BASIC DESIGN STUDY REPORT

ON

THE PROJECT FOR IMPROVEMENT

OF

ELECTRIC POWER SUPPLY

IN

MONROVIA

THE REPUBLIC OF LIBERIA

AUGUST 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR IMPROVEMENT OF ELECTRIC POWER SUPPLY
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PREFACE

In response to the request of the Government of the Republic of Liberia, the Government of Japan has decided to conduct a basic design study on the Project for Improvement of Electric Power Supply in Monrovia and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Liberia from 19th April to 15th May, 1987, a study team headed by Mr. Seiichi Kanai, Deputy Head, First Basic Design Study Division, Grant Aid Planning & Survey Department, JICA.

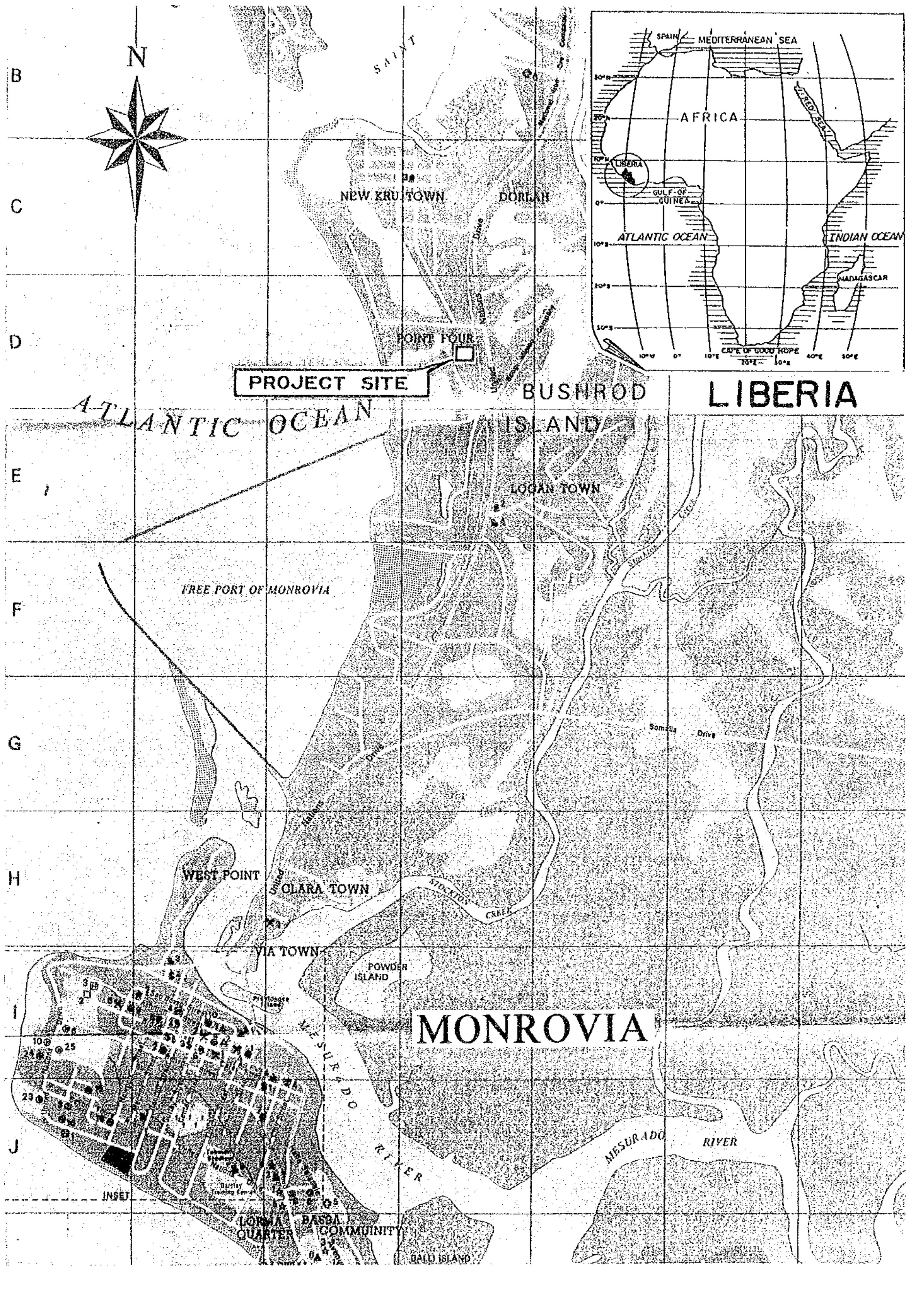
The team had discussions with the officials concerned of the Government of Liberia and conducted a field survey in Monrovia area. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between the two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Liberia for their close cooperation extended to the team.

August, 1987

Keisuke Arita
President
Japan International Cooperation Agency



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POINT FOUR
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FREE PORT OF MONROVIA
WEST POINT
CLARA TOWN
VIA TOWN
POWDER ISLAND
STOCKTON CREEK
MESURADO RIVER
LORMA QUARTER
BASSA COMMUINITY
BALD ISLAND
INSET
SAINT
Somalia Drive
SPAIN
MEDITERRANEAN SEA
AFRICA
RED SEA
LIBERIA
GULF OF GUINEA
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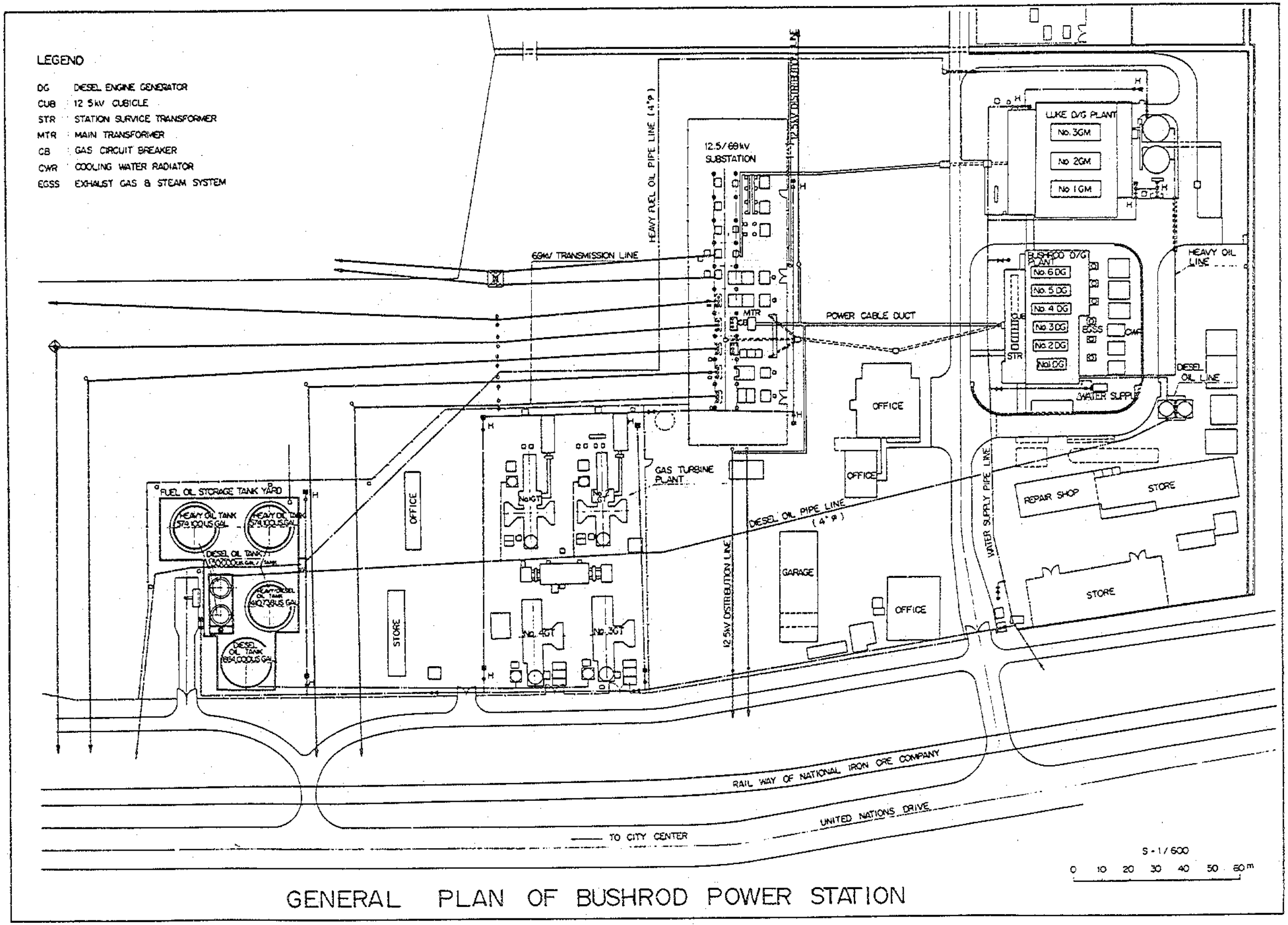
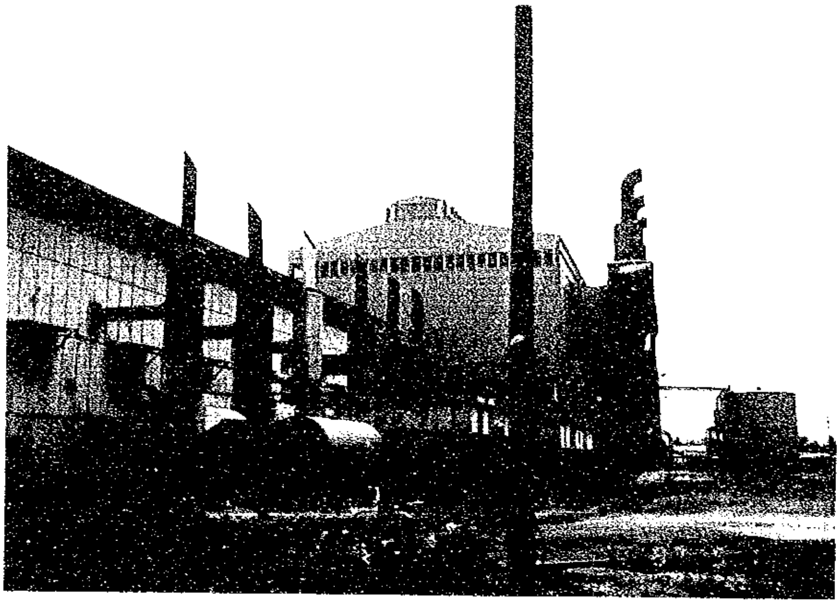
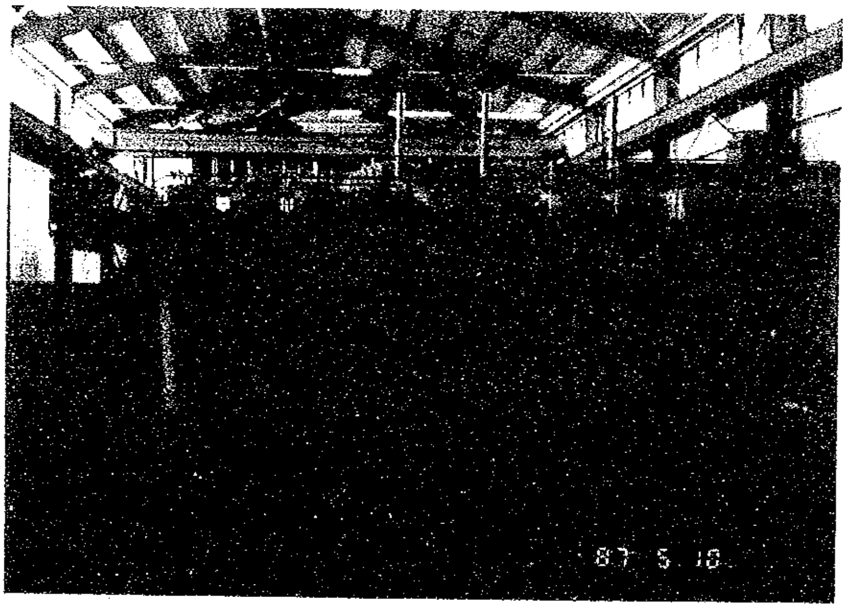


