank capacity of 90,000 t including the existing 54,000 t and the Power IV Project's 40,000 t would mean a monthly transportation capacity of 21, 500 t or 260,000 t annually, which is appropriate.

There are 295 working days a year excluding holidays, however, it is planned that fuel will be transported by one train a day, 260 days a year, so as to cope with the transportation needs 2 to 3 years after the target year.

Therefore, approximately 1,000 t per day should be transported. This means one train consisting of tank wagons each with a 35 t capacity. Fuel trains will be operated with a fixed number of wagons and will have a four-day operation cycle (round-trip time) including loading at Port Sudan — going to Khartoum — unloading at Khartoum — returning to Port Sudan. Four trains will be used in this transportation scheme so as to transport the annual fuel requirement of 260,000 tons.

Round-trip time will be shortened to three days in the future as indicated in Table 3-22, when the demand for fuel increases, by improving the loading facilities at Port Sudan and reducing the transportation time by speeding up the train.

Table 3-22 Required round-trip time

Unit: hour

Location	Task	Plan for FY 1989/90	Case I	Case II
Port Sudan (PS)	Shunting	6	6	1
	Loading	14	8	6
	Margin	6	6	1
PS → KRT	Running	27.5	24	24
	Margin	3.5	3	3
Khartoum (KRT)	Shunting	2	2	2
	Unloading	7	7	7
	Margin	1	1	1
KRT → PS	Running	26	24	24
	Margin	3	3	3
Total		96	84	72
Margin (included in total)		(13.5)	(13)	(8)
Round-trip time (day)		4	3.5	3

[Note] "Running" includes the stopping time at way stations.

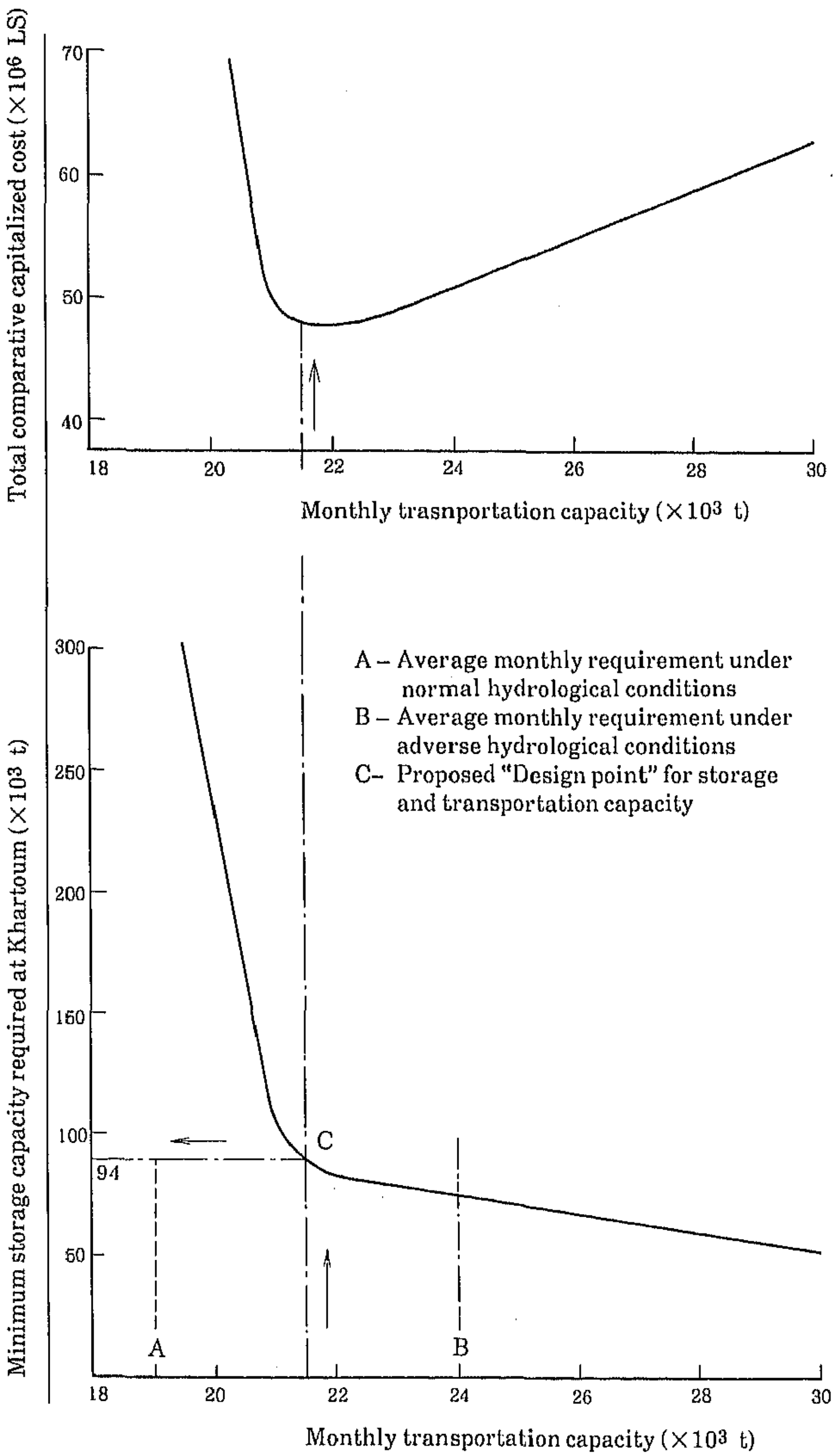


Fig. 3-4 Transportation capacity and storage tank requirements

(3) Equipment and facilities

① Diesel locomotives

Railway tank wagons will be hauled by means of a double-heading operation with 1,650 HP locomotives with 13-ton axle loads. The required number of locomotives is calculated by the following :

2 (double heading) × 4 (No. of trains) + 2 (standby units) = 10 (locomotives)

Until the new locomotives are introduced, the existing 10 class 1900's diesel locomotives that are presently out of service will be rehabilitated and used.

② Tank wagons

Tank wagons with a 35-ton capacity, equipped with heating coils will be used in this Project. The required number of tank wagons is calculated by the following :

28 units × 1.1 (10% standby units) × 5 (trains) = 155 tank wagons

Until the new tank wagons are introduced, existing wagons will be used by modifying their brake (replacing vacuum brakes with air brakes) and adding heating coils.

③ Communications equipment

Installation of the following facilities

- Radio communications equipment interconnecting related sections of Khartoum, Atbara and Port Sudan
- Radio equipment for trains and their nearest station

④ Terminal facilities

- Extension of loading tracks and inlets, as well as installation of steam heating coil at petroleum companies in Port Sudan
- Extension of unloading tracks and inlets, and fuel storage tank, as well as installation of steam heating coils at thermal power stations in Khartoum

3-2. Review of the request

——Fuel Transportation Project——

The report of the previous study team had 1988/89 as the target year, but in this report it has been changed to 1989/90 because the locomotives will not be available until March 1989 for the Fuel Transportation Project. A check will be made to see if the volume of fuel transportation in 1990/91, when the Power IV Project will be finished, can be dealt with.

3-2-1. Power generation plan and fuel consumption

The monthly fuel consumption is described in Table 3-21, when the locomotives will come into full use for the Fuel Transportation Project. Table 3-21 also indicates that the annual fuel consumption (transportation) of that year will vary from 209,000 t to 259,000 t, depending upon the hydrological conditions.

The minimum monthly transport quantity is calculated from these values ;

- when hydrological conditions are normal .... 17.5×10^3 t
- when hydrological conditions are adverse ....21.6×10^3 t

Figure 3-5 indicates the minimum capacity required for the storage tank, which varies with the transportation capacity. In 1989/90, the minimum capacity for storage tanks will be 43.6×10^3 t (when hydrological conditions are normal) and 52.5×10^3 t (when hydrological conditions are adverse) respectively.

If the transportation capacity increases, the minimum capacity for the storage tanks decreases. For example, when the hydrological conditions are adverse, the minimum capacity for the storage tanks varies as in Figure 3-6 with transportation capacities of 21.6×10^3 t, 25.0×10^3 t and 30.0×10^3 t. Accordingly, Figure 3-7 indicates the relation between monthly transportation capacity and the minimum required capacity of storage tanks.

Therefore, the capacity of the present storage tanks can meet the requirements of 1989/90 (when the hydrological conditions are adverse).

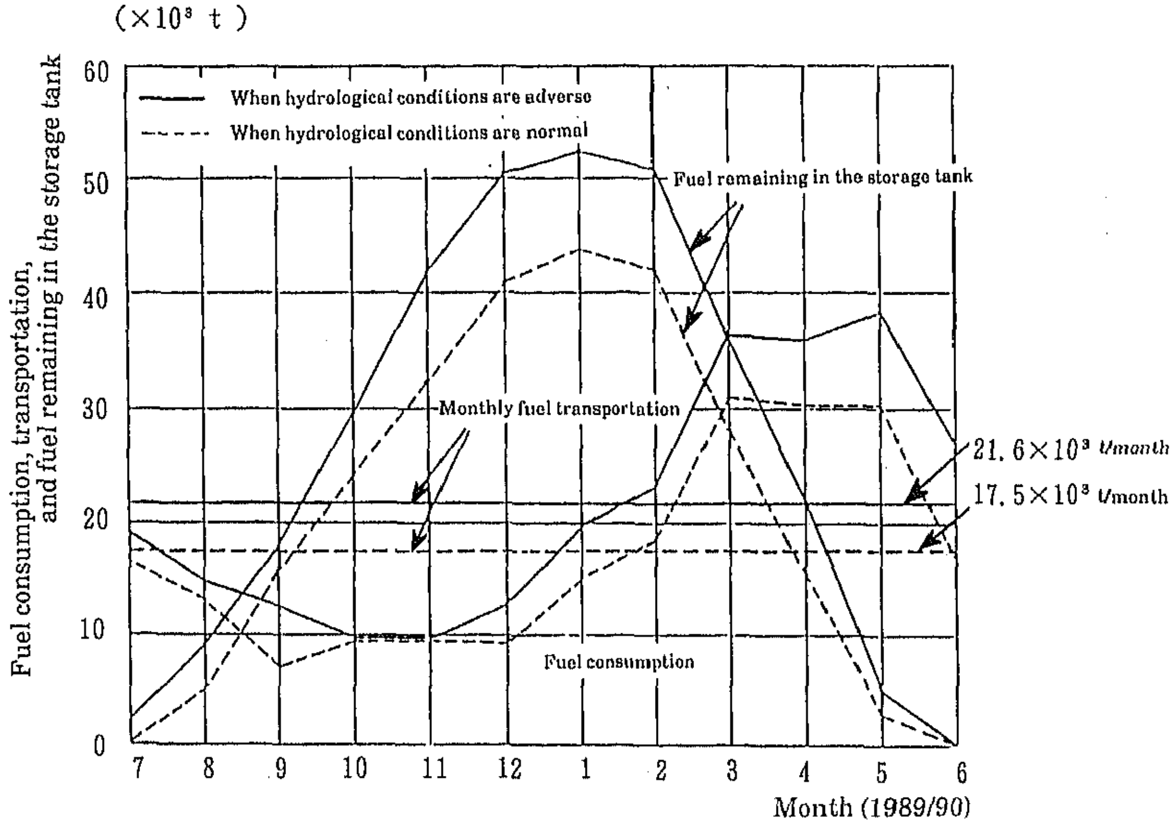


Fig. 3-5 Monthly fuel consumption and fuel remaining in the storage tank

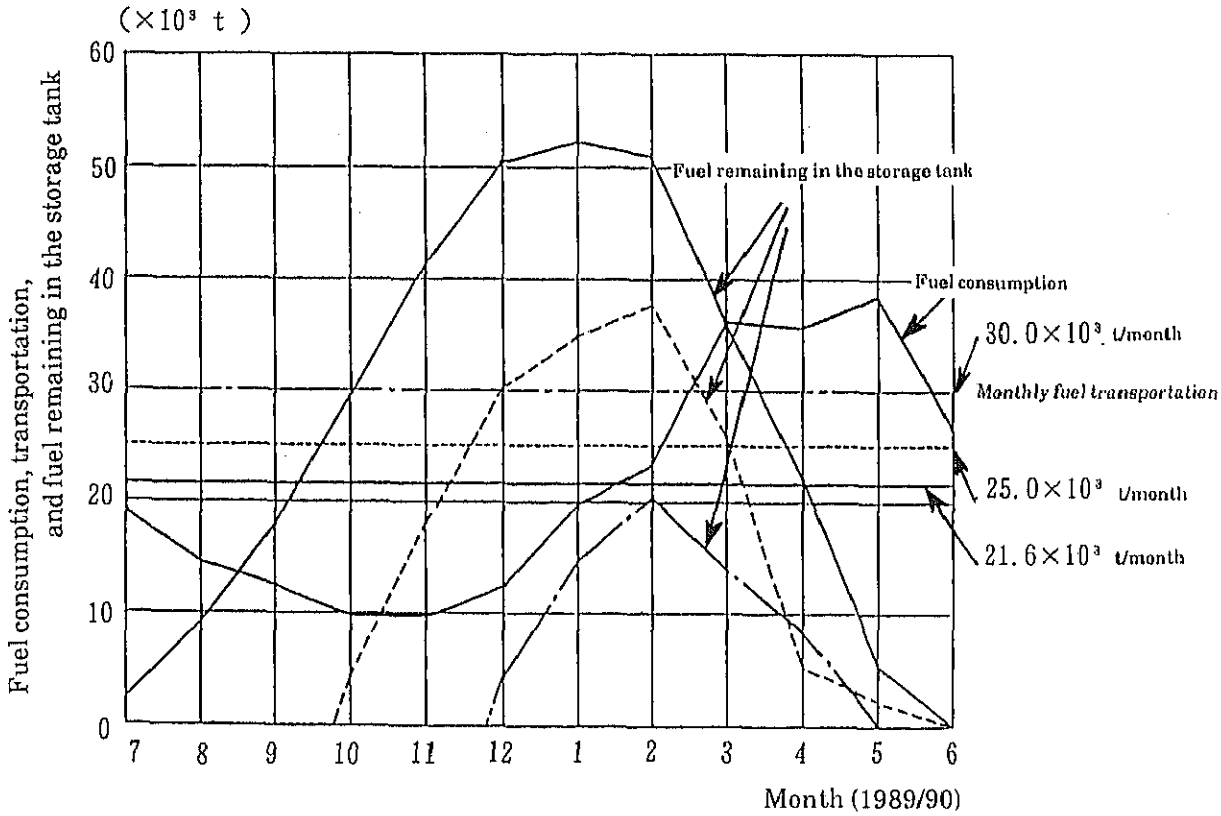


Fig. 3-6 Monthly fuel consumption and fuel remaining in the storage tank

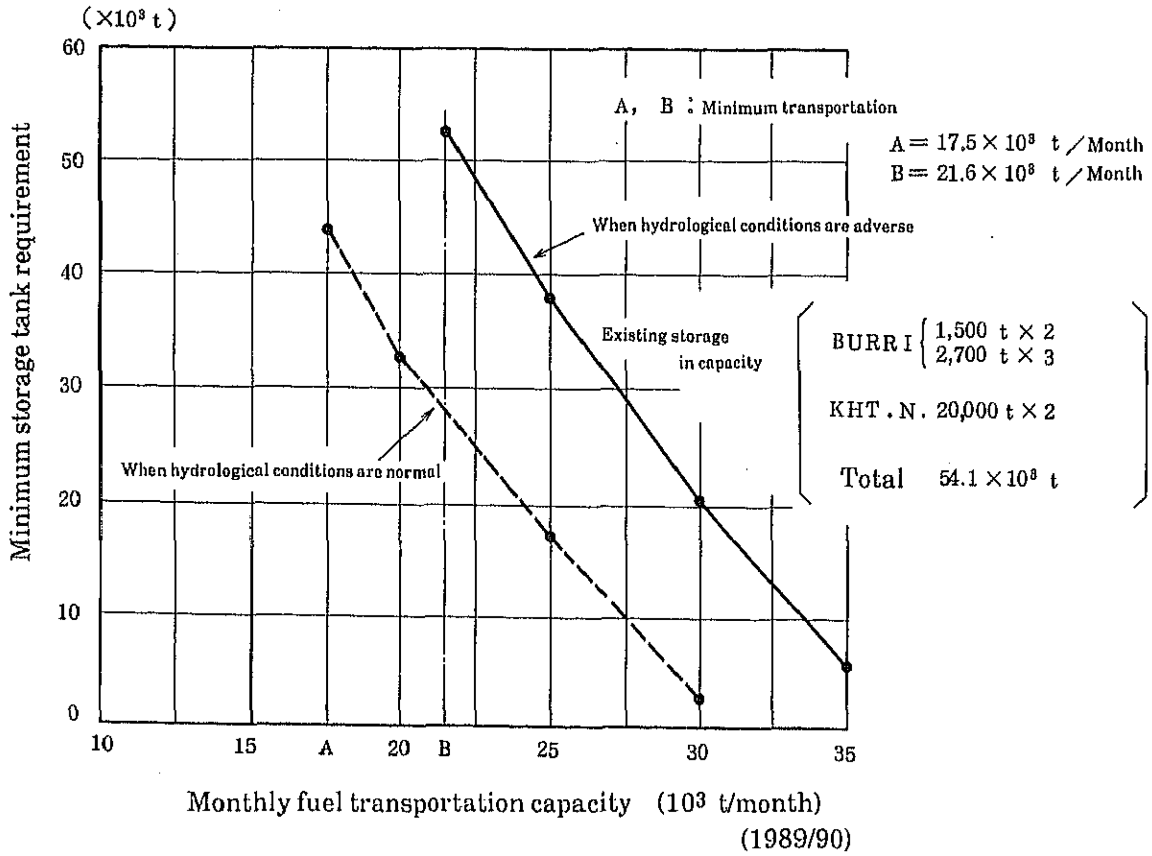


Fig. 3-7 Fuel transportation capacity and storage tank requirements

But, it is apparent that the minimum capacity of the storage tanks will increase with the increase of thermal power generation, and consequently a 40,000-ton tank facility is planned to be built in the Power IV Project.

Concerning daily transportation capacity, when annual working days are assumed to be 295, the minimum value is calculated for the year 1989/90 as follows :

- when the hydrological conditions are normal .... 708 t
- when the hydrological conditions are adverse ....878 t

and allowing some safety margin, the transportation capacity should be about 900 t/day. Further, in the year 1990/91, the annual fuel transportation will be 246,000 t (when the hydrological conditions are normal) to 296,000 t (when the hydrological conditions are adverse).

3-2-2. Fuel transportation scheme

(1) Formation of trains

As to the method of transportation, it is desirable to conduct uniform transportation every day in order to make effective use of equipment. From the volume of fuel oil to be transported, as indicated previously, the number of tank wagons for a fuel train is calculated as follows :

900 t/day ÷ 35 t/wagon = 25.7 wagons/day

Therefore, a tank wagon, when loaded, weighs 52 tons (17 tons when empty) and one Manama and one Brake Van (tare 20 t each) are coupled before and after the train. Consequently, the total hauling load is calculated as follows :

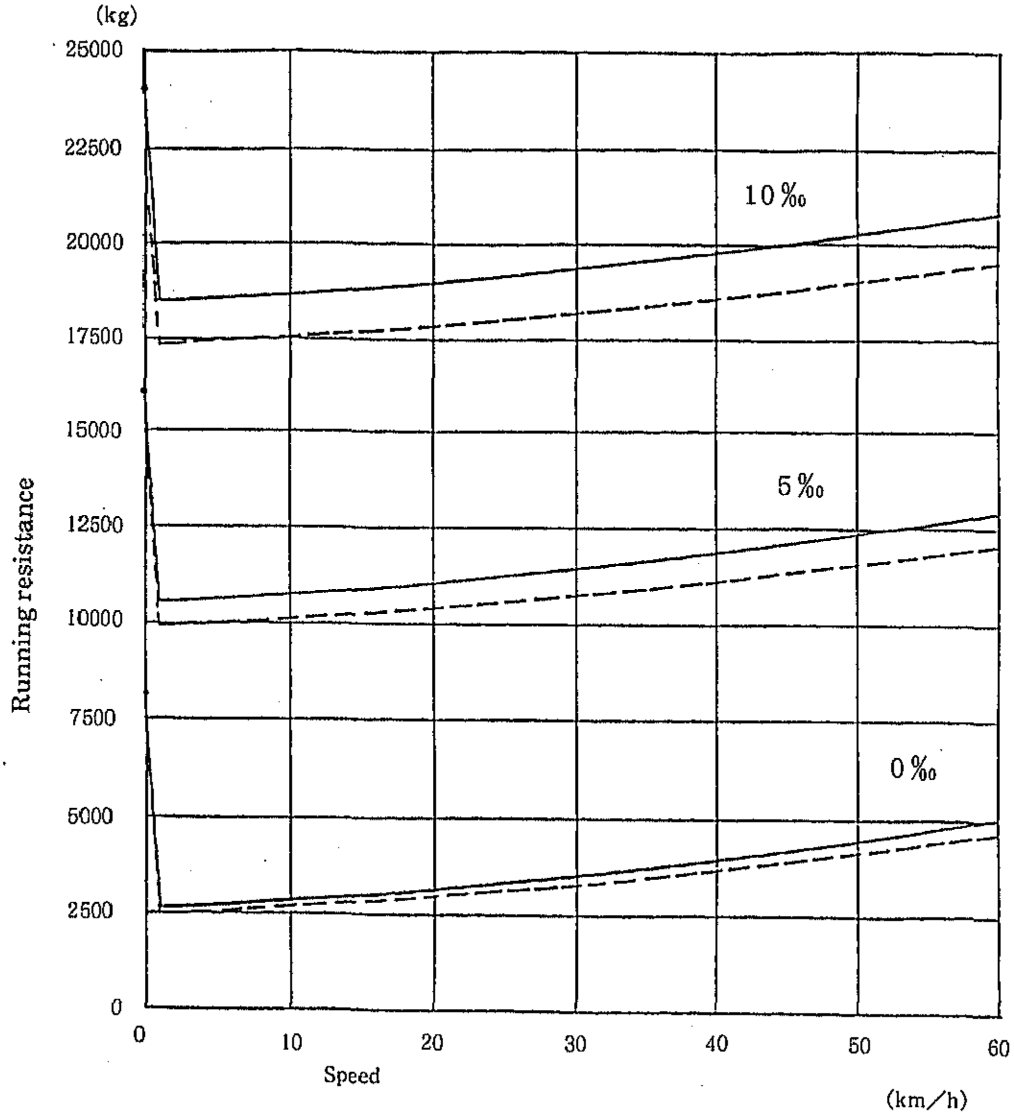
Port Sudan → Khartoum

52 t × 26 wagons + 20 t × 2 wagons = 1,392 t

Khartoum → Port Sudan

17 t × 26 wagons + 20 t × 2 wagons = 482 t

The running resistance and required horsepower of a loaded train on upgrades of 0, 5, and 10‰ are shown in Fig. 3-8 and 3-9. The running resistance was obtained by the Davis Formula and the starting resistance calculated on the basis of 6 kgf/t for locomotives and 5 kgf/t for wagons.
As for the conditions of track between Port Sudan and Khartoum, there is a continuous upgrade (10‰ maximum) from Port Sudan to Summit (124 km approximately), including a 60-km section with an incline close to 10‰. The section is the decisive factor in deciding locomotive performance. As can be understood from Fig. 3-9, ascending of an upgrade of 10‰ at a speed higher than 30 km/h requires an output of more than 3,250 PS, but it is impossible to mount a large diesel engine of such horsepower on a 6-axle locomotive weighing 96 t. Consequently, it is considered necessary to use two coupled locomotives, as proposed by SRC.
Also, taking into account the approximately 60 km of continuous upgrade close to 10‰, a balancing speed (speed at which tractive force and running resistance are balanced) higher than 30 km/h is desired, which means the total horsepower of the two locomotives will have to be 3,500 to 4,000 PS, that is, diesel locomotives of the 2,000 PS class will be required.

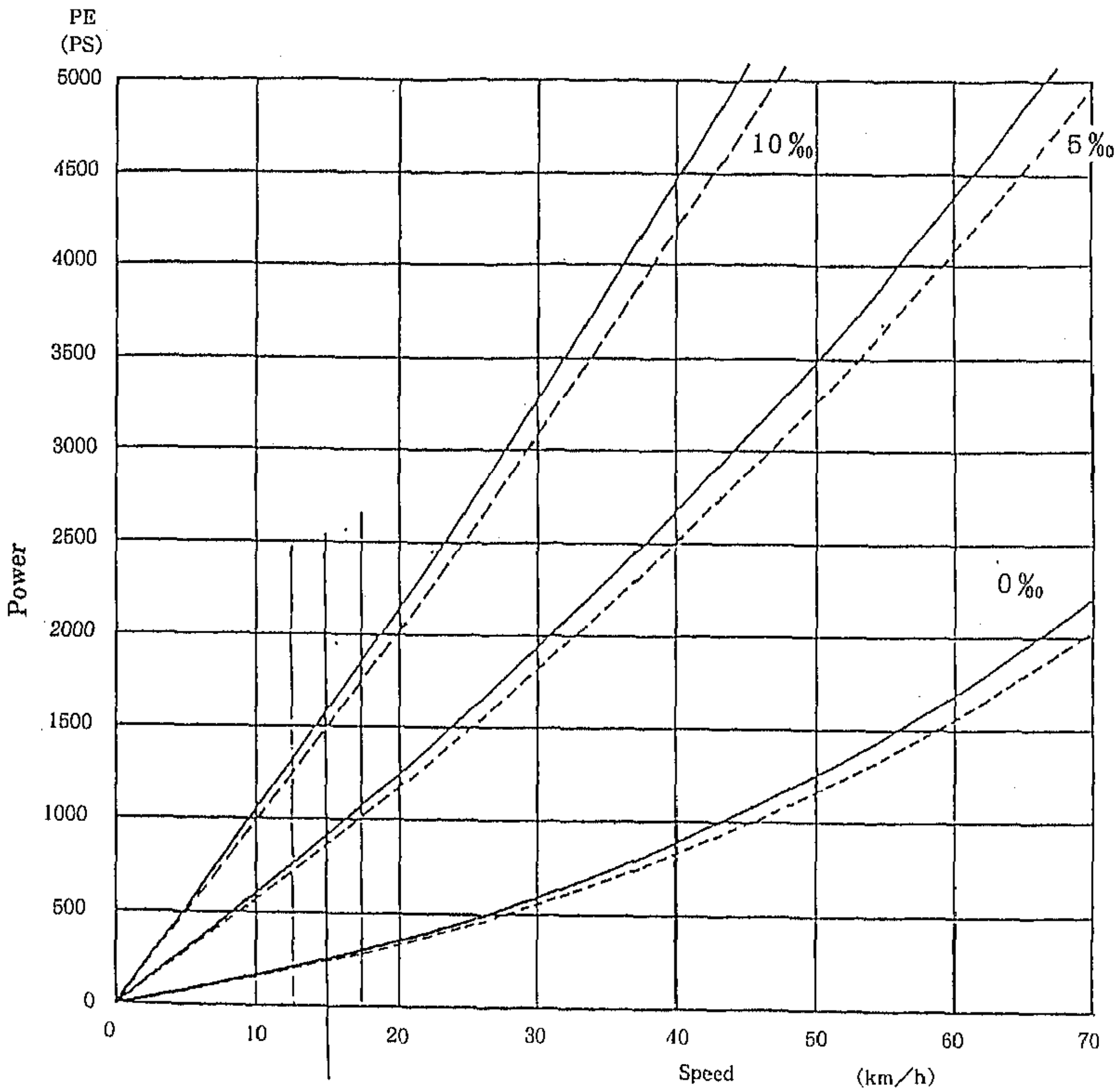


Conditions
Tank wagon (52 t) ×26 + Manama,
Brake Van (each 20 t)
—— Double head (96 t × 2 locomotives) hauling
---- Single head (96 t × 1 locomotive) hauling

DEL Running resistance
r = 1.472+0.00932V+0.00053V^2 (kg/t)
Tank wagon running resistance
r = 1.662+0.01398V+0.00015V^2 (kg/t)

Fig. 3-8 Running resistance

Considering the maintenance level of SRC and the conditions under which the locomotives are to be used in the route concerned (supposing an ascent at 36 km/h, a 3.5-hour operation at full power, an outside air temperature of 48°C, and an altitude close to 1,000 m ----- Summit), the engine to be mounted must be of a large-sized and low revolution type (about 1,000 rpm) with horsepower to spare.