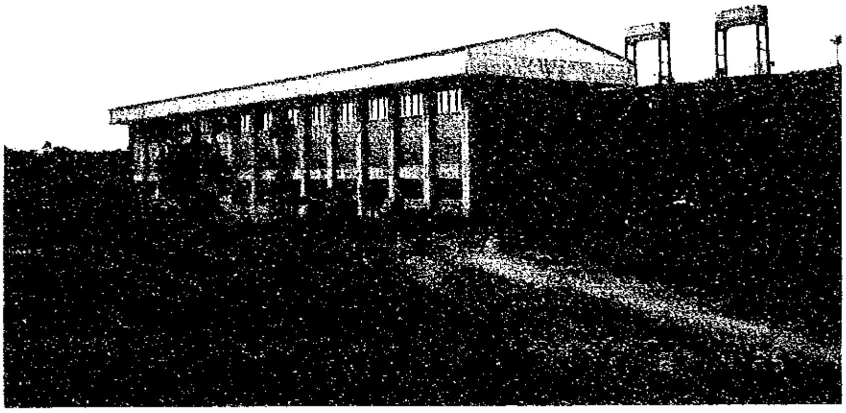
GENERAL PLAN OF BUSHROD POWER STATION



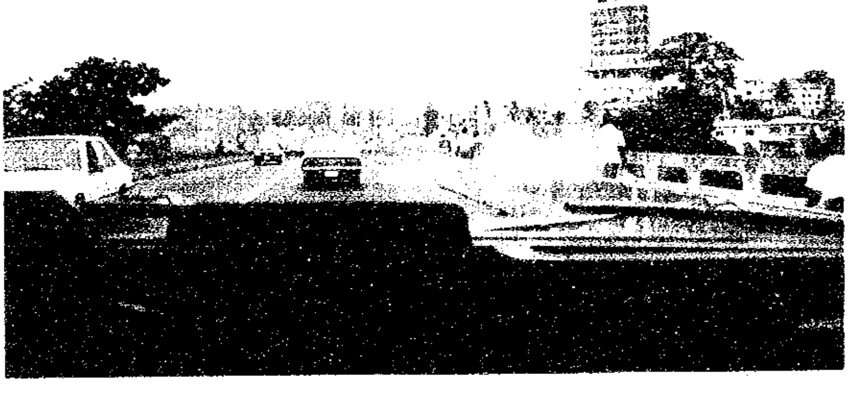
Outside View of Bushrod and Luke Diesel Power Plant



Bushrod Diesel Engine Generator (Retired)



Mt. Coffee Hydro Power Station



Monrovia City

SUMMARY

The Republic of Liberia is located on the west coast of the western bulge of the African Continent, slightly north of the Equator, with an area of approximately 110,000 square kilometers. Its population is estimated at 2,220,000, of which about 460,000 people live in Monrovia, the capital of Liberia.

Since 1980, the major export industries, especially iron ore, rubber and timber have been slumping due to the recession in industrialized countries and the economic growth has also been declining for these several years. Such sluggish economic activity has affected the national economy, particularly the government fiscal situation, with the result that public revenues have dropped significantly while public expenditures have not substantially been reduced. In view of the recent budgetary constraints, the country continues to depend on foreign borrowings for financing, especially for the development budget. As a consequence, cumulative debt service obligations are rising and new development projects in Liberia have been virtually halted or scaled down due to the financial difficulties.

Liberia's public electricity supply is the responsibility of the Liberia Electricity Corporation (LEC) - a statutory corporation of which all shares are held solely by the government. The LEC serves major consumers in a narrow coastal area from Robertsport to Buchanan including Monrovia, through the Monrovia Power System (MPS). This is the country's only electric power system. There are other small scale individual power systems in rural areas operated by the LEC, but they are isolated and not yet integrated with the MPS. There also exist a considerably large number of privately-owned generating facilities operated by the enclave economic sector and many small private industries and commercial business maintain their own generating facilities either as a back-up to public supply or as their main power source.

To satisfy its Monrovia System demand, the LEC presently has 184.3 MW of generating facilities, of which 64 MW are from hydro power generating facilities located at the Mt. Coffee dam and 120.3 MW are supplied by thermal power generating facilities at Bushrod Island.

The feature of the electric power supply to the Monrovia Power System is that because of seasonal variations in available water resources at the

hydropower station, the LEC's firm capacity varies between the dry season (December to April) and the rainy season (May to November). The system, therefore, has to rely heavily on thermal power generation (diesel and gas turbines) during the dry season, whereas during the rainy season power is supplied mainly from hydropower generating facilities. Moreover, Luke Power Plant, the main power source during the dry season, is frequently inoperational because of failures, and the operating costs of the gas turbine plant are high. This continued situation of unreliable electricity supply has led to intensive load shedding which has been carried out since around 1982. In fact, this inadequate power supply situation became so severe that periods of load shedding rose to about twenty hours a day during the dry season in 1986.

The Government of Liberia is seriously concerned about this situation as a stable power supply is indispensable to the people's daily lives and industrial development. To improve the situation, the LEC has formulated the Five-Year Development Plan (1987-1991) for improvement of electric power supply and is now striving to undertake early implementation of this medium term development plan.

Under these circumstances, the Government of Liberia has requested grant aid from the Government of Japan for a 10 MW diesel generating facility which ranks the first priority among the 30 MW diesel generating facilities planned under the Five-Year Development Plan. Upon receiving the request, the Japan International Cooperation Agency (JICA) sent a basic design study team to Liberia from April 19 through May 15, 1987 to carry out a field survey, collect necessary data and information, and to confer with the government organizations.

The present thermal-power generating facilities are concentrated on Bushrod Island, north of the capital Monrovia. Bushrod Station commenced operation in 1961 and is equipped with five diesel generators with a total installed capacity of 11.5 MW. However, only two of them with a capacity of 3 MW are currently available, and even these are expected to retire by 1988.

The gas turbine plant which commenced operation in 1966 has four units of generators with a total installed capacity of 68 MW. Nevertheless, one of them has a damaged turbine blade, with no prospect of resuming operation in the foreseeable future, and another one has been closed down for a long time due to a defective starting motor. As a matter of fact, only two (2) units of generaters with a dependable capacity of 31 MW could be operational while the study team stayed in Monrovia.

Luke Diesel Plant, the main power source during the dry season, was commissioned in 1980 with three diesel generators with a total capacity of 36 MW. However, operational troubles are frequent, so it is difficult to rely on it as a stable supplier of electricity.

Currently, the peak demand and annual energy requirement in the Monrovia Power System are 67 MW and 432 GWh, respectively, and these figures are projected to increase to 75 MW and 484 GWh by 1991. Under the long-term development plan, the LEC intends to construct a reservoir on the upper stream of the St. Paul River to supply hydroelectric power. However, it is anticipated that because of considerable time and costs involved, it would be unable to realize the project in the near future. Therefore, an alternative to the said project is counterproposed. This envisages installation of a 30 MW diesel generating facility at Bushrod Power Station, and as an emergency measure, a diesel generator of at least 10 MW capacity in order to alleviate the sustained load shedding for the public and household consumption (to reduce 6 hours of load shedding preferably to about 1 hour). This project is also aimed at saving fuel costs by US$2.0 million per annum by decreasing dependence on gas turbine generation of which operating costs are extremely expensive.

As a result of the field survey, it has been concluded that an additional 10 MW diesel unit should be installed on the old foundations in the existing Bushrod power-house so that the existing facilities can be utilized effectively and costs can be minimized.

An outline of the equipment to be provided is as follows:

Diesel engine, 7,080 PS	:	2 units
AC generator, 5,000 kW	:	2 units
Switchgear, transformer, control & protection panel, etc.	:	1 lot

The implementation of this project is to be divided into two phases due to the budgetary scheme of the grant aid program and also in order to provide adequate guidance and instruction in operation and maintenance for a longer period. Each phase will be twelve months.

Negotiations with the Government of Japan and various procedures required for the implementation of the project will be carried out through the Ministry of Foreign Affairs of Liberia. The executing agency will be the LEC which will be in charge of the duties and responsibilities related to the implementation of the grant aid facilities. Furthermore, upon completion of the project, the LEC will own the facilities and will be responsible for their operation and maintenance. No problem will be raised with the LEC judging from its present capability of operation and maintenance of the existing facilities.

After commissioning of the proposed diesel power generating facility, annual operation and maintenance expenses to be incurred are estimated to be about US$1.0 million. It is believed that this can be covered entirely by an annual revenue from electricity sales which is estimated at about US$3.1 million.

The LEC is committed to securing necessary spare-parts and fuel for its operation and maintenance in the future. It is convinced that the implementation of this project will help dissolve the power shortage problem which has recently come to worsen and, in the end, will be instrumental in enhancing the living standards of the Monrovian citizens and revitalizing Liberian industries.

In view of the above, the implementation of this project is indeed of profound significance for Liberia and is judged to be fully viable within the scope of the grant aid program of the Government of Japan.

CONTENTS

CHAPTER 1 INTRODUCTION

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The Republic of Liberia is situated on the west coast of the Continent of Africa. After the change of government in 1980, the economy of the country slumped as a result of the sharp reduction in exports of iron ore, natural rubber, and timber which had once been the country's main industries. The economic growth rate has been negative for the past five years. Such a slump in economic activities substantially affected the national financial position and sharply reduced the governmental revenue. Thereby the country is to seek foreign aid to finance development programs. As a result, national debts have increased, and a large number of development projects in the country have been suspended or scaled down due to the financial difficulties.

Meanwhile, the Liberia Electricity Corporation (hereinafter abbreviated as LEC), which is responsible for power generation in the Republic of Liberia, supplies power to the Monrovia Power System, the only power system in the country. The Monrovia Power System serves the metropolitan area through hydroelectric power plants (total output 64 MW) and thermal power plants (total output 120.3 MW). The power supply to the system is provided mainly by the hydroelectric power plants in the rainy season (from May to November). However, during the dry season (from December to April), it must rely heavily or totally on the thermal power plants (diesel or gas turbines) due to the unregulated river flow at hydroelectricity dam. Thus, the power output during the dry season drops considerably. Furthermore, partly because the Luke Diesel Plant, which contributes a major source of the power supply during dry season, is apt to break down, and partly because the generating costs of the gas turbines are very high, it has been rather difficult to secure stable power supply to the service areas, resulting in routine load shedding. Being concerned about the present status of power supply, which is indispensable to everyday life and industry, the Government of Liberia has prepared the Five-Year Development Plan (1987 - 1991) and has exerted strenuous efforts to promote it.

Under these circumstances, the Government of Liberia requested of the Government of Japan grant aid cooperation for an urgently required 10-MW diesel generating unit, part of the 30-MW plant project detailed in the medium-term power rehabilitation plan.

In accordance with the request, the Government of Japan decided to execute a basic design study and entrusted the Japan International Cooperation Agency (JICA) to carry it out.

JICA dispatched a basic design study team to the Republic of Liberia for a period of 27 days from April 19 to May 15, 1987 for the purpose of assessing the appropriateness of the project and to determine the details and scale of the project. The team carried out site surveys, collected data, and held discussing with the relevant ministries and agencies of the Liberian Government. .

The basic agreement reached as a result of the discussions with the Liberian side was summarized in the "Minutes of Discussion on the Project for Improvement of Electric Power Supply in Monrovia in the Republic of Liberia" which were duly signed by the representatives of both parties on April 28, 1987.

The composition and survey itinerary of the team, the agencies visited and persons interviewed, minutes of discussions, lists of materials collected, and other information are attached as appendices at the end of this report.

After returning to Japan, the study team engaged in domestic work to study the appropriateness of this Project based on the site survey results. It is concluded, as a results, that the installation of diesel generating units, which require a relatively short construction period, is appropriate since the local power conditions require an urgent solution. This report describes the implementation plan for the Project, covers the selection of equipment and materials, the basic design of the generating units, and the construction and maintenance plans.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2.1 GENERAL CONDITIONS

The Republic of Liberia is a tropical country situated in the extreme southwest of western Africa, bordering on Sierra Leone to the northwest, the Ivory Coast to the northeast, and Guinea to the north. It faces the Atlantic Ocean to the southwest. The land covers an area of 111,370 km^2 (approximately one-third the area of Japan).

Liberia has a tropical climate with high temperatures and high humidity, a rainy season (May through November) and a dry season (December through April). The annual average temperature and humidity are 27°C and 80%, respectively. Rainfalls are heaviest in the coastal districts, approximately 5,000 mm per annum.

Developments were initiated in the coastal districts, where plantations, savannahs and forests are dispersed. It has a dominant interior area of densely forested foothills, and the interior is a mountain area where the Wologisi Mountains and Nimba Mountains run east-west.

Monrovia is the capital, and is situated at the mouth of the St. Paul river, one of the country's main rivers which flows to the Atlantic Ocean.

2.2 ECONOMY AND SOCIAL OVERVIEW

2.2.1 Economic Development

(1) Economic structure

Due to its historical background, the Liberian economy is divided into two sectors: the modern and the traditional. The modern sector covers industries under the concessions of foreign enterprises engaged in the development of rubber, iron ores and timber, the major primary products of Liberia. Since foundation, this country has been promoting open economic policies through the introduction of foreign capitals. Following the initial large-scale development of a natural rubber plantation by the U.S. company Firestone, some American, West German and Swedish companies acquired the rights to mine iron ores and started mining operation in Liberia. The ongoing stripping of forest resources in the adjacent countries attracted the attention of foreign companies to the forests and woods in Liberia, and many companies entered into logging development. Under the initiatives by those foreign enterprises, modern industries have been forming enclave sectors, scattered in the form of plantations or mines. The plantations and mines are export-oriented and their production accounts for 80% of the GDP of Liberia.

On the other hand, the traditional agricultual sector is based on the traditional self-sufficient economy supported by the agricultural farmers that account for 70 per cent of the nation's population. Small-scale, low-productivity rice production features the traditional agriculture, and the income level of the general farmers is much lower than that of those who work for the modern sector.

Represented by the export of the primary products of rubber, iron ores and lumber, processing and manufacturing industries have not been developed. Strong foundation has not been formed yet for manufacturing industries, because of the insufficient domestic markets and the competition with imported consumer goods.

Table 2-1 shows the gross domestic product of Liberia from 1980 through 1984.

Infrastructures such as roads and social infrastructures such as schools, medical facilities and public facilities are seen mainly in urban areas, particularly in Monrovia. Monrovia's increasing population caused by the inflow of people from rural districts, have been causing serious problems including the shortage of houses, degradation of living environments, and increasing unemployment.

Table 2-1 Gross Domestic Product (1980 - 1984)

(US$ Million)

	1980	1981	1982	1983	1984
Agriculture	63.0	49.4	56.0	56.6	61.4
Rubber	21.0	21.3	22.6	25.2	30.1
Forestry	23.0	12.3	10.6	9.4	10.6
Other	19.0	15.8	22.8	22.0	20.7
Mining & Quarrying	111.0	97.7	99.0	85.8	79.7
Iron Ore	106.0	92.0	91.8	80.3	75.7
Other	5.0	5.7	7.2	5.5	4.0
Manufacturing	26.0	23.6	21.2	21.6	20.5
Construction	15.0	14.0	13.0	12.8	12.4
Government Service	39.6	50.4	47.8	47.8	47.0
Other Services	111.6	107.1	100.8	101.2	99.4
(Traditional Sector) *2	(80.0)	(82.4)	(84.9)	(87.7)	(N.A.)
GDP at 1971 Factor Cost *3	366.2	342.2	337.8	325.8	320.4
GNP at Current Market Cost *3	800.8	753.9	756.0	714.6	716.0

Note: *1 Preliminary
*2 World Bank estimates
*3 Traditional Sector is not included

Source : Economic Survey, Ministry of Planning & Economic Affairs (MPEA) 1985
Issues and Options in the Energy Sector, IBRD 1984

As mentioned above, the Liberian economy has a twin structure of modern and traditional sectors. There is a marked difference between the income levels of the two, which bear little linkage to each other. The dual economic structure must be the major issue to be tackled in the future economic development of this country.

The official currency of Liberia is the U.S. dollar. One Liberian dollar is worth one U.S. dollar.

(2) Recent economic growth

The Liberian economy that had previously marked fair growth began to show deceleration in the 1970s, and has been markedly declining in the 1980s.

The recent stagnation of the Liberian economy has been due greatly to external factors such as the recession in the industrialized countries and the low prices of the primary products. The prices of natural rubber, iron ores and lumber, Liberia's main export products, have been dropping, reflecting the sluggish consumption by the advanced countries, and this has resulted in a substantially negative growth in terms of GDP in the past five years (See Table 2-2).

Table 2-2 Nominal and Real GDP Trend
(1980 - 1984)

(US$ Million)

	1980	1981	1982	1983	1984
GDP at Constant Factor Cost (1971)	366.2	342.2	337.8	325.8	320.4
Annual Growth (%)	-4.7	-6.6	-1.3	-3.6	-1.7
GDP at Current Market Cost	800.8	753.9	756.0	714.6	716.0
Annual Growth (%)	4.5	-5.9	0.3	-5.5	0.2

Source: Economic Survey, MPEA 1985

In addition to those external factors, structural factors inherent in the Liberian economy are also great. The structural problems include: (a) the main industries are concentrated on the export of primary products and are greatly dependent on overseas international markets; (b) the official currency being the U.S. dollar and consequently being free from foreign currency regulations, the Liberian domestic economy depends to a great extent on the investment of foreign capital by foreign companies; (c) in contrast to the modern sector, the agriculture in the traditional sector remain in the subsistence state of small scale and low productivity; and (d) the industrial sectors which should be the accelerator to pull the domestic economy are not fully developed, therefore the nation must depend on imports for the supply of capital goods, raw materials, parts, and consumer goods.

Realizing that the natural rubber, iron ore and timber export industries have not been the active driving force of the nation's economic development, long-term strategies for the diversification of the economic structure as well as for the drastic development of the traditional sector will be necessary to solve those structural problems stated above.