Conditions
Tank wagon (52 t) ×26+Manama,
Brake Van (each 20 t)
—— Double head (96 t × 2 locomotives) hauling
---- Single head (96 t × 1 locomotive) hauling

DEL *Running resistance*
$r = 1.472 + 0.00932V + 0.00053V^2$ (kg/t)
Tank wagon running resistance
$r = 1.662 + 0.01398V + 0.00015V^2$ (kg/t)

Fig. 3-9 Locomotive power requirements

Since it is impossible to mount a 2,000 PS class diesel engine on a 6-axle locomotive weighing 78 tons (axle load is limited to 13 tons), the study should presuppose a 6-axle locomotive weighing 96 to 99 tons in total allowing an axle load of 16 to 16.5 t maximum. Also the locomotive for such an upgrade requires a rheostatic brake to be used in descending the grade, which is another factor that increases the weight. Further, in order to cope with any trouble with the locomotive on the gradient section, it is desirable that the ascent as well as the descent of the gradient be done with only one of the two locomotives (even if the speed becomes very slow).

For only one locomotive to be able to ascend the grade, it should be capable of drawing out the train and the balancing speed should be higher than the rated speed of the traction motor.

(2) Usage of Locomotives

In order to ascend the 10‰ grade (minimum curvature radius of 388 m) between Port Sudan and Summit, pulling 26 loaded 35-ton capacity tank wagons and one Manama and Brake Van, the double heading of 2,000 PS diesel locomotives (6-axle with a tare of approximately 96 t) is required, or if a single locomotive is to be operated, the number of wagons in the formation must be reduced.

Accordingly, the usage of locomotives between Khartoum and Port Sudan can be conceived in the following three ways :

(A) Double heading throughout all of the section.

(B) Double heading only on the upgrade section (Port Sudan ----- Summit) and single traction on other sections.

(C) Reduction of the number of freight wagons and an increase in the number of trains for the upgrade section only, and changing the formation at the top of the grade to organize a train of 26 wagons.

Of the above, an example of (B) is shown in Fig. 3-10. In the case of item (C), a train of 20 wagons, for instance, is operated to the top of the grade, besides another train of 18 wagons every three days.

Of these 18 wagons, 6 are detached every day to be added to a 20-wagon train to form a 26-wagon train to be operated from Summit. A comparison of the three methods is shown in Table 3-23.

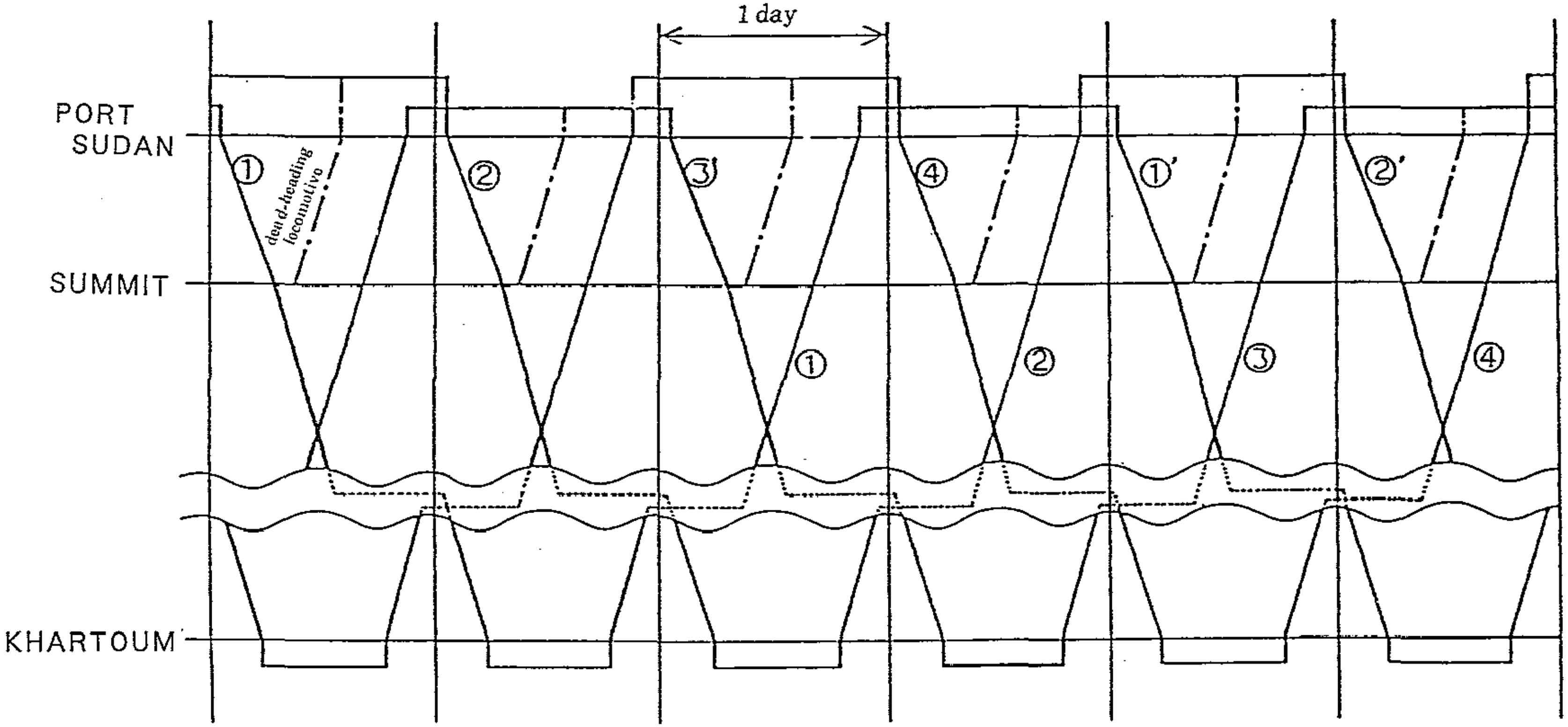


Fig. 3-10 Double heading operation only on the upgrade section
(Port Sudan to Summit)

Table 3-23 Comparison of locomotive usage

Alternative	Merit	Demerit
(A)	1. Higher running speed on the gradient 4.3 hours to run from Port Sudan to Summit (130 km) at 30 km/h speed. 2. No shunting work required en route. 3. The train can be operated even when one of the locomotives fails. 4. Efficient transportation is possible in Khartoum by dividing the train into two parts (Khartoum North and Burri). 5. This alternative has the greatest flexibility for accommodating future growth in demand.	1. This alternative requires many locomotives (10).
(B)	1. The speed inprovement on uphill sections is the same as in alternative A. 2. This alternative requies a relatively small number of locomotives (seven). 3. Shunting of tank wagons is not required en route. (It does not take long to disconnect locomotives.)	1. Any problem in the locomotive significantly affects the transportation scheme. The dispatch of a rescue locomotive takes considerable time. 2. There is no safety margin in the hauling speed capacity on level sections. Furthermore, this alternative requires more powerful locomotives. 3. Deadheading of locomotives for gradient sections is required (i.e., it requires more personnel).
(C)	1. This alternative requires a relatively small number of locomotives (seven).	1. This alternative requires a large number of tank wagons (additional number of tank wagons to compose one train). 2. Any problem in the locomotive significantly affects the transportation scheme. 3. Shunting work of tank wagons is required at the way stations (i.e., it requires additional personnel and additional time). 4. This alternative requires more powerful locomotives.

The following factors must be considered when evaluating Table 3-23.

① Speed on the uphill section

Approximately 30 km/h in alternatives (A) and (B) : (Locomotive output 1,600/1,700 HP)
Approximately 28 km/h in alternative (C) : (Locomotive output 2,250 HP)

There is no problem regarding speed on the uphill section speed because it is approximately 30 km/h. If this speed should be come approximately 20 km/h, an additional two hours would be required to negotiate the uphill section, considerably influencing the total time requirement.

② Shunting work en route

The way stations are located in the desert, and there are problems regarding the allocation of personnel there. Therefore, workers doing shunting must be transported by train, which means additional staff are required.

③ Measures to cope with locomotive troubles

On account of the Sudanese topography, the railroad runs through mostly desert, and locomotives are prone to having trouble. Furthermore, once trouble occurs, much time is required to send rescue locomotives, in view of the location of the locomotive depots and other relevant factors.

At present, delays of more than five hours account for 40% of total delays, far outnumbering the 10% of delays between 30 minutes and five hours; this fact is a symptomatic manifestation of the problem mentioned above.

A long delay in the fuel transportation scheme influences loading work and other phases of the process, and in some cases the next train will have to be cancelled. It thus becomes necessary to consider a substantial safety margin in the transportation capacity, and this results in costly investments in equipment and facilities.

The allotment of rescue locomotives at intermediate bases helps shorten rescue time, but requires additional locomotives (for example, four stand-by locomotives would be required if they should be allotted every 200 km so as to reach a broken down train in two hours). This alternative is not practical because many sheds and inspection/repair facilities would be required for the additional locomotives.

Measures to handle locomotive troubles are particularly important in the Sudan, in view of the topographic and climatic conditions of the country.

Comprehensive judgement of the above leads to the conclusion that item (A), the method of double heading throughout the entire section, is the most appropriate.

(3) Round-trip time

Round-trip time consists of the time required for loading at Port Sudan, running of loaded wagons from Port Sudan to Khartoum, unloading at Khartoum, running of empty wagons from Khartoum to Port Sudan, wagon allocation, shunting for train formation and a margin at each stage. These periods of time, as planned by SRC, are shown in Table 3-24, and plotted in Figure 3-11.

Table 3-24 Required round-trip time

Task		Required time
Port Sudan (PS)	Shunting Loading Margin	6 hours 14 6
PS to KRT	Running (including inspections) Margin	27.5 3.5
Khartoum (KRT)	Shunting Unloading Margin	2 7 1
KRT to PS	Running Margin	26 3
Total		96 hours (4 days)

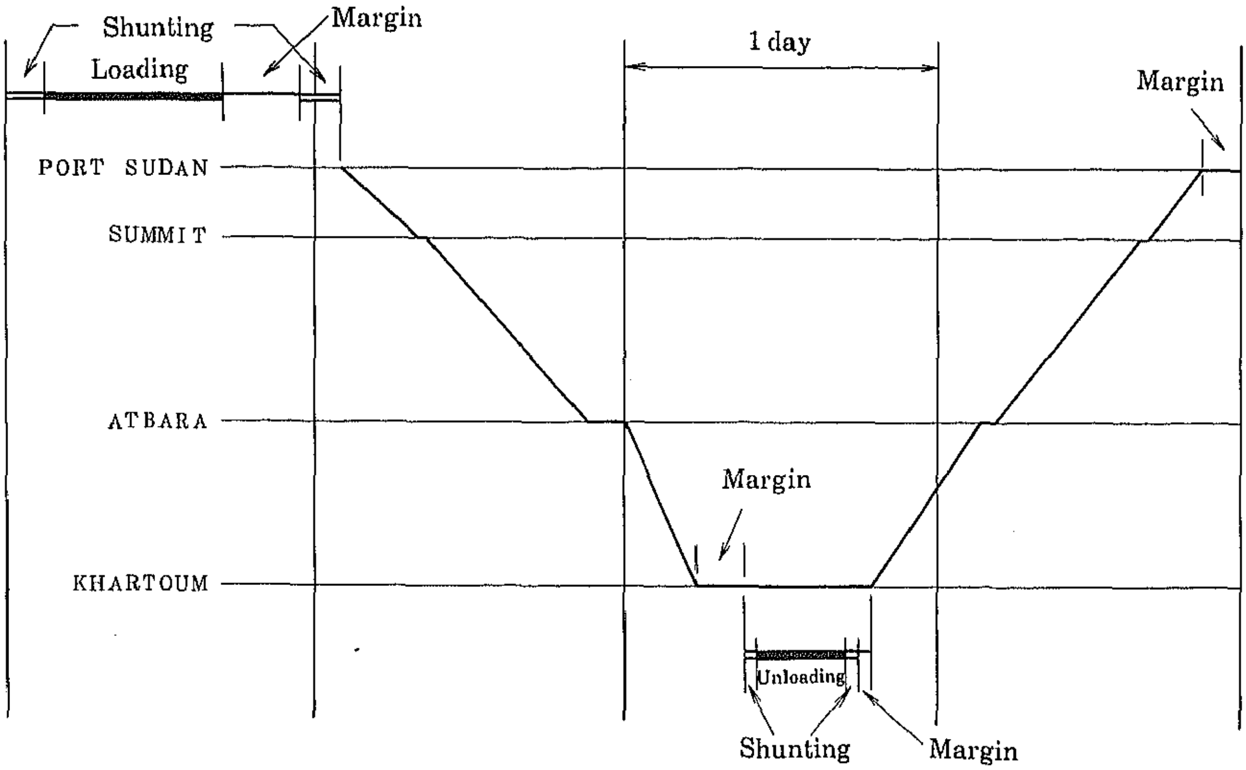


Fig. 3-11 Round-trip time of fuel transportation

According to the Project proposed by the Sudan, if fuel transportation demand should increase further, round-trip time would be shortened to three days by improving the various facilities and shortening the loading and running time. Loading time and running time account for a considerable proportion of the round-trip time, but the former can be reduced considerably by simultaneous loading at various oil companies and by raising shunting work efficiency through the proper use of shunting locomotives.

On the other hand, it is difficult to improve running speed significantly, in view of SRC facilities and their state of maintenance. In reality, however, it is possible to achieve a considerable reduction in the time by raising the speed limit of the tank wagons and by improving the inspection system at the way stations. The rolling stock inspection system should be decided by considering the special conditions in the Sudan and the experience of SRC, but it seems that there are too many inspections at the way stations at present. For example, if the inspections were to be conducted every 24 hours (Japanese National Railways conducts them every 48 hours), and if trains were scheduled to minimize stopping frequency and time at way stations, a greater part of the stopping time at the stations (approximately 9 hours now) would be saved.