(3) External trade and balance of payments

(a) External trade structure

The foreign trade structure of Liberia is featured by the export of primary products including iron ore, natural rubber, timber, cocoa, coffee and diamonds, and by the import of among others, industrial products, consumer goods, petroleum oil and rice.

The foreign trade amount of Liberia accounts for a great part of the nation's economy. In 1984, for instance, the ratio of exports and imports to the GDP amounted to 55.24% and 44.3%, respectively. As for the exports, Liberia's largest export item is iron ore, which amounts to more than 60% of the nation's total exports, followed by natural rubber (20.2%), timber (5.0%), cocoa (3.4%), coffee (3.0%) and diamond (2.4%). The export of these six items accounted for 96% of the total exports. (See Table 2-3.)

Table 2-3 Value and Structure of Exports
(1981 - 1984)

(US$ Million)

Items	1981 (%)	1982 (%)	1983 (%)	1984 (%)
Iron ore	325.4(61.5)	311.1(65.2)	267.8(62.5)	279.0(61.7)
Natural rubber	86.7(16.4)	53.4 (11.1)	73.1(17.1)	91.3(20.2)
Timber	32.5(6.1)	29.2(6.1)	22.2(5.2)	22.6(5.0)
Cocoa	13,8(2.6)	8.8(2.0)	11.5(2.7)	15.3(3.4)
Coffee	19.4(3.7)	22.8(4.8)	18.2(4.3)	13.7(3.0)
Diamond	23.4(4.4)	26.3(5.5)	17.2(4.0)	10.9(2.4)
Others	28.0(5.3)	25.8(5.3)	18.1(4.2)	19.3(4.2)
Total	529.2(100.0)	477.4(100.0)	427.6(100.0)	452.1(100.0)

Source: Economic Survey, MPEA 1985

Table 2-4 lists the amounts and quantities of the major export items. Throughout the four year period, the major export of iron ore maintained an overwhelming share in the total exports but showed a marked decrease due to the depression of the iron and steel industries in the U.S. and Europe. The export of natural rubber increased in quantity but the amount fluctuated considerably reflecting the downslide in the international price. The export of timber decreased to remain at low levels in both the amount and its international price.

Table 2-4 Volume, Value and Unit Price of Export Product (1981 - 1984)

(US$ Million)

Item		1981	1982	1983	1984
Iron ore	Amount	325.40	311.10	267.30	279.00
	Q'ty (Million tons)	20.70	16.40	15.70	16.90
	Per ton ($)	15.72	18.97	17.03	16.51
Natural rubber	Amount	86.70	53.40	73.10	91.30
	Q'ty (Million kgs)	76.90	60.10	73.60	87.90
	per kg ($)	1.13	0.89	0.99	1.03
Diamond	Amount	23.40	26.30	17.20	10.90
	Q'ty(thousand carats)	336.00	433.00	330.0	236.70
	Per carat ($)	69.64	60.70	52.10	46.00
Lumber	Amount	32.50	29.20	22.20	22.20
	Q'ty (thousand m^3)	199.80	190.10	156.70	183.50
	Per m^3 ($)	162.60	153.60	141.70	123.20
Coffee	Amount	19.40	22.80	18.20	13.70
	Q'ty (Million kgs)	8.30	10.00	7.40	4.90
	Per kg ($)	2.34	2.28	2.46	2.80

Source: Economic Survey, MPEA 1985

Table 2-5 shows value of import products, 1981 - 1984. They are broadly classified into consumer goods, capital goods, and raw materials. Foodstuffs, having an outstandingly large share in consumer goods, are featured by the import of rice which is the staple food of the nation (the self-sufficiency ratio of rice is 75%). While the import of machines maintained a constant high share, the import of parts sharply dropped as the result of the depression in the domestic manufacturing industries.

In the export of raw materials, crude oil had a dominant share until the oil refinery owned by the Liberia Petroleum Refinary Company ran out of order. In and after 1983 to date, the importation of crude oil is superseded by the importation of refined oil. The high percentage share of crude oil and subsequently refined oil, from 27% in 1982 till a little less than 20% in 1984, in the total imports has been a heavy burden on the economy of the nation in spite of recent low oil prices.

Table 2-5 Value of Import Products
(1981 - 1984)

(US$ Million)

Items	1981	1982	1983	1984
Consumer Goods	136.1	113.8	127.8	112.0
Foodstuff	80.5	74.4	75.2	60.3
Durables	6.3	5.1	7.2	8.1
Semi-durables	16.0	9.5	14.2	12.2
Non-durables	27.5	18.0	23.2	22.9
Transport equipment	5.8	6.8	8.0	8.5
Capital Goods	89.6	95.6	90.6	75.5
Machinery	44.1	46.4	35.6	39.1
Transport equipment	23.7	25.0	24.6	17.6
Parts	21.8	24.2	30.4	18.8
Raw Materials	251.7	219.0	193.0	75.7
Crude oil	129.6	94.1	-	-
Construction materials	16.1	16.3	16.1	11.6
Others	106.0	108.6	177.1	164.1
Total	477.4	428.4	411.6	363.2

Source: Economic Survey, MPEA 1985

(b) Balance of Payments

It is difficult to trace the trend of the balance of international payments of Liberia accurately because of the limited availability of statistical data, but traditionally the nation's trade balance have been maintaining surpluses, with exports exceeding imports. In contrast, the invisible trade balance has continued to show a deficit. As a result, the current account balance had been in the red every year until recently, and private investment had been introduced on a long-term basis as a principal measure to offset the deficit. In recent years, the trade balance surplus has been increasing with the decrease of imports, owing to the domestic business slump, and the invisible trade balance has also been sluggish generally, pushing the current account balance into the black. (See Table 2-6.)

Table 2-6 Foreign Trade Balance (1980 - 1985)

(US$ Million)

Items	1980	1981	1982	1983	1984	1985
Export (F.O.B.)	600.4	529.2	477.4	427.6	452.1	435.6
Import (C.I.F.)	533.9	477.4	428.4	411.6	363.2	284.4
Trade balance	66.5	51.8	49.0	16.0	88.9	151.2
Current account balance	-104.4	-77.3	-48.6	-91.5	11.0	87.4

Source: Economic Survey, MPEA 1985

However, the ratio of the export price to the import price has been declining in recent years. Typically, the export prices of the nation's representative primary products have been in a downward trend, while the import prices of industrial products have tended to go up. Thus, the terms of trade has become unfavorable. (See Table 2-7.)

Table 2-7 Liberia's Terms of Trade (1981 - 1985)

Items	1981	1982	1983	1984	1985
Export price index	100	108.4	101.3	99.9	99.4
Import price index	100	105.4	100.3	109.7	101.7
Terms of trade	100	107.8	101.0	91.1	97.7

Source: Statistical Bulletin of Liberia, MPEA 1987

(4) Economic Development Plan and Energy Policy

(a) Economic development plan

The First National Socio-Economic Development Plan (1976 - 1980), the first of the full-scale five-year national development plan by the Government of Liberia, started in 1976. The Second Development Plan, which had been planned to immediately follow the completion of the first Program, was postponed for one year due to the change of regime by a coup d'etat and was started in 1981 for five years ending in 1985.

The Government of Liberia was planning to implement the Third Development Plan in succession to the Second Five-Year Program, but discontinued the planning for the Third Program. Instead, an interim development program, "Economic Recovery Program (1986/87 - 1988/89)", was announced in September 1986. This Program has not yet been launched but has still been in the process of amendment. As announced, the "Economic Recovery Program" has focussed on the urgent development targets as follows:

- Promotion of export industries
- Reduction of budget deficit and external debt
- Improvement in investment environments

The estimated improvement in the financial balance and the reduction of external debt of the Government by the implementation of the Economic Recovery Program are listed in Table 2-8.

Table 2-8 Budgetary Prospects by Economic Recovery Program

(US$ Million)

Items	1986/87	1987/88	1988/89
Revenues	246	275	300
Current revenue	193	215	237
LPRC/other	53	60	63
Current Expenditures	129	135	142
Wages	97	90	83
Other recurrent	32	45	59
Grants	28	28	28
Payment for external debt	194	187	119
Fiscal revenue and expenditure gap	-49	-19	+67
Financing of the gap	90	113	82
Domestic financing	40	20	15
External financing	50	93	67
Changes in arrears	-41	-94	-149

(b) Energy Policy

The energy policy of the Liberian Government is presented in the Integrated National Energy Program (INEP) announced in June 1985 by the National Energy Committee (NEC) which is a consultative committee to the President. INEP proposes the promotion of the following as the principal energy issues in Liberia:

- Reliable supply of low-cost oil.
- Efficient consumption of fuels and effective utilization of energy resources in Liberia, to free the nation from dependence on imported oil.
- Reorganization and improvement in managerial efficiency of the energy supply agencies.

For materialization, INEP proposes and urges the implementation of:

(i) The establishment of a new Energy Planning Agency (EPA) being responsible for the national energy policy.

(ii) Managerial improvement and efficient operation of the Liberia Petroleum Refining Company (LPRC) which takes charge of the import of petroleum, and the Liberia Electricity Corporation (LEC) which is the major power supplier in Liberia.

(iii) The development of the domestic energy resources including wood as fuels, water resources (including small-scal hydraulic generation), coastal petroleum and natural gas, and substitute energies (such as biomass).

(iv) The establishment of Rural Electric Authority for improving rural power generation systems.

2.2.2 Social Development

(1) Population composition

The gross population of Liberia is said to be 2.22 millions as of 1986. The figure 3.6% indicating the rate of population increase in this country is one of the highest among African countries. Table 2-9 shows the population distribution by region in this country. Five hundred and eighty thousand people, 26% of the gross population, live in Montserrado county in which Monrovia is located. The population of the four counties of this Montserrado plus Lofa, Bong and Nimba, where leading iron mines are located, accounts for more than 60 % of the gross national population. Monrovia is called Greater Monrovia, where 464,000 people, over 20 % of the gross population were concentrated as of 1986. An average annual population growth rate is estimated as high as 7.7% since 1974 when the previous census registered 204,210. As the result of the high population concentration in Greater Monrovia, the city has been suffering serious urban problems such as unemployment, housing shortage, and aggravated living environment.

As for the age composition of the population, 43% of the population are aged 14 and younger, 49% are in the working ages between 15 and 54, and 8% covers those who are 55 years old and older. The nonproductive population accounts for a high 51%. The average life expectancy is 55 years.

The average number of members per family is said to be four to five in urban areas and five to six in rural areas. The per capita GNP in 1985 was $470.

Table 2-9 Population Distribution (1962 - 1986)

Country/Territory	Census Year 1962	1974	1984	1986(Est.)
LIBERIA	1,016,443	1,503,368	2,101,628	2,221,280
Bomi County	39,388	62,140	66,420	67,276
Bong County	130,405	182,199	255,813	268,138
Grand Bassa County	99,566	123,400	159,648	166,898
Grand Cape Mt. Co.	32,190	56,601	79,322	83,866
Grand Gedeh Co.	48,256	71,823	102,810	109,007
Kru Coast Territory	21,280	27,115	35,267	36,897
Lofa County	131,554	180,737	247,641	261,022
Marshall Territory	12,664	20,732	31,190	33,282
Maryland County	54,805	64,483	85,267	89,424
Montserrado Co.	168,757	321,808	544,878	582,430
Nimba County	162,855	249,692	313,050	325,722
Rivercess County	28,756	27,746	37,870	39,870
Sasstown Territory	9,540	9,952	11,524	11,383
Sinoe County	44,639	57,642	64,147	65,448
Gibi Territoty	31,970	47,298	66,802	70,703
Greater Monrovia	80,992	204,210	421,058	464,428

(2) Manpower

The employed labour force in Liberia is estimated at 659,000 in 1986, more than 80 % of whom live in rural districts and are engaged in plantations or the traditional agriculture. Approximately 8 % of the work force are engaged in commercial activities. Only a small part of the work force are employed in the industrial sector which consists mostly of medium-and small-scale manufacturing industries having a small employment capacity. Government employees account for 7 %, according to the statistics, but are said to actually amount to more than 10 % according to unofficial information. (See Table 2-10.)

Table 2-10 Labor Force Copmosition
(1982 - 1986)

	1982	1983	1984	1985	1986
Agriculture	479,276	496,229	513,459	530,694	548,267
Industry	10,381	10,749	11,356	11,495	11,875
Commerce	46,716	48,369	49,996	51,728	53,435
Government organizations	40,373	41,800	43,410	44,705	46,179
Total	576,746	597,147	618,221	638,622	659,696

Source: 1984 Housing and Population Census MPEA

2.3 PRESENT POWER SITUATION IN LIBERIA

(1) Background

In 1926, Liberia commissioned its first power development scheme. In that year, a privately-owned small hydro-electric power unit of 4 MW was built by Firestone, the U.S.-based firm. In 1947 a 4 MW thermal power unit was installed and additional thermal units with a total generating capacity 13 MW were in operation from 1961 to 1963 on Bushrod Island. In 1964, with U.S. cooperation, the nation's largest power project named the T.J.R. Faulkner and the W.F. Walker hydro station was completed. This now consists of a hydro power station (2 x 15 MW + 2 x 17 MW) and a large dam named Mt. Coffee on the St. Paul River (usually called "Mt. Coffee power station").

With an increasing generating capacity, a power grid expansion program has been ongoing on a step-by-step basis, mainly from the

Bushrod Power Plant, and has finally developed into the existing Monrovia Power System.

During this period, there was a shift from the power development authorities of the Ministry of Public Works to the Monrovia Power Authority, and in 1973, the Liberia Electricity Corporation (LEC) was established by the Government as an independent state-owned enterprise. Presently, LEC, under the direct control of the President of the State, is operated as the sole national agency responsible for the generation, transmission and distribution of power.

(2) Liberia Electricity Corporation (LEC)

(a) Board of directors

The Board of Directors is a committee organized to advise on policies and strategies for managing LEC. The Board was chaired by the Minister of National Defence until April 1987. The Board consisted of the following members:

1.	Chairman	:	Minister of National Defence
2.	Committee member	:	Chairman, Joint Security
3.	Ditto	:	Minister of Public Works
4.	Ditto	:	Minister of Commerce, Industry and Transportation
5.	Ditto	:	President, National Housing and Savings Bank
6.	Ditto	:	Assistant Director General, Liberia Broadcasting System
7.	Ditto	:	Chief Engineer Executive Mansion
8.	Ditto	:	Managing Director of LEC

As the result of reshuffling in April 1987, there was a shake-up of members. As of the end of June, no new Board members were yet appointed.

(b) Organization

As shown in Table 2-11, the organization of LEC is headed by the Managing Director, assisted by four Deputy Managing Directors. The LEC is organized in the following divisions and departments and each Deputy Managing Director is authorized to supervise and manage the respective divisions:

1. Managing Director

   Public Relation Division
   Internal Audit Division
   Training Institute

2. Deputy Managing Director: Operation Division

   Generation Department
   Transmission and Distribution Department

3. Deputy Managing Director: Technical Division

   Corporate Planning Department
   Commercial - Technical Department
   Rural Electrification Department

4. Deputy Managing Director: Administration Division

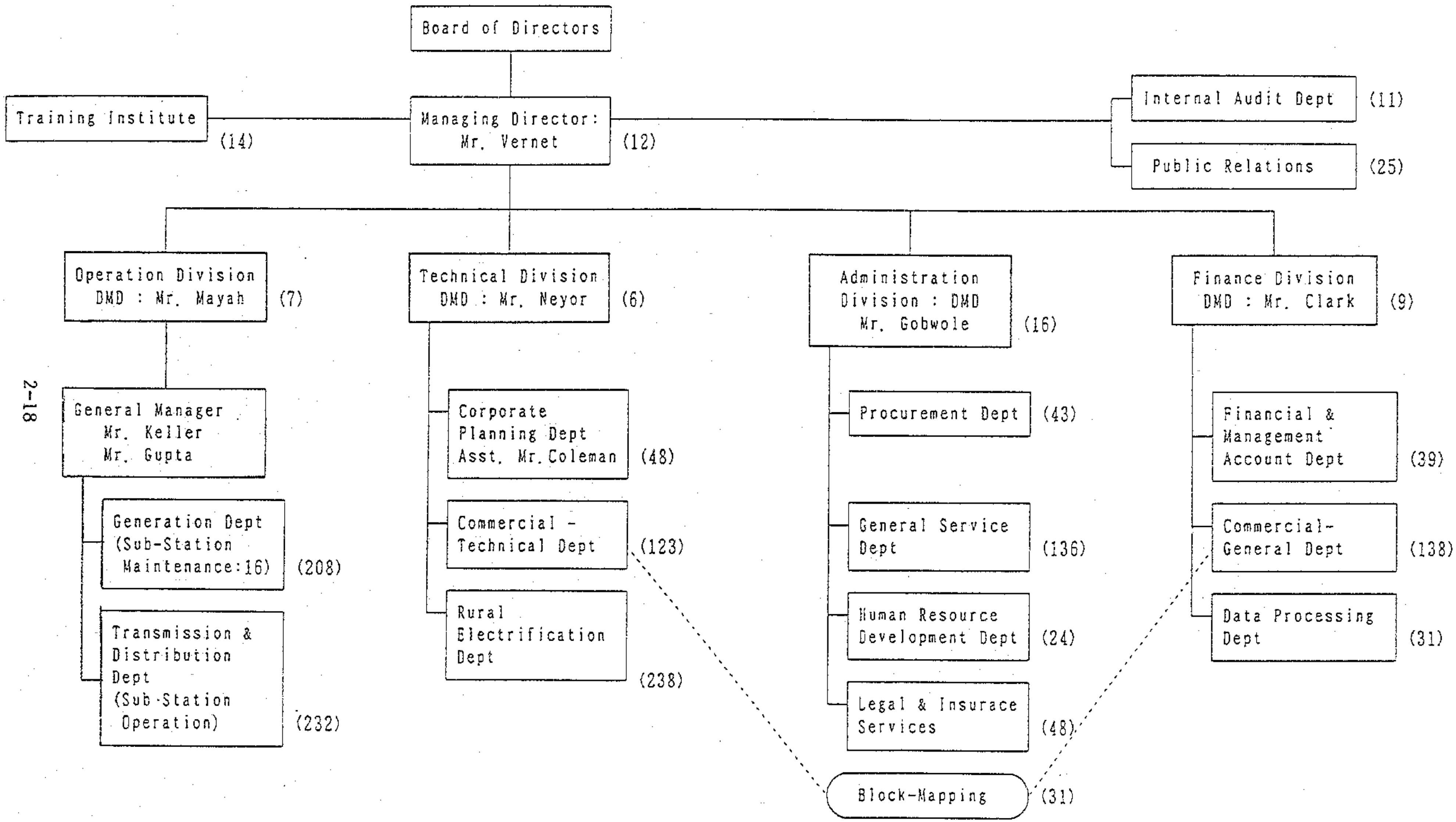
   Procurement Department
   General Service Department
   Human Resource Development Department
   Legal and Insurance Service Department

5. Deputy Managing Director: Financial Division

   Financial and Management Account Department
   Commercial - General Department
   Data Processing Department

Additionally, the Office of the Block Mapping Project is operated as a task force organized specifically to check illegal use of electric energy, promote the installation of

Table 2-11 Organization of the LEC



Note: ( ) shows number of personnel

watt hour meters and watch/observe the power services to consumers under contract. The role of this Office presents one of the positive measures undertaken by the LEC which is now suffered from non-payments or delayed payments of electricity charges. Organizationally, this Office is assigned to both the Commercial-Technical Department and Commercial-General Department.

Because rural electrification is not a part of the LEC's own undertaking but officially commissioned to LEC by the Government, the Rural Electrification Department is operated financially under a separate accounting system.

2.4 ELECTRIC POWER FACILITIES

2.4.1 Profile on National Power System

The total existing power facilities in Liberia comprise LEC owned and privately owned facilities. The total generating capacity installed amounts to 366.2 MW, of which a generating capacity of 193.4 MW accounting for 53% is owned and operated by LEC, as shown in Table 2-12.