As stated previously, the reduction of round-trip time has a great effect on improving the service efficiency of equipment, increasing transportation capacity and curtailing cost. The relation between round-trip time and transportation capacity is indicated in Table 3-25.

Table 3-25 Round-trip time and transportation capacity

Round-trip time		4 days	6 days
Required number of rolling stock	Diesel loco.	6	6
	Tank wagon	26 × 3 units	26 × 3 units
Operated 295 days		198,000 t	265,500 t
Operated 325 days		219,000 t	292,500 t

According to the Sudanese plan, the operating days of trains are estimated at 295 days and 260 days taking into account holidays and also time for recovery from any trouble. However, holidays, although necessary for train crews, are unnecessary for diesel locomotives and freight cars, and so it appears possible to exclude the period for cars in reserve and car inspection. Consequently, the possibility of a 325-day operation was tentatively considered in Table 3-25.

3.2.3. Equipment plan

(1) Diesel locomotives

The Sudanese plan indicates that, for the annual transportation of 260,000 t of fuel for thermal power generation, 28 wagons × 4 trains + 1 train to spare, totaling 140 tank wagons, and 10 diesel locomotives in dual combination for traction are required.

However, from the study of the required round-trip time (see Table 3-25), it is clear that, if the 3-day cycle is realized, three sets of diesel locomotives in dual combination (6 units) and three trains made up of 26 tank wagons each (26 wagons × 3 × 1.1 = 86 wagons) can transport 265, 500 t a year. Also it is known that the number of trains stated above is sufficient to annually transport 198,000 t when a 4-day cycle is adopted.

On the other hand, the quantity of fuel oil to be transported in 1989/90 (when these locomotives are presumably put in service) is estimated at 209,000 t (when hydrological conditions are normal) and 259,000 t (when hydrological conditions are adverse).

Consequently, if the above quantity of 198,000 t is considered to be an addition to the 64,000 t actually carried by SRC in 1985/86, the transportation demand when hydrological conditions are adverse can be met even if operated on a 4-day cycle. Further, in case a complete 3-day cycle operation can be realized, it can transport up to approximately 330,000 t, sufficient to cope with the demand in 1992/93 (when hydrological conditions are normal).

The above estimate presupposes 295 operation days a year, making it unnecessary to set aside spare diesel locomotives to cover maintenance. Spares in the case of failures would also be considered unnecessary if the 6-axle locomotive with an axle load of 16 t to 16.5 t, capable of climbing the gradient alone without assistance from other locomotives, is used in combination.

(2) Tank wagons

With aid from France (45% grants, 55% soft loans), 105 wagons have already been acquired and an additional 36 wagons are expected to be obtained by the end of December 1986.

Therefore, even supposing 4 trains of 26 wagons each (26 × 4 × 1.1 = 115 wagons) are to be operated, a sufficient number of wagons is available, eliminating the possibility of a wagon shortage for some time to come.

(3) Communications equipment

① Communications equipment between trains and their nearest stations

The greater part of the terrain along the railway line is covered by desert with sandy dust and high temperatures prevailing, an environment that tends to cause engine trouble.

In addition, the distance between stations is long and there is no means of communication except for the "wireless between trains and their nearest stations". Consequently, it is necessary to install the same type of wireless equipment that existing locomotives have in themselves to be put in service to transport fuel to secure stable fuel transportation.

② Main intercity communications equipment

SRC has long-distance communications equipment that consists of shortwave radios and bare aerial lines borrowed from STC, but the latter is unreliable due to its poor circuit quality, while the usage of the former is restricted, and there are no spare machines.

Therefore, it is desirable to provide new independent radio equipment in the three cities of Khartoum, Atbara and Port Sudan to enable communication during fuel transportation at any desired time. However, for communication only once a day together small bits of information, the need is not pressing.

Organizations (NEC, GPC, etc.) other than SRC have their own radio equipment as well, and also there is the STC telephone line. In order, however, to improve the reliability of circuits and equipment, it is desirable to install radio equipment separate from these existing lines, but since its use is not frequent and is not used directly for train operation it is not a pressing need.

③ Local communications equipment

In order to effectively carry out shunting work to load and unload fuel, it is preferable to install communications equipment for the exclusive use of SRC, NEC and oil companies within the same city, but at present there exists the STC circuit, and it should be utilized to the maximum limit.

(4) Terminal equipment

The extension and expansion of the unloading line, enlargement of the unloading gate and installation of the steam heating equipment in Burri and Khartoum North Power Stations are considered very effective to improve the unloading system in Khartoum. Also, the installation of additional fuel storage tanks is effective in handling the fluctuations in transportation volume and stabilizing generated energy.

Improvements in the loading system at Port Sudan are to be done by the petroleum companies, for which, however, a study is required as regards such improvements as the enlargement of the loading gates and the installation of a heating system (which at present only Shell Company has) to reduce the round-trip time, as well as realize simultaneous loading at several oil companies by improving the efficiency of wagon shunting work.

Especially, the loading work at Port Sudan, which takes much time at present, needs a thorough examination and much can be expected from the resulting improvement.

3-3. General outline of the plan

As a result of the investigation conducted as described so far,this study mission considers the following as appropriate for the Fuel Transportation Project :

3-3-1. Electric power demand and fuel consumption

The future electric power demand, the hydraulic and thermal power generating programs based on the Power IV Project, and the volume of fuel (furnace oil only) needed for thermal power generation are shown in Table 3-26. (Actual results and forecast)

There are several kinds of fuel for power generation, but in this table, the volume of furnace oil only, transported by railway, is shown.

In accordance with Table 3-26, the volume of fuel to be transported under the Fuel Transportation Project will reach a maximum of 265,500 t (3-day cycle) : 209,000 t in 1989/90 when the diesel locomotives are put in service and 246,000 t in 1990/91 when the Power IV Project is completed.

Table 3-26 Annual thermal generation and fuel consumption (Actual results and forecast)

(same as Table 3-9)

Fiscal Year	Power demand	Hydro genertion		Thermal generation		Fuel consumption		Fuel transport	
		Average	Adverse	Average	Adverse	Average	Adverse	Rail	Truck
	GWh	GWh	GWh	GWh	GWh	10^3 t	10^3 t	10^3 t	10^3 t
1981/82	873	746		127		33.9		33.9	
82/83	934	773		161		41.0		41.0	
83/84	1,014	781		233		61.6		61.6	
84/85	1,233	949		284		91.8		36.7	55.1
85/86	1,218	(825)		(393)		127.8		63.9	63.9
86/87	1,593	1,106	940	487	653	134	180	100%	
87/88	1,714	1,106	940	608	774	167	213	by	
88/89	1,839	1,200	1,020	639	819	176	225	rail	
89/90	1,961	1,200	1,020	761	941	209	259		
90/91	2,095	1,200	1,020	895	1,075	246	296		
91/92	2,232	1,200	1,020	1,032	1,212	284	334		
92/93	2,386	1,200	1,020	1,186	1,366	327	376		
93/94	2,554	12,00	1,020	1,354	1,534	373	423		
94/95	2,736	1,200	1,020	1,536	1,716	423	473		
95/96	2,938	1,200	1,020	1,738	1,918	479	528		

(Note) Average : when hydrological conditions are normal
Adverse : when hydrological conditions are adverse
Fuel consump. : annual volume of fuel consumed
Fuel transport : annual volume of fuel transported

3-3-2. Transportation program

There is a need to increase the volume of transportation in proportion to the increasing fuel requirements, but this need should be dealt with by increasing the number of operating days and reducing the cycle time.

The train should be made up of 26 tank wagons and one Manama and Brake Van, totalling 28 vehicles, and drawn by dual locomotives (910 t of fuel can be transported).

Three such trains would be able to handle an annual volume of up to 198,000 t (4-day cycle) , if the number of working days is increased to 295. Before the annual transportation demand exceeds 198,000 t, the loading and unloading time in Port Sudan and Khartoum should be cut down, and at the same time, the running schedule should be studied to determine how the 3-day cycle can be executed. The 3-day cycle will enable the transportation of a volume up to 265,500 t.

The increase in thermal power generation, in case hydro-electric power generation cannot be operated normally due to a shortage of water, can be met in principle by increasing the number of operating days to more than 295.

3-3-3. Fuel transportation equipment

(1) Diesel locomotives

Six units of 6-axle diesel locomotives of the 2,000PS class are required. Since the axle load must be less than 16.5 t, the weight of the locomotive will come to 96 to 99 t.

In addition, the locomotive must be designed so as to be capable of ascending and descending the gradient section alone without the assistance of the other of the pair, which might become inoperable during operation.

(2) Tank wagons

Eighty six (86) tank wagons (26 wagons $\times$ 3 $\times$ 1.1 = 86 wagons) with a 35-ton capacity (tare of 17 t) now in the possession of SRC are to be utilized.

(3) Terminal equipment

Improvements in the loading equipment in Port Sudan should be realized by 1989/90 when the quantity of fuel transported exceeds 198,000 t/year.

Also, improvements in the unloading equipment and increasing the capacity of fuel storage tanks by 40,000 t in Khartoum should be realized by 1990, in accordance with the Power IV Project.

(4) Communications equipment

In consideration of the geography and other conditions, radio equipment equivalent to the present ones have to be installed on the newly provided locomotives : one radio per locomotive would suffice because of double header operation.

On the other hand, the need for inter-city communication equipment appears not to be urgent since it is not used frequently nor directly for train operation, although it is preferable to provide a separate system in the future in consideration of the poor reliability of the existing equipment.

3-3-4. Implementation and management organization

All the rolling stock to be used for the Project will be managed by SRC. Fuel loading, transportation and unloading will be carried out by the following organizations.

(a) Loading	Oil companies
(b) Transportation (including shunting)	SRC
(c) Unloading	NEC

The main line diesel locomotives will be owned and managed by NEC, and its operation and maintenance entrusted to SRC. In addition, operation, management and maintenance of railway facilities including tank wagons, rolling stock (shunting locomotives, etc.) and tracks will be carried out by SRC.

3-3-5. Facility management

Facilities for the Project will be maintained and managed by the organizations owning them. Main line diesel locomotives will be managed by NEC, while operation and maintenance will be done by SRC.

Weekly, monthly and major repairs will be conducted at the Atbara Workshop. On the other hand, daily checks will be carried out at Port Sudan, Atbara or Khartoum to ensure efficient operation schedules.

Operation of fuel trains will be controlled by the Eastern Regional Office in Port Sudan, Northern Regional Office in Atbara, or Central Regional Office in Khartoum, under the supervision of the head office in Atbara.

CHAPTER 4. BASIC DESIGN

CHAPTER 4. BASIC DESIGN

4-1. Design policy

It is easy to construct diesel locomotives in Japan, and the Japanese rolling stock industry has an extensive record of producing and exporting locomotives. Therefore, the locomotives required for this Fuel Transportation Project will be constructed in Japan. The parts and components mentioned below, however, will be imported from other countries for reasons described in the following.

- Engine

  Large diesel engines for locomotives (over 1,600 PS) have not been manufactured lately in Japan in view of the small demand in the domestic market. As a matter of fact, when the output is of this class most of the diesel locomotives recently exported from Japan use imported engines. Accordingly, it seems appropriate to use imported engines also in this case.

- On-board radio equipment

  SRC is presently using on-board radio equipment in its locomotives, and hence, the radio equipment to be used in the diesel locomotives of this Project should be compatible with the existing ones. Under the circumstances, it seems to be most cost-effective to purchase compatible radio equipment from the manufacturer of the existing equipment.

4-2. Design conditions

The following design conditions are considered.

(a) Special precautions against dust (particularly for seals, air intakes, and others) because most of the railroad sections are located in desert regions with frequent sandstorms.

(b) The environmental temperatures during normal use are assumed to range from 15°C to 43°C, gathered from the monthly average of minimum and maximum temperatures recorded in the past. The maximum allowable temperature is 48°C, which is the maximum atmospheric temperature.

(c) The track gauge is 1,067 mm, and SRC rolling stock gauge is to be used.

(d) In principle, UIC (International Union of Railways) standards are to be used for these locomotives.

(e) The performance of the locomotives should be sufficient to negotiate the 10‰ continuous uphill section between Port Sudan and Summit at a balanced speed of 30 km/h, and the other flat sections at 60 km/h or more.

(f) The diesel-electric traction system is to be adopted in this Project, considering the large output and SRC's experience.

(g) The tank wagons of this Project do not use vacuum brakes. Therefore, an air brake system is to be equipped, and dynamic brakes will be used in the downhill section between Summit and Port Sudan.

(h) The axle load is 16 t (permissible load being 16.5 t) with six-axle driving, and the gross weight of the locomotive is 96 t.

(i) The bonnet-type and one-side cab locomotive configuration is to be adopted in this Project, considering the ease of maintenance. Two master controllers, one for each traveling direction, will be provided to reduce driver fatigue on long trips.

(j) The Co-Co type truck is to be adopted, considering SRC's experience. The welded structure bogie is accepted, in view of the small quantity to be constructed.

(k) Double heading multiple unit control operation should be possible. Multiple unit control operation with the existing locomotives is not considered however.

(l) The AC main generator is to be adopted, in view of the ease of maintenance and lower incidence of trouble.

4-3. Design specifications

The basic specifications of the diesel locomotives designed under the aforementioned design conditions are shown in Table 4-1, and the figure is shown in Fig. 4-1.