Table 2-12 Present Status of Installed Power Generating Capacity in Liberia

LEC	193.4 MW (53%)
(Including isolated generating system: 9.1 MW)	
Private power systems	172.8 MW (47%)
BMC	95.0 MW
LAMCO	63.0 MW
Fire Stone	9.8 MW
V.O.A.	5.0 MW
Total	366.2 MW (100%)

The remaining share, or 172.8 MW in installed capacity, is owned by the foreign industries as independent generating facilities and is further broken down into 95 MW operated by BMC, the iron-ore mining company, 63 MW by LAMCO, the U.S. - Swedish mining company, 9.8 MW by Firestone, the rubber plantation company and 5.0 MW by V.O.A. Also, there are a number of small generating units operated by private manufacturers for their own plants. However, actual power production data are not available.

From the description, it is clear that the generating capacity installed and operated by private industries is a relatively high ratio of the nation's total generating capacity. This indicates that the power supply system being provided by LEC is still lagging behind the national power demand.

2.4.2 Outline of LEC Power System

Since 1961, in order to meet the ever-increasing power demand, LEC has continued to invest in the expansion of the power generating facilities. As of 1987 it has a total installed capacity of 184.4 MW, which can be broken down by power generation type as follows:

Hydro electric power	64.0 MW (34.7%)
Diesel power	52.3 MW (28.4%)
Gas turbine	68.0 MW (36.9%)
Total	184.3 MW(100.0%)

(Not including 9.1 MW for isolated power systems)

(1) Hydro-electric power generation facilities

Liberia has an abundance of water resources. There are six large rivers, the St. Paul River which runs through the suburb of Monrovia, St. John River, Lofa River, Cestos River, Moro River on the Sierra Leona border and the Cavalla River on the Ivory Coast border.

In the past, developments were concentrated solely on the river basin of St. Paul, where in 1964 the nation's first hydro-electric power station (run of river type) at Mt. Coffee was constructed with U.S.AID assistance. Initially, the power station was designed for an output of 30 MW, however, in 1972 under the World Bank finance, this was increased by 34 MW to a total output of 64 MW.

In reality, however, the St. Paul River is affected by fluctuating discharges between the dry and rainy seasons; in particular, water flow is diminished during the dry season. For this reason, the hydro-electric power output tends to be limited substantially during the dry season and any shortage in power output is covered by the thermal power output. To cope with this situation, LEC is considering, in its "Long-term Development Plan", construction of a reservoir upstream of the Mt. Coffee dam to provide for possible water shortages during the dry seasons.

In this respect, the LEC's future responsibility is to seek a way to shift the thermal power load on a step-by-step basis to low-cost hydro-electric power in order to reduce a greater dependency upon the oil-fired power generating units.

Mt. Coffee dam

Unit	Installed capacity (MW)	Available capacity (MW)	Year of Completion
No. 1	15.0	15.0	1962
No. 2	15.0	15.0	1965
No. 3	17.0	17.0	1972
No. 4	17.0	17.0	1972
Total	64.0	64.0	

(2) Thermal power generation facilities

The major share of power production is through the thermal power generating system, or more than 60 % of the LEC's total installed capacity, of which approximately 40 % is for diesel generating units and 60 % for gas-turbine generating units. It is LEC's intention to minimize the power from the expensively fueled gas-turbine generation to that of a greater reliance upon diesel generating units. However, gas turbine power is still indispensable with its higher share ratio because of the rising power demand.

Table 2-13 illustrates a summary of power generating units owned and operated by LEC. Operational records on existing power station are showned in attached Table 2-14 and Fig. 2-1.

Table 2-13 Summary of LEC's Generating Facilities

Unit		Year Installed	Installed Capacity (MW)	Available by 1986 (MW)	Assumed Retirement Year
Bushrod Diesel	2	1961	2.0	-	*
	3	1961	2.0	-	*
	4	1963	2.5	-	*
	5	1963	2.5	1.5	1988
	6	1963	2.5	1.5	1988
Total			11.5	3.0	
Bushrod GT	1	1966	15.0	-	2001
	2	1969	15.0	14.0	2001
	3	1973	19.0	17.0	2001
	4	1973	19.0	-	-
Total			68.0	31.0	
Luke Diesel	1	1980	13.6	12.0	2000
	2	1980	13.6	12.0	2000
	3	1982	13.6	12.0	2003
Total			40.8	36.0	
Mt. Coffee	1	1964	15.0	15.0	2014
	2	1965	15.0	15.0	2015
	3	1972	17.0	17.0	2022
	4	1972	17.0	17.0	2022
Total			64.0	64.0	
Total with Mt. Coffee			184.3	134.0	
Total without Mt. Coffee			120.3	70.0	

* Already retired

(3) Transmission lines

The sole, main transmission line owned by LEC, is the Monrovia transmission system serving major consuming areas such as Monrovia and its vicinities at a rating voltage of 69 kV. This system is linked to the BMC system which operates as a large generating unit for industrial use.

The transmission line route consists of a single circuit on the support of wooden poles and double circuits on steel towers. Conductors are mostly made of high-strength aluminum alloy (AAAC) 158.6 sq.mm in size. An underground cable of 185 sq. mm is partially used. Although the whole transmission system forms a loop connection, some section switches are kept open at all times. Therefore, loop operation is not applied to this system. Attached Table 2-15 shows a list of transmission lines. Fig. 2-2 shows one line diagram on the existing Monrovia Power System in 1986 and Fig. 2-3 shows a map of transmission lines.

(4) Substations

Substations to step down the voltage from 69 kV to 12.5 kV and are being operated at 16 sites as shown in Table 2-16. Each transformer unit capacity is standardized at 20 MVA and installed at two banks for each substation with sufficient allowance when demand increases.

Table 2-16 LEC's Substations

Substation	Rated Transformer (Capacity/MVA)	1985 Peak Demand (MW/MVA)	Project 1996 Peak Demand (MVA)
Bushrod	2 x 3 x 3.125	12.2/14.4	18.7
Krutown	2 x 15/20	8.9/10.5	13.7
Newport	2 x 15/20	8.8/10.4	13.5
Capitol	2 x 15/20	10.8/12.7	16.5
Congotown	2 x 15/20	9.0/10.6	13.8
Paynesville	2 x 15/20	9.1/10.7	13.9
Gardnersville	2 x 15/20	6.6/7.8	10.2
Virginia	1 x 6.3	3.3/3.9	5.1
Kle	1 x 5.0/7.5	1.7/2.0	2.6
Bomi Hills	2 x 5.0	1.3/1.5	2.0
Todee	3 x 0.333	0.2/0.25	0.33
Kakata	3 x 0.833	2.3/2.7	3.5
Robertsfield	1 x 5/7	2.1/2.5	3.3
Buchanan	1 x 7.5/10.5	2.1/2.5	3.3
Mt. Coffee	1 x 2.5	2.4/2.8	3.7
Bong Mines	2 x 10	Rated Value	30.0

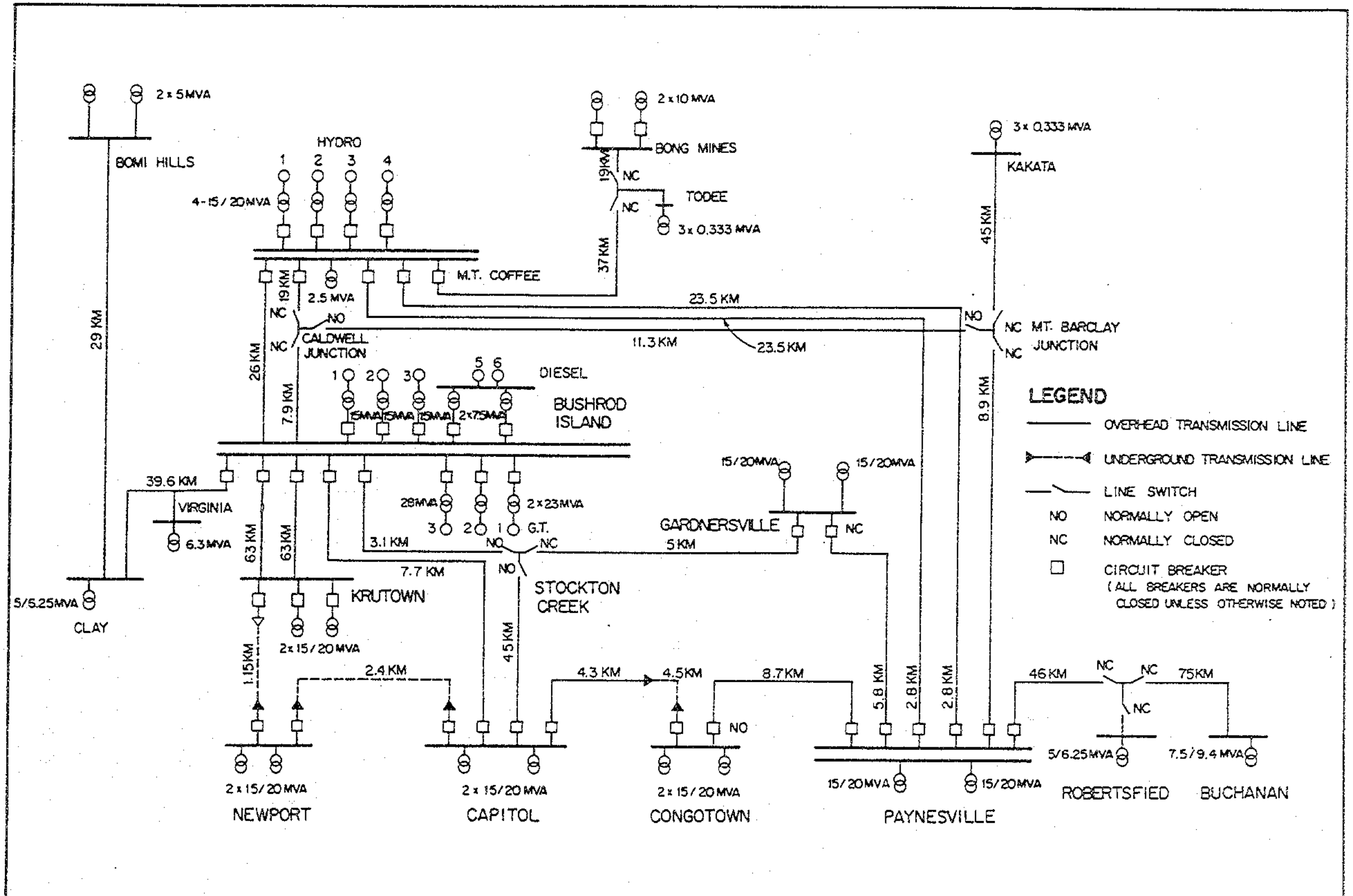


Fig. 2-2 ONE LINE DIAGRAM OF THE LIBERIA ELECTRICITY CORPORATION

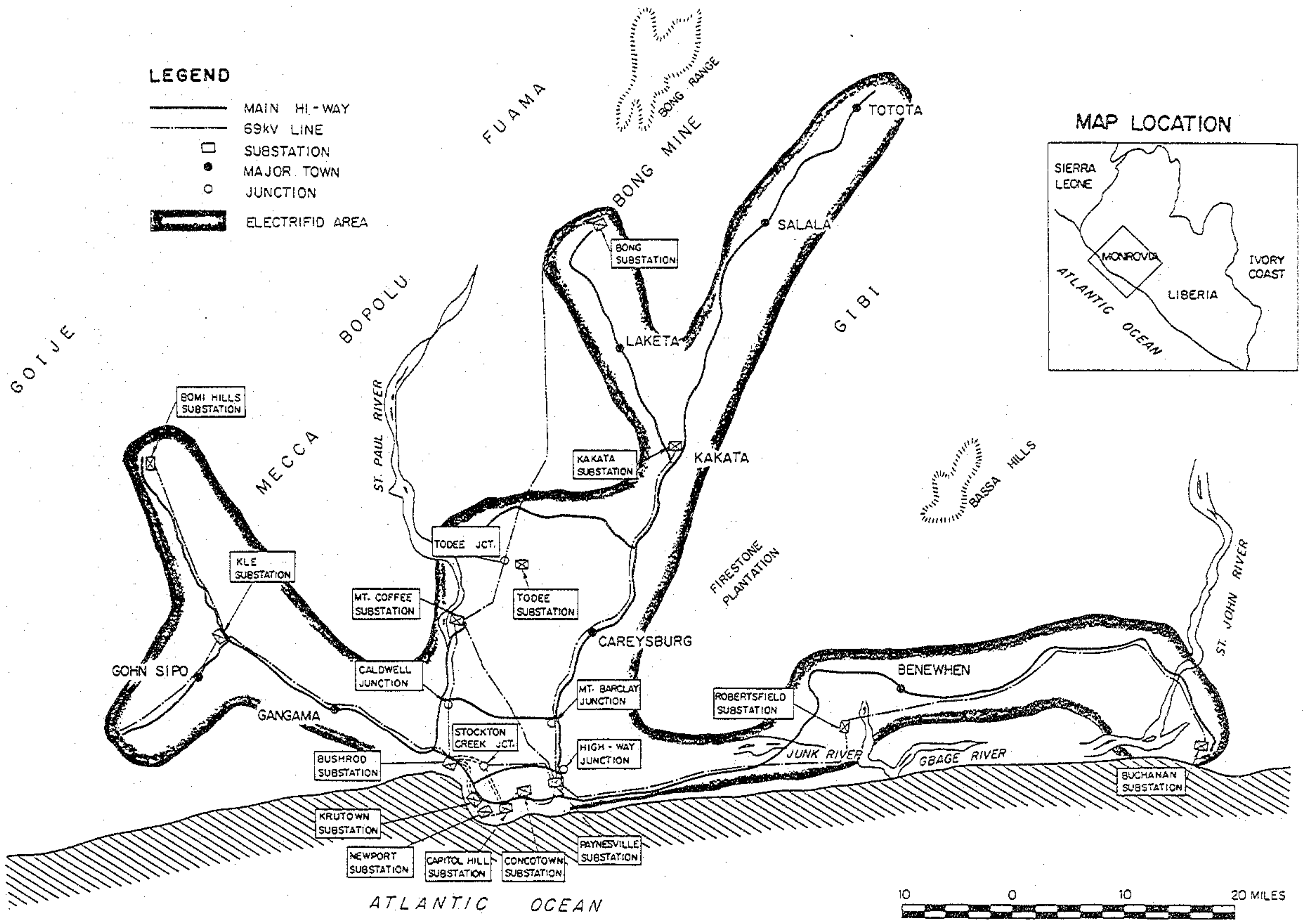


Fig.2-3 AREA MAP, TRANSMISSION LINES AND SUBSTATIONS

(5) Distribution lines

The high-tension distribution system is designed for a rating of 12.5 kV, and a low tension distribution lines is a 3-phase 4-wire system, 400 V/230 V. Either concret or wooden poles are used for support and the direct earthing connection applies to the neutral point.

Because of frequent power-failures or voltage fluctuations due to frequent conductor parting, X-Arm burning and connectors overheat, etc., it is apparent that the existing distribution system still needs improvement to better serve the customers.

(6) Isolated power supply systems

The Government has commissioned LEC to undertake the power generation and distribution services for rural districts. The project's service area covers the remote rural communities outside of Monrovia. The installed capacity being operated for this purpose totals 9.1 MW and consists of small, old individually operated diesel engines of less than 1,000 kW per unit. (Table 2-17). Local residents to benefit from the governmental rural electrification project are estimated at about 40,000 persons so far. The problem with rural electrification is that costs of diesel engine fuels are great. According to the World Bank study in this regard, it is reported that in 1983 it would cost 6.3 million U.S. dollars to produce 27 MWh and this would result in a deficit of about 5.3 million U.S. dollars taking into account an estimated revenue of no more than 930,000 U.S. dollars from sales of corresponding energy. The main reason for such a deficit would be attributable to the very small number of consumers having watt hour meters installed at home, approximately 15 % of total consuming households. In the absence of meters, the consumers can only be charged a flat minimum rate regardless of the level of their consumption. The result is that the average revenue from energy sales (at a unit price of 3.5 cents per kWh) is naturally much lower than the production cost (at 23.3 cents per kWh).

The INEP recommends that the oil-fueled diesel generating units should be replaced by the charcoal fired or small hydro power generating units. However, this plan has stalled because of financial difficulties in the government budget. Since the electrification scheme in rural parts of Liberia is still lagging behind actual power needs, it should be given greater considerations as one of the main tasks for future development.

Table 2-17 Major Local Electrification Facilities (1983)

Location	No. of Units	Installed Capacity (kW)	No. of Households in Contract	Energy Production (GWh)	Fuel Consumption (1,000 US gallon)
Harper	2	1,300	1,058	4.2	402
Gbarnga	2	4,580	1,050	6.0	576
Greenville	3	1,000	1,000	3.9	368
Voinjama	2	1,300	700	2.9	271
Zwedru	3	1,300	640	3.0	288
Sanni Welli	1	950	524	3.2	299
Kolba City	2	285	245	1.2	106
Robertsport	2	505	320	1.5	143
Bellafanai	1	333	100	1.0	92

Source: Issuese and Options in Energy Sector, IBD 1984

(7) Electric power exchange agreement with BMC

In order to cope with an acute power demand increase, the LEC concluded a power exchange agreement with the Bong Mining Company (BMC) in April 1981. Under this agreement, LEC is entitled to receive power from BMC to make up for a decline of the power generating capacity at the Mt. Coffee Dam during the dry season while reciprocally, BMC can receive sufficient power from the LEC's hydro power genearting units during the rainy season, at a much cheaper price than that available from its own diesel generating unit. This is a great advantage to both parties. Before they entered into this agreement, BMC had procured part of the energy requirements from LEC. After the agreement was enforced, the mutual power supply system was established at the ratio of 1 to 1.3 in bartering of electricity between LEC and BMC respectively. The ratio of 1 to 1.3 is determined from the generating cost differential. The generating cost of diesel units of BMC is higher than the hydroelectric power generating cost of LEC's units. It is therefore agreed that BMC is entitled to receive much more energy as is differentiated in costs. Every year, the generating cost is reviewed for renewal of the power exchange agreement. BMC is an owner of generating facilities for the exploitation of iron ore, operating 11 diesel generating units of 95 MW in total installed capacity, as shown in Table 2-18.

Table 2-18 Generating Facilities Owned and Operated by BMC

Unit	Installed Capacity (MW)	Year Installed
1	8	1965
2	8	1965
3	8	1964
4	8	1968
5	9	1970
6	9	1970
7	9	1970
8	9	1972
9	9	1977
10	9	1977
11	9	1977
Total	95	

Implementation of power transfers between LEC and BMC in and after 1981 is as follows:

	From BMC to LEC (GWh)	From LEC to BMC (GWh)
1981	6.9	20.5
1982	32.9	27.9
1983	38.5	32.3
1984	26.6	33.2
1985	26.4	38.5
1986	35.4	34.6

2.4.3 Foreign Assistance in Power Sector

Assistance from foreign countries has played an active role in Liberian electric power development.

The foreign assistance given to the Liberian electric power sector began with the St. Paul River's hydro-power generation project (Mt. Coffee Dam) in 1963. The USAID of the United States offered a 25-million-dollar loan, and a dam with generating capacity of 30 MW (15 MW x 2) was completed. It was an epoch-making electric power development project. After that, the World Bank gave the major assistance to the electric power sector. It provided a First Loan of 7.4 million dollars in 1970 to implement the expansion of the Mt. Coffee Dam for 34 MW (17 MW x 2). For the Second Loan in 1971 and 1973, 7.6 million dollars was used to install two gas turbine generator units with a total capacity of 38 MW (19 MW x 2). For the Third Loan in 1975, a group of Indian consultants were sent to the LEC as an management support team with a view to improving the operation and financial management. Furthermore, in 1978 in order to increase the capacity of electric power generation, 10 million dollars were financed to build the Luke Diesel Plant with a capacity of 40.8 MW (13.6 MW x 3). For this Fourth Loan, the World Bank co-financed a total of 30 million dollars in cooperation with the Saudi Fund, the Arab Bank and European investment banks.