Table 4-1 Basic specifications of diesel-electric locomotives

Classification		96 t diesel-electric locomotive
Type		
Use		Main line locomotive for fuel transportation
Rolling stock gauge		SRC Rolling stock gauge
Axle layout		Co-Co
Weight	Gross weight (t)	96 t
	Tare weight (t)	90 t
Performance	Maximum operation speed	80 km/h
	Maximum tractive force (kg)	28,800 ($\mu = 0.3$)
Overall gear ratio		
Main dimensions	Gauge (mm)	1,067
	Overall length between coupling centers (mm)	16,800
	Overall width (mm)	3,022
	Overall height (mm)	4,000
	Overall wheel base (mm)	12,900
	Distance between truck centers (mm)	9,000
	Driving wheel diameter (mm)	914
	Coupler height (mm)	851
Body type		Bonnet type One side driver's cab
Truck	Type	
	Fixed wheel base (mm)	3,900
	Type	Cast steel or welded, coil-spring supported type
Minimum radius of curvature (m)		137

User			Sudan
Outline	Designed for fuel transportation in tropical desert zone. Dust-proof construction, equipped with train radio.		
Engine	Classification		Diesel engine
	Type		
	Quantity		1
	Continuous rating		1,650 - HP/ rpm
	Fuel		Diesel oil
	Fuel consumption rate		g/HP/h
	Accessories	Supercharger type × quantity	
		Intercooler × quantity	
		Starting motor × quantity	
		Charging generator × quantity	
	Weight (dry) (kg)		
Main generator	Clssification & type		
	Continuous rating	Capacity × quantity	975 - KW×1
		Voltage × quantity	
		Rotation speed	
	Weight (kg)		

Main rectifier	Classification & type		
Main rectifier	Continuous rating		975 KW ~
Traction motor	Classification & type		
Traction motor	Continuous rating	Capacity × quantity	150 KW ~ ×6
Traction motor	Continuous rating	Voltage × current	
Traction motor	Continuous rating	Rotation speed	
Traction motor	Weight (including gear & case) (kg)		
Ventilator for traction motor	Driving system		
Ventilator for traction motor	Capacity ×quantity		
Cooling equipment	Method		Forced ventilation Radiator type cooler installed at the chamber side
Cooling equipment	Radiator		
Cooling equipment	Ventilator	Driving system	
Cooling equipment	Ventilator	Capacity × quantity	2,100 m^3/min ~ × 1
Brake equipment			Automatic air brake
			Dynamic brake
			Hand brake
Air compressor	Type		
Air compressor	Driving system		Belt-driven
Air compressor	Capacity × quantity		
Control system			Double-heading multi-unit control operation
Control circuit voltage			
Operation safety equipment			Dead-man equipment
Broadcasting & communications equipment			On-board radio equipment

Battery	Type	NIFE
Battery	Method	Nickel-Cadmium
Battery	Capacity × quantity	
Battery	Voltage	
Air-conditioning & ventilation	Air-cooling & ventilation	Ventilator × 2 Ventilation equipment
Air-conditioning & ventilation	Heating	Not provided
Train heating equipment		Not provided
Coupling equipment	Coupler	Alliance No. 2
Coupling equipment	Damper	Rubber damper
Lighting	Interior	Driver's cab 40W×2 *Engine room 20W×6*
Lighting	Exterior	Headlight 200W×4 Taillight 40W×4
Auxiliary equipment		
Expendables	Fuel	5,000 ℓ
Expendables	Sand	360 ℓ
Expendables	Water	800 ℓ
Remarks		

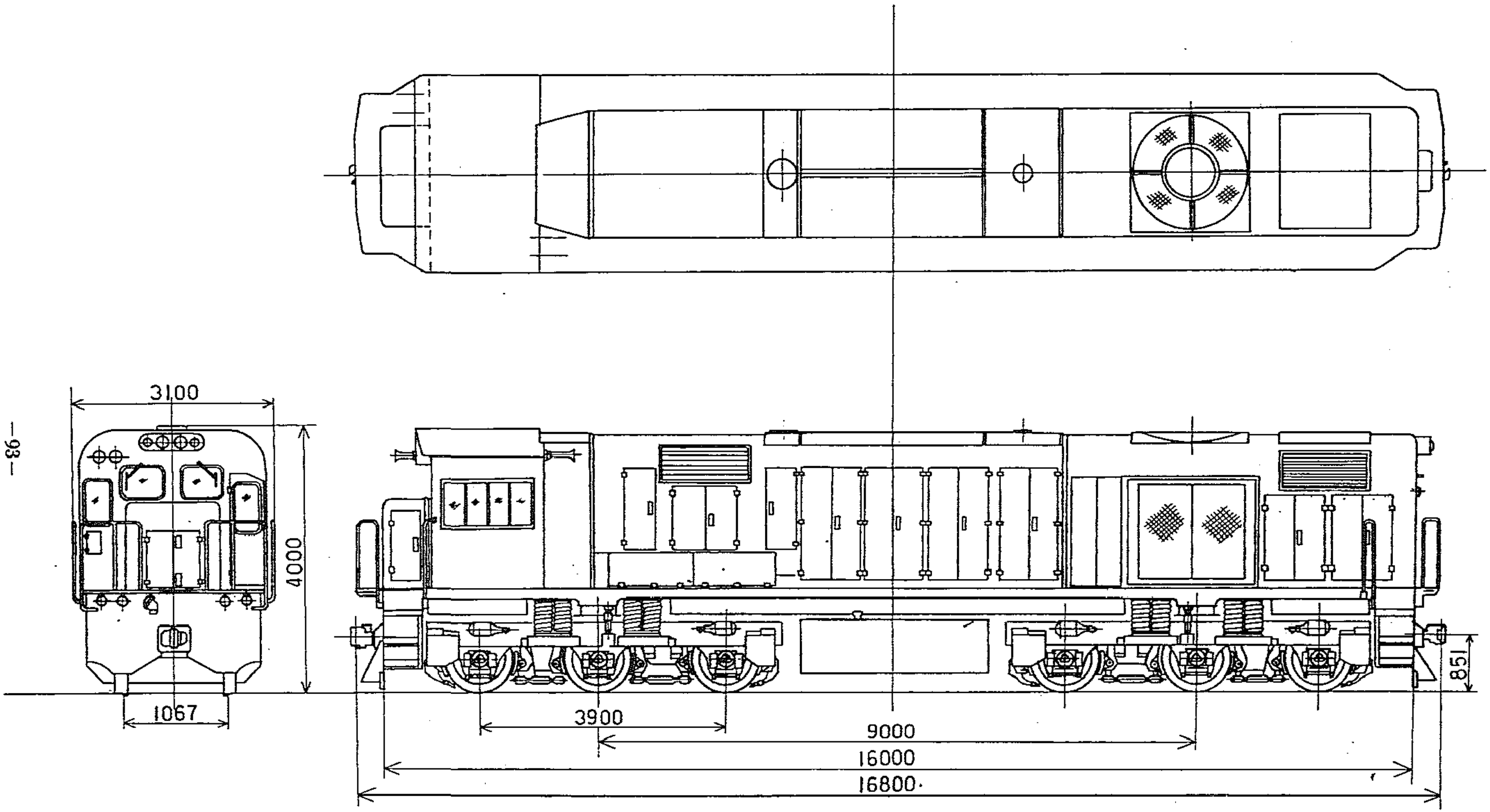


Fig. 4-1 Diesel-electric locomotive figure

4-4. Implementation plan

① Work to be undertaken by Japan and the Sudan

For the locomotives to be procured, Japan will be responsible for the detailed design, construction (including the installation of train radio equipment), transportation to Port Sudan, and landing of the diesel locomotives. Furthermore, Japan will dispatch technical personnel responsible for the operation and handling guidance.

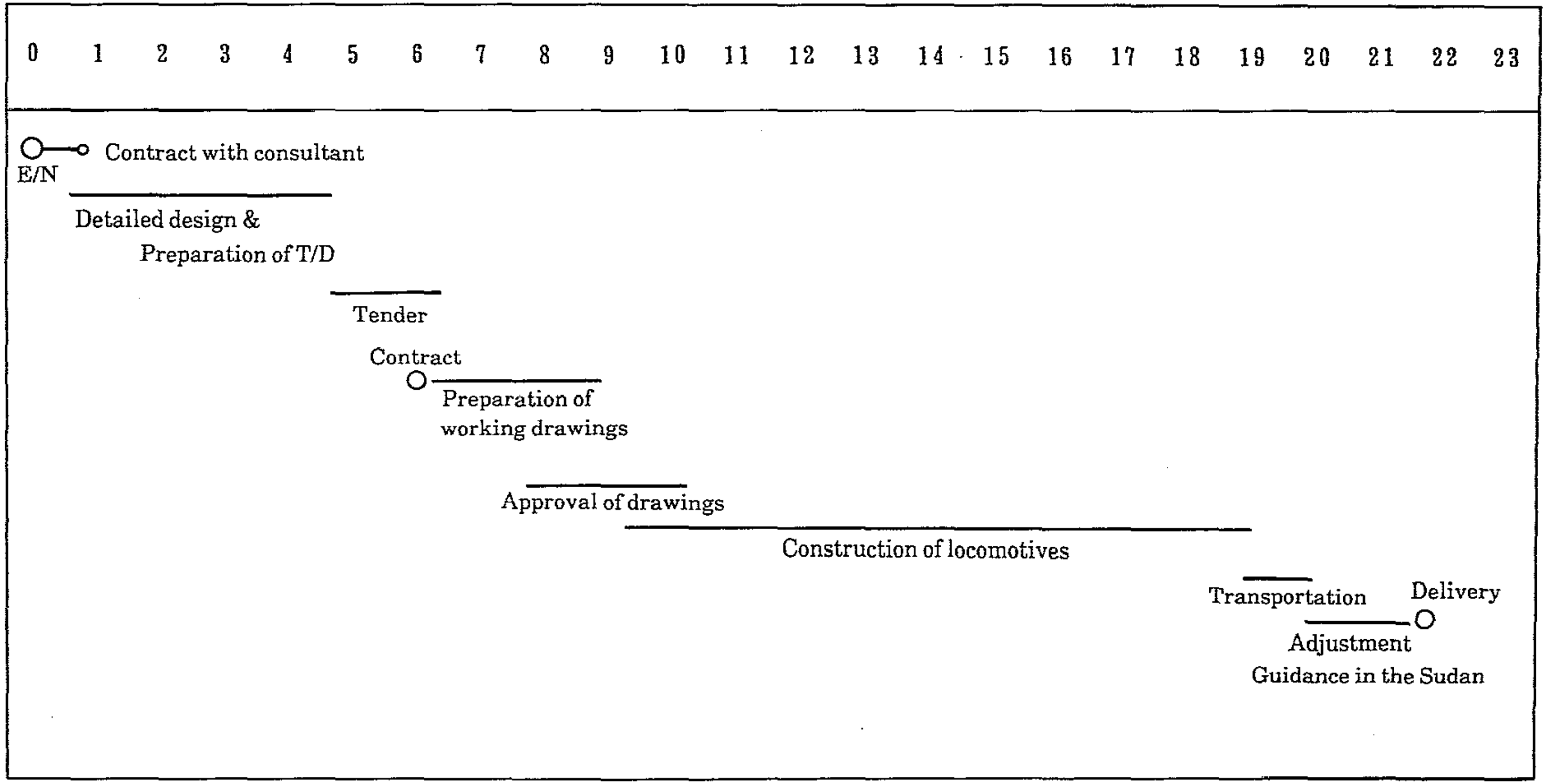
The Sudan will be responsible for allocating fuel required for the deadheading of the locomotives after their landing, hiring workers including drivers, and supplying other required equipment.

② Implementation schedule

The implementation schedule comprising the detailed design and the preparation of the tender document after the Exchange of Notes, construction of locomotives, guidance on operation and handling, delivery, etc. is shown in Table 4-2.

Table 4-2 Implementation schedule

Unit : Month



4-5. Maintenance and administration costs

Before starting this Project, it is necessary to define the scope of responsibility of the various organizations concerned in the Sudan to prevent mistakes and delays.

Main line locomotives will be owned by NEC, and SRC will be relied on for their operation and maintenance, but the other rolling stock (tank wagons, shunting locomotives, and so on) is owned and its operation and maintenance is executed by SRC.

In the operation of the main line locomitives, a particular care will be required to prevent confusion caused by the mixed operation of fuel transportation trains with other trains, and to prevent the low locomotive availability seen at present by doing appropriate maintenance, particularly getting funds for spare parts. To efficiently use the rolling stock, particularly the locomotives, it is very important to define an effective operation scheme.

The procurement of spare parts and the improvement of maintenance techniques are vitally important for the diesel locomotive maintenance and particularly critical in the Sudan where the locomotives are operated under dusty conditions and high temperatures. Approximately 3% of the cost of a new locomotive is allotted as the cost for spare parts to maintain similar diesel locomotives in Japan. It is obvious that a larger percentage will be required for maintenance materials in the Sudan, in view of the unfavorable environmental conditions.

The main spare parts are the wear parts for the engine, compressor, brake rigging equipment and packings, etc., and other parts found defective during inspection. The systematic change of lubricating oil is also very important.

Furthermore, maintaining a clean environment at the time of overhaul and inspection, as well as precautions against dust when assembling the locomotive, must be carefully worked out. It is therefore necessary to secure a dustfree space for assembling the bearings and engine.

Systematic and uninterrupted training is required to achieve technical progress. It is especially important to define responsibilities regarding accidents and troubles, and to promote a proper spirit for accomplishing duties.

The maintenance and administrative costs required by this Project must be examined within the context of the conditions in the Sudan. In reality, an accurate calculation of these costs is difficult, but the approximate costs related to the main line diesel locomotives are calculated in the following.

(a) Fuel costs

Fuel costs are calculated by assuming a fuel consumption rate of 180 g/HP.hr.

- Fuel consumption in a trip from Port Sudan to Khartoum is calculated in the following equation :

$$180 \text{ g/HP.hr} \times (3{,}300 \text{ HP} \times 4.3 \text{ hr} + 1{,}000 \text{ HP} \times 18.7 \text{ hr}) = 5.9 \text{ t}$$

- Fuel consumption in a trip from Khartoum to Port Sudan is calculated in the following equation :

$$180 \text{ g/HP.hr} \times (3{,}300 \text{ HP} \times 1.3 \text{ hr} + 800 \text{ HP} \times 14.7 \text{ hr}) = 3.0 \text{ t}$$

Therefore, if fuel consumption for stopping at stations and small handling is added, locomotives are assumed to consume approximately 10-tons of fuel on a round-trip between Port Sudan and Khartoum.

When hydrological conditions are normal, the volume of fuel to be transported to power plants in 1989/90 is assumed to be 209,000 t. For this transportation, 233 round-trips (209,000 t ÷ 900 t = 232.3) are necessary, and the trains will consume 2,330 tons of fuel. (233 × 10 t)

The unit price of light oil is 1,120 LS (3.5 LS/gallon as of Nov. 1986), and as for lubricating oil, assuming its cost to be 15% of the cost of light oil, the annual cost will be : $1{,}120 \text{ LS/t} \times 2{,}330 \text{ t/year} \times 1.15 = 2.61 \times 10^6 \text{ LS/year}$

(b) Maintenance cost

Generally, maintenance costs are assumed to be about 6% of the cost of a new locomotive. Assuming that a new main line diesel locomotive costs $6{,}544 \times 10^3$ LS ($1{,}636 \times 10^3$ US$), the maintenance cost will be :

$6{,}544 \times 10^3 \text{ LS/unit} \times 0.06\text{/year} \times 6 \text{ units} = 2.36 \times 10^6 \text{ LS/year}$

(Note : 1 US$ = 4.0 LS ----- as of Nov. 1986)

Approximately 1/2 of this amount must be set aside for spare parts. It is necessary to have a maintenance cost with sufficient margin of safety that considers the conditions in the Sudan, where failures are prone to occur due to large quantities of blowing dust.

(c) Wages of personnel

Necessary personnel per train consists of a locomotive driver, a assistant driver, a conductor and an inspector, a total of 4 persons. To this, the shift crew should be added, raising the total number of necessary personnel to 12 persons.

4 persons × 3 group = 12 persons

The operation time per trip, including a break in Khartoum, is calculated at 70 binding hours. Since the working weeks of SRC is 42 hours/week, 70 hours ÷ 42 hours = 1.7, namely, the personnel will board a train once every 1.7 weeks. On the basis of an attendance rate at 0.9, the number of personnel required will be :

$$12 \text{ persons} \times 1.7 \text{ weeks} \times 7 \text{ days/week} \times \frac{295}{365} = 129 \text{ persons}$$

Shunting personnel are assumed to work in 3 shifts in Port Sudan and Khartoum (attendance rate 0.9) : 4 persons × 4 ÷ 0.9 = 18 persons. The number of crewmen and shunting personnel required totals 147 persons (129 + 18 = 147).

If the wage per person in SRC is 2,500 LS/year, to which 50% is added as a travelling allowance, overtime premium and the like, the total labor cost of the boarding personnel will come to : $2{,}500 \text{ LS/year} \times 147 \times 1.5 = 0.55 \times 10^6 \text{ LS/year}$.

CHAPTER 5. EVALUATION OF THE PROJECT

CHAPTER 5. EVALUATION OF THE PROJECT

Electricity is fundamental for industrial development and guarantees a cultural life for a nation. The Sudan has been developing power generating facilities from the Power I to III Projects, and now the Power IV Project is being implemented to reinforce thermal power plants and associated substations and transmission lines.

Four international financial institutions, including IDA, have provided soft loans for the main power generation part of the Power IV Project. Grant aids from eight countries, including Japan, are expected to be for to the rest of the Project. Japan is being requested to provide a grant aid for the acquisition of diesel locomotives and associated telecommunications equipment for fuel transportation.

Needless to say, fuel transportation is indispensable for thermal power generation, and it has a direct influence on the success of the Power IV Project, which consists mainly of thermal power reinforcement. Therefore, the implementation of the this Project will result in the successful implementation of the Power IV Project, which is supported by many countries and international financial assistance institutions, and is thus urgent and important to the Sudan.

The value of imports is two or three times that of exports in the Sudan, and the country's foreign exchange situation is very serious. Thus, the reinforcement of power supply to provide motive power for irrigation pumps, tanneries, textiles and other industries to promote exports in order to earn much needed foreign currency is extremely important.

This chapter examines the effects of fuel transportation on NEC and SRC, transportation costs, and compares railway with truck transportation.

5-1. Benefits to the Sudan

With the completion of the Power IV Project, with aid from various countries, the installed capacity in the Sudan will be reinforced from 365 MW (Hydro 194 MW, Thermal 171 MW) to 571 MW (Hydro 225 MW, Thermal 346 MW). Power generation will be doubled from 1,218 GWh to 2,095 GWh. It is expected to decrease electric service interruption and to rehabilitate economic activity (for example, opening the way for agricultural products such as cotton, gum Arabic, and sesame ; and for domestic production of industrial products or machinery).

Also, small privately owned generators (estimated to be 100 MW) with low efficiency will be replaced by power from NEC. This means that the Sudan as a whole will be able to reduce petroleum consumption because the use of expensive light oils (for private generators) will be reduced and replaced with less costly heavy oil at NEC's plant with higher fuel efficiency.

Assuming that 100 GWh of the total private power generation will be replaced by NEC, 50,000 t of light oil (average fuel consumption rate is estimated to be 500 t/GWh) will be conserved, while heavy oil consumption will be increased by 27,500 t (average fuel consumption rate : 275 t/GWh).

Thus the reduction of petroleum consumption is favorable for the Sudan, which relies on imports for all its petroleum, acting positively in saving of foreign exchange, as well as in energy and protecting environment by reducing air pollution. It is also expected to be effective for social economic improvement by curtailing production costs through the use of less costly electricity, and by replacing of power from private generators with power from NEC. These are the effects that will be attained by stabilizing the power supply through increasing the supply capability with the Power IV Project. The effect of transporting fuel required for the Project by rail is the contribution to the smooth implementation of the above-mentioned Power IV Project.

5-2. Effect on NEC

Maximum benefit of the implementation of the Fuel Transportation Project will be the smooth implementation of the Power IV Project as mentioned above. Effect of the former Project on NEC is the stable supply of fuel. An examination is made to see to what extent the unstable supply of fuel will influence the management of NEC.

Both the Power IV Project of the Sudan and the Power IV (IDA) Project of the World Bank are being studied on the assumption that, through the donation of diesel locomotives from Japan, the transportation capacity of SRC will be improved so as to permit the railway transportation of the whole entire requirement for power generation.

If the above is not realized due to a failure to improve railway transportation capacity, the following three cases are possible.

(A) The increase in the volume of fuel transportation is carried by truck, but capacity is a little below the required volume.

(B) The increase in the volume of transportation is carried by truck, and although capacity is increased every year (at the same increasing rate as (A)), there is a certain limit to truck transportation.

(C) Where the volume of fuel transported is only 80% of the requirement of the year.

The assumed operating conditions of NEC under these 3 hypothetical cases compared with the implementation of the planned railway project is shown in Table 5-1.

From Table 5-1, it is known that, even if stable railway transportation is realized, NEC's net profits will be only a few percent around 1989/90, and should the required transportation capacity not be secured, this will result in negative net profit, and the electricity rate would have to be increased to cover the loss.

Case A: It is assumed that the volume of transportation will increase by 10% every year from 1986/87.

Should the volume of fuel transportation be below the scheduled volume, thermal-generated energy and energy sales will decrease and operating income will also decrease. On account of this, the net profit after deducting debt service will be reduced substantially resulting in continuous deficit from 1989/90 onward. It is obviously impossible to let such conditions continue, and therefore, the electricity rate must be raised 2 to 3% higher than the commodity price escalation in order to achieve a profitable enterprise.

Case B: This is the case where it has been assumed that there is a certain limit to fuel transportation by truck. The limit is taken to be 100,000 t/year, and including fuel transported by rail, the annual quantity available to NEC will be 164,000 t. The rate of increase in truck transportation, until it reaches this limit, has been determined to be the same as that in that Case A.

The increase in thermal power generation reaches its uppermost limit from 1989/90 onward, and the difference between the generated energy and the scheduled generated energy becomes larger year by year and the operating revenue in 1995/96 drops to 61% of that projected. This is because the volume of fuel transported amounts to only 34% of that scheduled in the Project, a great difference from the scheduled volume.

On account of this, the operating profit is decreased and the net profit after deducting debt service becomes negative from 1989/90 when the volume of fuel transportation reaches the maximum limit, and thereafter, operating income will show a continuous deficit of about 10%. To balance income and expenditures, it is necessary to raise the electricity rate by about 10% every year.

Case C: This is the case where it has been assumed that, although the volume of fuel transportation increases every year, it remains at 80% of the annual requirement.

In this case, NEC's financial situation will have a trend more or less the same as that in Case A. Deficits will be registered in almost all the years from 1989/90 onward, therefore the electricity rate will have to be raised 2 to 3% higher than that of the escalation of commodity prices, in order to achieve financial balance.

From the preceding statements, it is evident that securing a sufficient volume of power generating fuel is indispensable for the implementation of the Power IV Project.

The main line diesel locomotives to be supplied under the Fuel Transportation Project will be owned by NEC, and be operated and maintained by SRC. By this arrangement, SRC will be able to transport fuel for power generation at a reduced tariff equivalent to the transportation cost. Therefore, it is expected to have the effect of suppressing increases in the electricity rate by reducing fuel costs and the costs of its transportation.

Table 5-1 Income statement of NEC

No.	Item	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
1	Power demand GWh	1,014	1,233	1,218	1,593	1,642	1,790	1,796
2	Hydraulic power generation GWh	781	949	(825)	1,106	1,106	1,200	1,200
3-1	Thermal power generation GWh	233	284	(393)	487	608	639	761
3-2	Thermal power generation A GWh	233	284	(393)	487	536	590	649
3-3	Thermal power generation B GWh	233	284	(393)	487	536	590	596
3-4	Thermal power generation C GWh	233	284	(393)	487	486	512	608
4-1	Fuel consumption $\times 10^3$ t	61.6	91.8	127.7	134.0	167.0	176.0	209.0
4-2	Fuel consumption A	61.6	91.8	127.7	134.0	147.4	162.1	178.4
4-3	Fuel consumption B	61.6	91.8	127.7	134.0	147.4	162.1	164.0
4-4	Fuel consumption C	61.6	91.8	127.7	134.0	133.6	140.8	167.2
5-1	Power sold (planned) GWh	779.6	(961.7)	(998.8)	1,338	1,440	1,545	1,647
5-2	Power sold A GWh	779.6	(961.7)	(998.8)	1,338	1,379	1,504	1,553
5-3	Power sold B GWh	779.6	(961.7)	(998.8)	1,338	1,379	1,504	1,509
5-4	Power sold C GWh	779.6	(961.7)	(998.8)	1,338	1,337	1,438	1,519
6-1	Operating revenue $\times 10^6$ LS	110.7	197.2	255.7	350.6	476.6	628.8	805.4
6-2	Operating revenue A	110.7	197.2	255.7	350.6	456.6	612.0	759.4
6-3	Operating revenue B	110.7	197.2	255.7	350.6	456.6	612.0	737.9
6-4	Operating revenue C	110.7	197.2	255.7	350.6	442.5	585.3	742.8
7-1	Variable cost $\times 10^6$ LS	29.7	50.2	75.5	112.6	148.9	193.6	251.6
7-2	Variable cost A	29.7	50.2	75.5	112.6	131.3	178.8	214.8
7-3	Variable cost B	29.7	50.2	75.5	112.6	131.3	178.8	197.3
7-4	Variable cost C	29.7	50.2	75.5	112.6	119.1	155.1	201.2
8	Fixed cost $\times 10^6$ LS	48.8	78.2	96.6	121.1	149.5	185.4	229.8
9	Repayment of loans $\times 10^6$ LS	21.6	30.6	66.8	89.9	138.7	227.1	337.2
10-1	Net income rate (planned) %	9.6	19.4	6.6	7.7	8.3	3.6	−1.7
10-2	Net income rate A %	9.6	19.4	6.6	7.7	8.1	3.4	−3.0
10-3	Net income rate B %	9.6	19.4	6.6	7.7	8.1	3.4	−3.6
10-4	Net income rate C %	9.6	19.4	6.6	7.7	8.0	3.0	−3.4

Table 5-1 Income statement of NEC

No.	Item	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
1	Power demand GWh	1,796	1,796	1,796	1,796	1,796	1,796
2	Hydraulic power generation GWh	1,200	1,200	1,200	1,200	1,200	1,200
3-1	Thermal power generation GWh	895	1,032	1,186	1,354	1,536	1,738
3-2	Thermal power generation A GWh	713	785	863	949	1,045	1,149
3-3	Thermal power generation B GWh	596	596	596	596	596	596
3-4	Thermal power generation C GWh	716	826	951	1,085	1,231	1,393
4-1	Fuel consumption $\times 10^3$ t	246.0	284.0	327.0	373.0	423.0	479.0
4-2	Fuel consumption A	196.2	215.8	237.4	261.1	287.3	316.0
4-3	Fuel consumption B	164.0	164.0	164.0	164.0	164.0	164.0
4-4	Fuel consumption C	196.8	227.2	261.6	298.4	338.4	383.2
5-1	Power sold (planned) GWh	1,760	1,875	2,004	2,145	2,298	2,468
5-2	Power sold A GWh	1,607	1,667	1,733	1,805	1,886	1,973
5-3	Power sold B GWh	1,509	1,509	1,509	1,509	1,509	1,509
5-4	Power sold C GWh	1,609	1,702	1,807	1,919	2,042	2,178
6-1	Operating revenue $\times 10^6$ LS	1,015.5	1,245.0	1,396.8	1,720.3	2,118.8	2,618.5
6-2	Operating revenue A	927.2	1,106.9	1,207.9	1,447.6	1,738.9	2,093.4
6-3	Operating revenue B	870.7	1,002.0	1,051.8	1,210.2	1,391.3	1,061.1
6-4	Operating revenue C	928.4	1,130.1	1,259.5	1,539.0	1,882.7	2,310.9
7-1	Variable cost $\times 10^6$ LS	348.2	461.3	583.5	752.8	940.0	1,190.5
7-2	Variable cost A	277.4	350.9	424.6	527.6	639.5	787.1
7-3	Variable cost B	231.8	266.4	293.2	331.4	364.8	408.3
7-4	Variable cost C	278.5	369.2	467.9	603.3	753.4	954.2
8	Fixed cost $\times 10^6$ LS	264.4	304.0	349.6	402.0	462.4	531.7
9	Repayment of loans $\times 10^6$ LS	397.9	457.6	526.2	605.2	696.0	800.4
10-1	Net income rate (planned) %	0.5	1.8	−4.5	0.1	4.6	5.8
10-2	Net income rate A %	−1.3	−0.5	−7.7	−6.0	−3.4	−1.2
10-3	Net income rate B %	−2.7	−2.6	−11.2	−10.6	−9.5	−8.7
10-4	Net income rate C %	−1.3	−0.1	−6.7	−4.6	−1.5	1.1

5-3. Effect on SRC

There is much more freight transport than passenger transport of SRC, and revenues generated by freight transport accounted for approximately 80% of the total in 1982/83. However, the volume of freight transport is declining year after year, and in 1983/84 it was 42% (ton.km) of the volume recorded 5 years before (1979/80). This seems to be not because of a decrease in transportation demand, but because of a decrease in transportation capacity (lack of available locomotives).
Table 5-2 shows the record of NEC's fuel transportation.

Table 5-2 Fuel transportation by SRC

Unit: 10^6 t.km

FY	1981/82	1982/83	1983/84	1984/85	1985/86
Freight transportation (t)	1,608	1,215	836	(800)	(800)
Fuel transportation (t)	26.7	32.3	48.5	29.1	50.3
Percentage (%)	1.7	2.7	5.8	(3.6)	(6.3)

Note: Estimated figures are used for freight transportation in 1984/85 and 1985/86.

SRC's freight transportation is decreasing year by year, while the importance of transporting fuel for NEC is increasing, so SRC is becoming an important customer of freight transport.
The fuel transportation demand under this Project as of 1989/90 is estimated to be 209,000 t, an increase of 145,100 t compared with the figures in 1985/86 (63,900 t). If the entire quantity is to be transported by railway, the increase in transport ton-km will be 145,100 t × 787 km = 114.2 × 10^6 t.km ; this is some 14% of the estimated total transport volume (some 800 × 10^6 t.km) of SRC in 1985/86. This increase in freight will be very effective for recovering the freight transportation of SRC.
From a business point of view, SRC can not expect much of an increase in revenues, because the locomotives will be owned by NEC and SRC will have to apply a reduced tariff with only a small profit. However, the increase in transportation quantity is desirable for SRC.

5-4. Transportation cost

Transportation expenses consist of depreciation cost (for initial investment), facilities maintenance cost, locomotive power cost (fuel), personnel expenditures, administrative costs, etc.

In reality, it is difficult to calculate these costs accurately, but they are examined in this section by referring to the FTS report.

① Initial investment

The initial investment includes that of rolling stock, track, signalling apparatus, stations, etc., but in this study it is assumed that only rolling stock is to be newly procured. As for the other items, the existing facilities are to be used.

The number of rolling stock required for a 3-day cycle transportation between Port Sudan and Khartoum and their total cost is shown in Table 5-4. The unit price of rolling stock is indicated in Table 5-3.

Table 5-3 Rolling stock cost

Item	Unit cost	Unit cost	Unit cost
Main line DL	270 × 10^6 yen	1,636 × 10^3 US$	6,544 × 10^3 LS
Shunting DL	170	1,030	4,120
Tank wagon	15	91	364
Manama + Brake Van	18 [1]	109	436

[Note] 1 : the unit cost has been estimated as tank wagon × 1.2
2 : exchange rate 1 US$ = 4.0 LS
1 US$ = 165 yen

Table 5-4 Number of rolling stock required and total cost

Item	Quantity	Unit cost	Total cost
Main line DL	6 units	6,544 × 10^3 LS	39.26 × 10^6 LS
Tank wagon	86	364	31.30
Manama, Brake Van	3	872	2.62
Shunting DL	2	4,120	8.24
		Total	81.42

The number of tank wagons was estimated at 86 units taking into account a 10% reserve ($26 \times 3 \times 1.1 = 85.8$).

· The depreciation of vehicles is to be done over a period of 15 years at the rate of 10% per year. Generally, the depreciation per year of a vehicle is calculated by the following formula :

$$N = \frac{r \times A \times (1+r)^n}{(1+r)^n - 1}$$

where, N : Depreciation cost per year

r : Depreciation rate per year

A : Price of the vehicle

n : Number of years of depreciation

Now, when the depreciation rate is 10% per year, the depreciation cost will vary according to the years of depreciation, as shown in the table below.

Interest rate	Year	Depreciation cost
10%	10	0.1627 × A
10%	15	0.1314 × A
10%	20	0.1273 × A

As regards the repayment of the loan, three financing conditions will be considered :

(a) Grant,

(b) 30-year loan, interest rate of 1.25% per year, payable in equal installments in 20 years after a grace period of 10 years.

and (c) 15-year loan, interest rate of 8% per year, payable in equal installments in 10 years after a grace period of 5 years. (For simplicity, the grace periods in the cases of (b) and (c) were disregarded and they were taken as 20- and 10-year loans, respectively, payable in equal installments.)

For tank wagons, the same financing conditions as for those procured with French aid, that is, 45% grants and 55% soft loans (30-year loan, interest rate 2%, payable in equal installments in 20 years after a grace period of 10 years), were applied. As for the procurement of other equipment including diesel locomotives for shunting services, the conditions of (c), which may be regarded as normal loan terms, were applied.

For repayment of the loan in equal installments of principal and interest, the formula already indicated, $N = \frac{r \times A \times (1+r)^n}{(1+r)^n - 1}$, can be applied, working out the amounts of installments as shown in the table below.

Condition	Interest : r	Year : n	Depreciation cost : N
a	1.25%	20	0.0568 × A
b	2.0	20	0.0612 × A
c	8.0	10	0.1490 × A

② Fuel cost

Gas oil needed for a diesel locomotive to make one round-trip between Port Sudan and Khartoum is estimated at about 10 t (see Section 4-5.). Also, the gas oil consumption of a shunting diesel locomotive is estimated to be 22.5 t/year (according to the English report), and its price 1,120 LS/t (November 1986). The cost of lubricants, etc. is assumed to amount to fifteen percent (15%) of the fuel cost.

③ Personnel cost of crew

From Section 4-5, it is assumed that 147 persons will be required for the operation of fuel transportation trains.

Assuming that the wage per person in SRC is 2,500 LS/year, to which 50% is added as a travelling allowance, overtime premium and the like, the total cost of the train crew will come to :

$2{,}500 \times 147 \times 1.5 = 0.55 \times 10^6$ LS/year.

④ Cost of vehicle maintenance

The English report estimated this cost to be 6% of the purchase price for main line diesel locomotives and 3% of the purchase price for other vehicles including tank wagons. Here, however, the maintenance cost of the shunting diesel locomotives was estimated to be 4% of their purchase price.

Table 5-5 Cost of vehicle maintenance

Item	Total cost	Maintenance cost
Main line DL	32.26×10^6 LS	2.36×10^6 LS
Tank wagon	31.30	0.94
Manama + Brake Van	2.62	0.08
Shunting DL	8.24	0.33
Total	81.42	3.71

⑤ Other expenses

As for other expenses, there are those for the maintenance of track, signals, stations, and the cost of station personnel, administration and technical services, but as such facilities and personnel are used for transportation of other items besides fuel and their costs cannot be precisely differentiated for present purposes, the figures of the FTS report have been used.

Rails, etc. and their maintenance	2.03×10^6 LS
Transportation	1.81
Administrative and technical	1.26
Total	5.10×10^6 LS

⑥ Total cost

The cost of railway transportation based on the conditions described above is indicated in Table 5-6.

Table 5-6 **Railway transportation cost**

Condition of diesel locomotive procurement	Condition A	Condition B	Condition C
Depreciation	10.70×10^6 LS	idem	idem
Fuel	3.84×10^6 LS	idem	idem
Personnel	0.55×10^6 LS	idem	idem
Vehicle Maintenance	3.71×10^6 LS	idem	idem
Other expenses	5.10 × 106 LS	idem	idem
Loan repayment	2.67×10^6 LS	4.90×10^6 LS	8.52×10^6 LS
Total cost	26.57×10^6 LS	28.80×10^6 LS	32.42×10^6 LS
Total cost/t	100.1 LS/t	108.5 LS/t	122.1 LS/t

The cost of transportation varies with loan conditions and depreciation. For instance, in the case of a 10-year depreciation at the rate of 10% per year, the cost goes up by 9.4 LS/t, while a 20-year depreciation lowers the cost by 1.2 LS/t.

The railway tariff for goods does not necessarily reflect the cost of transportation. It could be affected by the margin of profit or by special discounts for policy reasons. A detailed analysis of the conditions and practices in the Sudan and SRC may reveal the need for modifying the method of cost accounting, but there is the possibility of a fairly large reduction in the present tariff (151.9 LS/t) for the transportation of fuel for the power plants of NEC.

5-5. Comparison with truck transportation

It is difficult to compare accurately railway transportation and truck transportation because in most cases road construction costs are borne by the national Government or local administrative organizations. In this study the comparison is made assuming that the proportion of "other expenses" in total road transportation costs are the same as those in total railway transportation costs.

(1) Cost of truck transportation (with 35-ton capacity tank truck)

Below is the estimate for the cost of truck transportation (with 35-ton capacity tank truck), based on the present status of truck transportation as described in Section 2-5-3.

① Tank truck price

The domestic price of a 35-ton capacity tank truck (engine output 350 ~ 450 PS), including customs duties, as all trucks are imported in the Sudan, is as below :

reproducted truck ----- 30 ~ 40,000 US$
new truck ---------------- 90 ~ 100,000 US$

This is broken down as :

traction portion ----- 55 ~ 65,000 US$
tank portion ---------------- 33 ~ 36,000 US$

In this estimate the new truck is adopted and its unit price assumed to be 90,000 US$/unit ($360 \times 10^3$ LS/unit).

② Depreciation

The depreciation period of these tank trucks is estimated to be one year (when reproducted) and 3 years (when new), but in reality, new trucks can perhaps be used from 3 to 5 years. In these estimates, depreciation will be for 3 and 5 years.

Interest : r	Year : n	Depreciation cost : N
10%	3	0.4021 × A
10	5	0.2638 × A

③ Repayment of the loan

Repayment of the loan for the procurement of tank trucks was studied based on loan condition (c) for railway transportation (15-year loan, interest of 8% per year, payable in equal installments in 10 years after a grace period of 5 years) and condition (d) (10-year loan, interest rate 20% per year, payable in equal installments in 10 years), which is considered to be normal loan terms in the Sudan.

Condition	Interest : r	Year : n	Amount of repayment : N
c	8%	10	0.1490 × A
d	20	10	0.2385 × A

④ Fuel cost

The cycle time (the time required for a round-trip between Port Sudan and Khartoum) of a tank truck is from 5 to 6 days. This time is broken down into a running time of 1.5 days for one trip of 1,200 km, and one day each for loading and unloading. Therefore, taking into account rest for the driver, the cycle time is estimated to be 6 days (with a driver and an assistant).

The average speed of trucks are approximately 60 km/h (35-ton capacity truck) and 55 km/h (50-ton capacity truck). If the distance is to be covered in 1.5 or 2 days, the driver must operate the truck 20 ~ 22 hours out of 36 ~ 48 hours. This is fairly severe, because there is no reserve driver and if he spent 48 hours at the wheel, he would have no rest.

The fuel consumption of a tank truck is 2.0 km/ℓ and 1,200 ℓ are consumed for running one round-trip of 2,400 km. With the cycle time taken at 6 days, 5 round-trips/month can be effected, consuming 6,000 ℓ/month of gas oil. (Gas oil price 3.5 LS/gallon.)

3.5 LS/gallon × 6,000 ℓ/month ÷ 3.78 = 5,556 LS/month

Lubricant oil is consumed at the rate of 12 gallons/month per truck, and its unit price is 25 LS/gallon, resulting in 300 LS/month per truck (12 × 25). One truck can transport 175 t/month (35 t × 5 trips/month, hence the fuel cost per ton is 33.5 LS/t ((5,556 + 300) ÷ 175 t).

⑤ Personnel cost

As for personnel cost, the wage of a truck driver is estimated at 1,200 LS/month (it generally is 1,000 ~ 1,200 LS/month and is several times the wage of SRC's personnel) and that of an assistant at 60% of the driver, plus 50% for overtime allowance and other miscellaneous expenses, and comes to 2,880 LS/month (1,200 × 1.6 × 1.5). This is then divided by the monthly transportation volume of 175 t (35 t × 5 trips) and results in 16.5 LS/t (2,880 ÷ 175).

⑥ Maintenance cost

The maintenance cost of a truck is 3,000 LS/month per unit, which is rather expensive as compared with that in Japan, this probably due to the difference in running distance and the difficulty of securing spare parts.

Divided by the monthly transportation volume of 175 t, a maintenance cost per ton of 17.5 LS/t (3,000 ÷ 175) is obtained.

⑦ Administration expenses

As for administration expenses, proper data could not be obtained, so to calculate the administration cost, the rate of 19.2% which is the percentage of "other expenses" within the total cost of railway transportation in the Section 5-4 was used.

⑧ Total cost

Under the conditions as stated above, the cost of truck transportation is calculated as in Table 5-7.

Table 5-7 Truck transportation cost (35-ton capacity)

Depreciation period of truck	5 years		3 years	
Condition of truck procurement	Cond. (c)	Cond. (d)	Cond. (c)	Cond. (d)
Depreciation	45.2 LS/t	idem	68.9 LS/t	idem
Fuel	33.5	idem	idem	idem
Personnel	16.5	idem	idem	idem
Maintenance	17.1	idem	idem	idem
Administration expenses	32.7	36.4	38.4	42.0
Loan repayment	25.5	40.9	25.5	40.9
Total	170.5	189.6	199.9	218.9

The above indicates that the transportation cost of trucks is fairly expensive as compared with that of the railway, even if a 35-ton capacity truck is used.

(2) Cost of truck transportation (with 12-ton capacity tank truck)

Truck transportation with a 35-ton capacity tank truck, now in use in the Sudan, is considerably high in efficiency so far as truck transportation is concerned. This can be well understood when it is compared with transportation with a 12-ton capacity tank truck taken up in this section.

The price of a 12-ton capacity tank truck which is not so different from that of a 35-ton capacity truck is estimated at US$67,000 ($268 \times 10^3$ LS). The depreciation, loan repayment, administration expenses, etc. are calculated in the same manner as in the preceding section.

As for fuel cost, taking the consumption of gas oil at 3 km/ℓ and the cycle time at 6 days, the cost comes to: $2,400 \div 3 \times 5 = 4,000$ ℓ/month. (But truck can transport only 60 t/month.)

The consumption of lubricant oil and others is estimated at 300 LS/month per truck, the same as the 35-ton capacity truck, as there is not much difference in engine output. Thus, the fuel cost per tons is: $(4,000 \times 3.5 \div 3.78 + 300) \div 60 = 66.7$ LS/t.

Personnel cost, with wages for one driver and assistant each estimated at the same amounts as stated in the preceding section, comes to:

2,880 LS/month ÷ 60 t/month = 48 LS/t.

The vehicle maintenance cost, as well, estimated at 3,000 LS/month per truck, the same as in the preceding section, amounts to:

3,000 LS/month per truck ÷ 60 t/month per truck = 50 LS/t.

The cost of transportation calculated under the conditions stated above is indicated in Table 5-8.

Table 5-8 Truck transportation cost (12-ton capacity)

Depreciation period of truck	5 years		3 years	
Condition of truck procurement	Cond. (c)	Cond. (d)	Cond. (c)	Cond. (d)
Depreciation	98.2 LS/t	idem	149.7 LS/t	idem
Fuel	66.7	idem	idem	idem
Personnel	48.0	idem	idem	idem
Maintenance	50.0	idem	idem	idem
Administration expenses	75.7	83.6	87.9	95.8
Loan repayment	55.5	88.8	55.5	88.8
Total	394.1	435.3	457.8	499.0

The above shows that the transportation cost of a 12-ton capacity tank truck is more than double that of a 35-ton capacity truck.

(3) Comparison of transportation costs

An overall comparison of truck transportation and railway transportation is summarized in Table 5-9.

Table 5-9 Comparison of transportation costs

Item	Railway	Truck	
Cycle time	3 days	6 days (35-ton)	6 days (12-ton)
Depreciation	41 LS/t	46 LS/t	97 LS/t
Fuel	14	34	67
Personnel	2	17	48
Maintenance	14	17	50
Administration expenses	19	34	79
Loan repayment	10	26	56
Total transportation cost	100	171	394
Transportation distance	800 km	1,200 km	idem
Depreciation period	15 years	5 years	idem

As can be seen, railway transportation is more economical in all areas, and in total, amounts to 58% of truck transportation. This is a rather big difference. Moreover, the road between Port Sudan and Khartoum, which has two lanes (one lane for each way), is congested a present with a great many large-sized trucks. This is partly because the transportation capacity of SRC has continued to deteriorate from 1976 on, and in addition, road maintenance is not well attended to, resulting in deterioration of the road surface.

Consequently, from the viewpoint of capacity, a large increase in transportation volume cannot be expected, and as indicated in the study conducted by the Sudanese authorities, it is considered appropriate to resort to railway transportation as a means to cope with the increase in power generating fuel for NEC.

5-6. Fuel transportation expenses and electricity fee

As mentioned in the evaluation of the Power IV Project, the fuel transportation expenses from Port Sudan to Khartoum are estimated at 126 LS/t, constituting 5.5% of the electricity charges at the generation end. This value is fairly high as compared with that of Japan, which is estimated to be approximately 2.5%, as described before.

In the Power IV Project, the locomotives for fuel transportation will be owned by NEC and their operation and maintenance entrusted to SRC. A study is now being made of the possibility of SRC reducing its tariff for fuel transportation in view of procuring locomotives free of charge. If this measure is adopted, the tariff to be borne by NEC will come to 100.1 LS/t, the net cost of railway transportation indicated in Table 5-6. This will reduce the proportion of fuel transportation expenses in the electricity tariff to 4.3%, resulting in a 1.2% reduction in electricity charges.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

Electric power is one of the most important sources of motive power for economic and social activities of a country and has a great influence on the daily life of a people. Power generation and supply capacities in the Sudan are at a low level as compared with those in other countries, and the Government gives high priority to increasing these capacities. The power demand forecasts made by the Sudan were adjusted on the basis of past records and relevant reports by a UK consultant and the IDA. However, it is conceivable that additional demand may be generated after the power grid improvement, as the present values are extremely low. To meet increasing demand, stable (without outage) power supply of a high quality (stable voltage and frequency) must be provided.

As to fuel oil transportation (cf. Chapter 5), the cost of rail transport is lower than that of road transport. As described in Chapter 2, road transport has qualitative problems and a limit to the quantity that can be transported, and it will be necessary to carry out stable transport by railway in the future.

As stated in Chapter 5, the Power IV Project has much influence on the Sudan, and the stable supply of fuel by implementing the Fuel Transportation Project is indispensable for the Power IV Project. A stable power supply contributes greatly to the socio-economical development and stabilization of a people's livelihood, so that NEC, as well as SRC, should fully commit themselves to the realization of this Fuel Transportaion Project.

The Study Team concluded that the required equipment under the Project is six diesel locomotives (for fuel trains) with radio equipment, although the request from the Government of the Sudan is ten locomotives. To make the best use of this equipment, the following recommendations are made :

To the Government of the Sudan :

(1) To clearly define responsibilities of related organizations for major components of the Fuel Transportation Project, including fuel procurement, loading and unloading, reliable train operation, provision of additional installation, operation and maintenance of facilities, and to monitor their performance at all times giving necessary advice and guidance to them.

(2) To guide SRC towards a tariff reduction for fuel transportation for NEC power plants, taking into account transportation costs, and to guide NEC towards suppressing electricity fees due to lower fuel tansportaion costs.

To NEC:

(1) To manage the operation and maintenance plans for the diesel locomotives, in consultation with SRC.

(2) To implement and complete the present program to upgrade fuel handling facilities (improvement of station tracks, installation of heating facilities, addition of storage tanks).

(3) To provide exclusive shunting locomotives.

(4) To carry out efficient loading in consideration of loading capacities of the oil companies, and thereby to minimize loading time.

To SRC:

(1) To give appropriate advice to NEC on the operation and maintenance plans for diesel locomotives. Also to carry out operation and maintenance of diesel locomotives on loan from NEC.

(2) To secure a budget for spare parts and other costs required for efficient rolling stock maintenance, to upgrade the worker's techniques and carry out reliable inspections and maintenance.

(3) To provide shunting locomotives for efficient fuel loading and unloading through discussions with NEC.

(4) To review the present train operation diagram and improve scheduled speed. In particular, to review the necessity of inspections of the tank wagons en route and to drastically reduce the stops and stopping time at intermediate stations.

This study concludes that six new diesel locomotives should be provided. As stated in Chapter 3, by reducing cycle time, locomotive requirements can be reduced and efficient train operation can be attained. Should fuel transportation drastically increases in the future, a new fuel transportation plan would be formulated.

Appendix

Appendix 1. Minutes of Discussions

Minutes of Discussions

On

The Basic Design Study (Phase II) on the Fuel Transport

For Power Projects in the Republic of The Sudan

In response to the request of the Government of The Republic of The Sudan, the Government of Japan decided to conduct a basic design study (Phase II) on the fuel transport for Power projects (hereinafter referred to as "Project") and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to The Sudan the study team headed by Mr.Kiyoshi Suwa, Assistant Director, Grant Aid Division, Ministy of Foreign Affairs, Government of Japan from 7th November to 13th November 1986.

The team had a series of discussions on the Project with the officials concerned of the Government of the Sudan headed by Mr. Abdel latif Ibrahim, Director General of NEC and conducted a field survey in Khartoum and Khartoum North area.

As a result of the study, both parties agreed to recommend to their respective Governments that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

Khartoum, November 12.1986

Kiyoshi Suwa
Team Leader
Japanese Study Team

Hashim Mohammed Ahmed
D.G.Sudan Railways

Abdel latif Ibrahim
D.G.National Electricity Corp.

Attachment

Attachment

1. The objective of the Project is to provide railway locomotives to National Electricity Corporation (NEC) of Sudan for fuel transport in connection with Power IV Project.

2. The Project is aimed to secure the continuity of fuel supply from Port Sudan to Khartoum and Khartoum North power stations and the GOVERNMENT OF THE SUDAN allow NEC to have the possible least cost of fuel transport as well as to have a stabilized electricity tarriff for the future.

3. It is agreed that NEC will be the owner of the locomotives allocated for this Project, while NEC and Sudan Railways Corporation (SRC) will adequately operate and maintain the locomotives effectively and secure adequate number of tank wagons for transporting the required amount of fuel from Port Sudan to Khartoum Thermal Power Stations. The proposed agreement between NEC and SRC should present the responsibilities of each part in order to achieve the above objectives of the Project. As SRC has a special agreement with Livestock and Meat Marketing Corporation since 1978, this agreement could be used as guidelines for the new agreement between NEC and SRC for the implementation of the Project and will be finalized once the financing of the Project is secured.

4. NEC and SRC stressed the importance of this project for the success of Power IV project, and in this respect clearly pointed out that both IDA (International Development Association) and ADB (African Development Bank), the two major cofinancers of Power IV, are insisting on finalizing the funding arrangements for fuel transport prior to finalizing their respective credit arrangements expected early 1987.

Appendix 2. List of the study team members

Name	Assignment	Present position
Kiyoshi SUWA	Mission leader	Assistant Director Grant Aid Division Economic Cooperation Bureau Ministry of Foreign Affairs
Nobutake FUKUDA	Railway trans- portation plan	Director, Consulting Engineer Japan Railway Technical Service
Katsuhiko YAMAMOTO	Power generation plan	Manager, Project Sy. & Pn. Office Overseas Engineering Department Electric Power Development Co., Ltd.
Tetsuya HIRAHARA	Economic Evaluation	Marketing & Contracting Office Overseas Engineering Department Electric Power Development Co., Ltd.

Appendix 3. Study schedule

11/2 (Sun)	Arrival at Washington
3 (Mon)	Visit to World Bank to get information on power projects
4 (Tue)	Visit to World Bank to get information on transportation projects
5 (Wed)	Departure from Washington
6 (Thu)	Arrival at and Departure from Paris
7 (Fri)	Arrival at Khartoum
8 (Sat)	Visit to NEC head office to have meeting with the officials concerned of NEC, SRC, and the World Bank
9 (Sun)	Visit to the World Bank resident office to get information Visit to Petro Trans head office to get information Visit to the Japanese embassy
10 (Mon)	Visit to NEC head office to get information and to discuss the Minutes and to have meeting with the officials concerned of MFEP, NEC, SRC, and the World Bank
11 (Tue)	Visit to SRC to get information Visit to NEC head office to discuss the Minutes
12 (Wed)	Visit to Petro Trans head office to get information Visit to NEC head office to discuss and sign the Minutes Survey of power stations of NEC (Khartoum North and Burri) Visit to MFEP to discuss the project
13 (Thu)	Visit to SRC to get information Visit to MFEP to discuss the project
14 (Fri)	Departure from Khartoum

Appendix 4. Member list of Authorities concerned

Name	Title	Organization
Teizo IGARASHI	Director, Resident office of USA	JICA
KANASE	Assistant	World Bank
Kenji YAMAGUCHI	Executive Director for Japan	World Bank
Takaya NAITO	Assistant to Executive Director	World Bank
A. Hisao SHIBUSAWA	Special Adviser to the Vice President South Asia Region	World Bank
HILLEGONDA J. GORIS	Senior Loan Officer Eastern and Africa Country Programs 2	World Bank
JANE E. HOLT	Project Officer, Transportation Division	World Bank
MARIO AGUILER	Senior Power Engineer Eastern and Southern Africa Projects	World Bank
Mohamed A. IBRAHIM	Operation Officer	World Bank
Indu GWYER	Operation Officer	World Bank
Hirozo USHIDA	Counsellor	Japanese embassy
Toshio KANEKO	First secretary	Japanese embassy
Masahide OCHI	Secretary	Japanese embassy
ADAM ABUDEL MOUMEN	Chairman, Board of Directors	SRC
HASHIM MOHAMED AHMED	General Manager	SRC
ABUDEL EL AZIM ELTOM	Regional Manager Khartoum	SRC
BABIKIR ABDALLA SAAD	Divisional Traffic Supt.	SRC
ABUDEL MONIEM MOHAMED ABUDEL MAGEED	Assistant Regional Manager	SRC
AHMED ELSAYED MOHAMED	Assistant Commercial Manager	SRC
ABUDEL LATIF IBRAHIM	Director General	NEC
ABBAS EL HASSAN	Senior Director of Engineering and Operation	NEC
JOHN GINDI	Director of Planning	NEC
ABUDEL BAGI OSMAN	Manager for System Planning	NEC
SHARIF MOHAMED SHARIF	Manager for Energy Resources	NEC
E. M. YASSIN	Director of Operations	NEC
AMIN SABRI AHMED	Manager, Management Information	NEC

Appendix 4. (Continued)

Name	Title	Organization
MOHAMMED SAEID	Assistant Inspector, Planning	MFEP
ISMAIL YUSUF	First Inspector, Planning	MFEP
OMER ABDEL SALAM	Deputy under Secretary	MFEP
HUMAN A. Y. HASHIN	Deputy under Secretary	MFEP
ABUDEL RAHIM AHMED A. RAHIM	General manager	Petro Trans

Appendix 5. List of data collected

1	Basic Design Study Report on "Fuel Transportation Project for Power Projects", Jan. 1986, JICA
2	"Fuel Transportation Study" Final Report, June 1984 Sir Alexander Gibb & Partners, Merz and Mclellan
3	Power IV Project Feasibility Study Sir Alexander Gibb & Partners, Merz and Mclellan
4	Long-term Power Program Sir Alexander Gibb & Partners, Merz and Mclellan
5	NEC Annual Report, 1984/85, NEC
6	Aide Memoire of the proposed Power IV Project, July 1986, World Bank (IDA)
7	Statement of Bank loans and IDA credit — Sudan, World Bank (IDA)
8	Initial Project Brief of "Railway Emergency Recovery Program" World Bank (IDA)
9	Final executive summary of "Power IV Project" World Bank (IDA)
10	Appraisal Report of "Power III Project", March 1980 World Bank (IDA)
11	Appraisal Report of "Power Rehabilitation Project", June 1985 World Bank (IDA)
12	Long-term development plan of NEC, NEC

JICA