Other than the countries above, the KFW of West Germany joined the finances in the expansion project for power transmission and distribution networks, and the Africa Development Bank (AFDB) offered the assistance to build a 15 MW gas turbine plant.

In the field of technical cooperation, JICA of Japan carried out the "Basic Survey for Power Source Development" in 1974 to examine the potential locations for hydropower generation on the St. John River. Moreover, the UNDP implemented the "Issues and Options in Energy Sector", a general survey of the Liberian energy sector in 1984. Recently, Egypt has sent three engineers (mechanical, civil and electric) to LEC under the technical cooperation scheme.

The main assistance received from abroad are listed in Table 2-19.

Table 2-19 Major Foreign Assistance to the Electric Power Sector

Financial Cooperation		
USAID	1963	Construction of hydroelectric power plant (Mt. Coffee Dam)
IBRD	1970	First Loan (for expansion of hydroelectric power plant)
AFDB	1970	Establishment of gas turbine plant
IBRD	1971/73	Second Loan (for establishment of gas turbine plant)
KFW	1974/76	Rehabilitation of power distribution network
KFW	1978/82	Expansion of power distribution network
IBRD	1975	Third Loan (technical assistance to improve sector management)
IBRD/FIB/ BADEA	1978	Fourth Loan (for construction Luke Diesel Plant)
Technical Cooperation		
JICA	1974	Basic Survey for Power Source Development
UNDP/IBRD	1984	General Survey for energy sector
Egypt	1984 -	Mechanical, civil and electric engineers are being stationed

2.4.4 Power Supply-Demand Situation

(1) Present conditions

(a) Electric power supply and demand

The LEC has had the power generation facilities to generate more than 430 GWh annually. However, since the beginning of the 1980s, the amount of electric power generated has been declining every year due to the the obsolete equipment and the curtailment in the fuel costs. By 1986 it had decreased to 376 GWh. The feature of the electric power supply in Liberia is the substantial difference in supply capacity between the rainy and dry seasons. The reason is that the Mt. Coffee Dam, which accounts for nearly 40% of the existing equipment capacity, becomes almost or completely inoperational during the dry season, owing to the shortage of water. (Refer to Table 2-20.)

Table 2-20 LEC Power Generation by Hydro/Thermal Power Generation Systems (1979 - 1986)

(GWh)

	1979	1980	1981	1982	1983	1984	1985	1986
Thermal	106.0	126.7	116.0	100.8	104.2	104.3	109.5	96.2
%	24.5	29.6	29.1	26.7	28.4	27.0	28.4	25.6
Hydro	326.8	302.0	282.9	276.8	262.8	282.1	276.3	279.8
%	75.5	70.4	70.9	73.3	71.6	73.0	71.6	74.4
Total	432.8	428.7	398.9	377.6	367.0	386.4	385.8	376.0
%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The LEC has been receiving power supply from the BMC in accordance with the Electric Power Exchange Agreement, to compensate for the shortage of electric power during the dry season. Yet the situation is still unsatisfactory. (Refer to Table 2-21)

Table 2-21 LEC Power Generation including BMC Contribution (1979 - 1986)

(GWh)

	1979	1980	1981	1982	1983	1984	1985	1986
LEC	432.8	428.7	398.9	377.6	367.0	386.4	385.8	376.0
Supply from BMC	-	-	6.9	32.9	38.5	26.6	26.4	35.4
Total	432.8	428.7	405.8	410.5	405.5	413.0	412.2	411.4

The supply-demand balance of electric power in Liberia is shown in Table 2-22.

Table 2-22 Supply-demand Balance of Electric Power in Liberia (1977 - 1985)

	Amount of Electric Power Generated (GWh) [1]	Amount of Electric Power Sold (GWh) [2]	Supply-demand Balance
1977	399.1	278.8	0.700
1978	404.7	282.0	0.700
1979	432.8	285.3	0.659
1980	428.7	285.8	0.667
1981	405.8	274.3	0.676
1982	410.6	274.8	0.669
1983	405.5	272.0	0.671
1984	413.0	217.1	0.647
1985	412.2	252.0	0.611

Note: 1) Includes portions supplied from the BMC during the dry season.

2) Includes portions supplied to the BMC during the rainy season.

Source: Five-Year Development Plan (1987 - 1991), LEC

The other feature of electric power supply in Liberia is that power transmission losses are extreme. This means that there are non-technical (commercial) losses caused by illegal use of elecric power, uncollected electricity bills, uninstalled watt hour meters, etc., as well as station use of the power plants, physical transmission and distribution losses (technical losses). These losses account for an substantial proportion of the total electric power generated in the country.

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Technical loss (GWh)	4.0	4.1	5.0	5.8	5.7	5.3	5.8	7.0	7.3
%	1.0	1.0	1.2	1.3	1.4	1.3	1.4	1.7	1.8
Commercial loss (GWh)	116.3	118.6	142.5	137.7	125.8	130.5	127.7	138.9	152.9
%	29.0	29.0	32.9	32.0	31.0	31.8	31.5	33.6	37.1

On the other hand, the demand for electric power in Liberia has been falling since the peak of 285.8 GWh in 1980. The Electric power consumption has declined by 2.6% a year, on average, to 242 GWh in 1985. In this background, elecric power consumption has declined due to the sluggish domestic economy. Moveover, the case of the decline is considered to be the result of the restrictions on the thermal-power plant operations implementation of extensive load sheddings due to problems in operations (increased fuel costs, deterioration of equipment. etc.).

(b) Load sheddings

Fig. 2-4 shows energy requirements in Monrovia Power System in 1984-86 and which power plant supplied the said energy requirements, Fig. 2-5 and Fig. 2-6 show typical daily load curves in rainy and dry seasons and how generator(s) shared the required energy. As can be seen in Fig. 2-4, a great decline in the power demand is seen around the dry season from about January to March every year, the reason being that consumption was suppressed due to the shortages of generating capacities. The load sheddings have been carried out since around 1982. Intensive load sheddings were implemented especially during the dry season in 1986 (January through May).

These load sheddings are being practiced under guidelines according to the priorities shown below.

Priority 1: Executive Mansion (President's Office)
Priority 2: Hospital
Priority 3: Water Supply Plant

Fig.2-4 LEC ENERGY GENERATION

LEC/BMC Energy Exchange and Monrovia Grid Energy Requirements

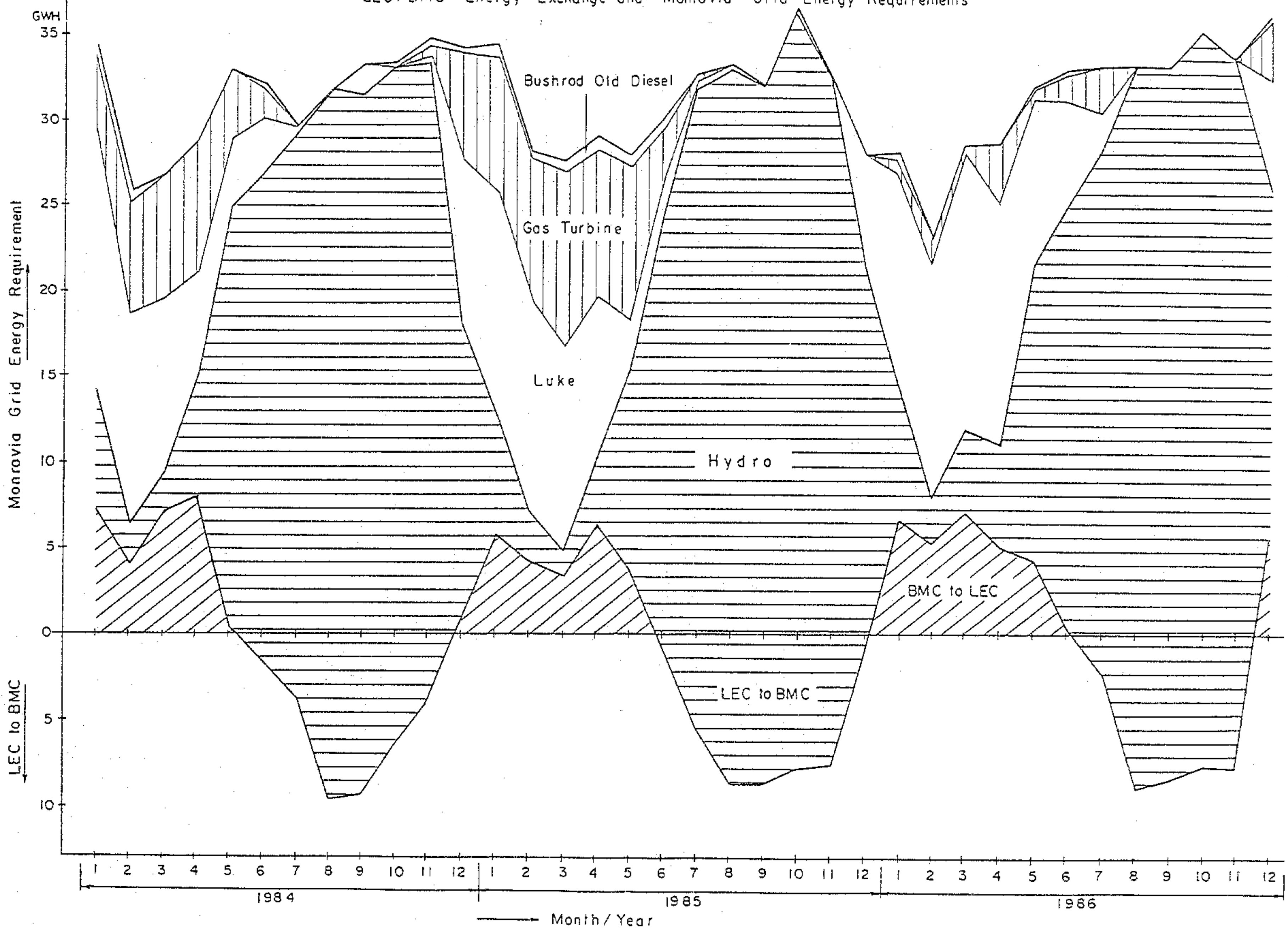


Fig. 2-5 SYSTEM LOAD CURVE
(RAINY SEASON)

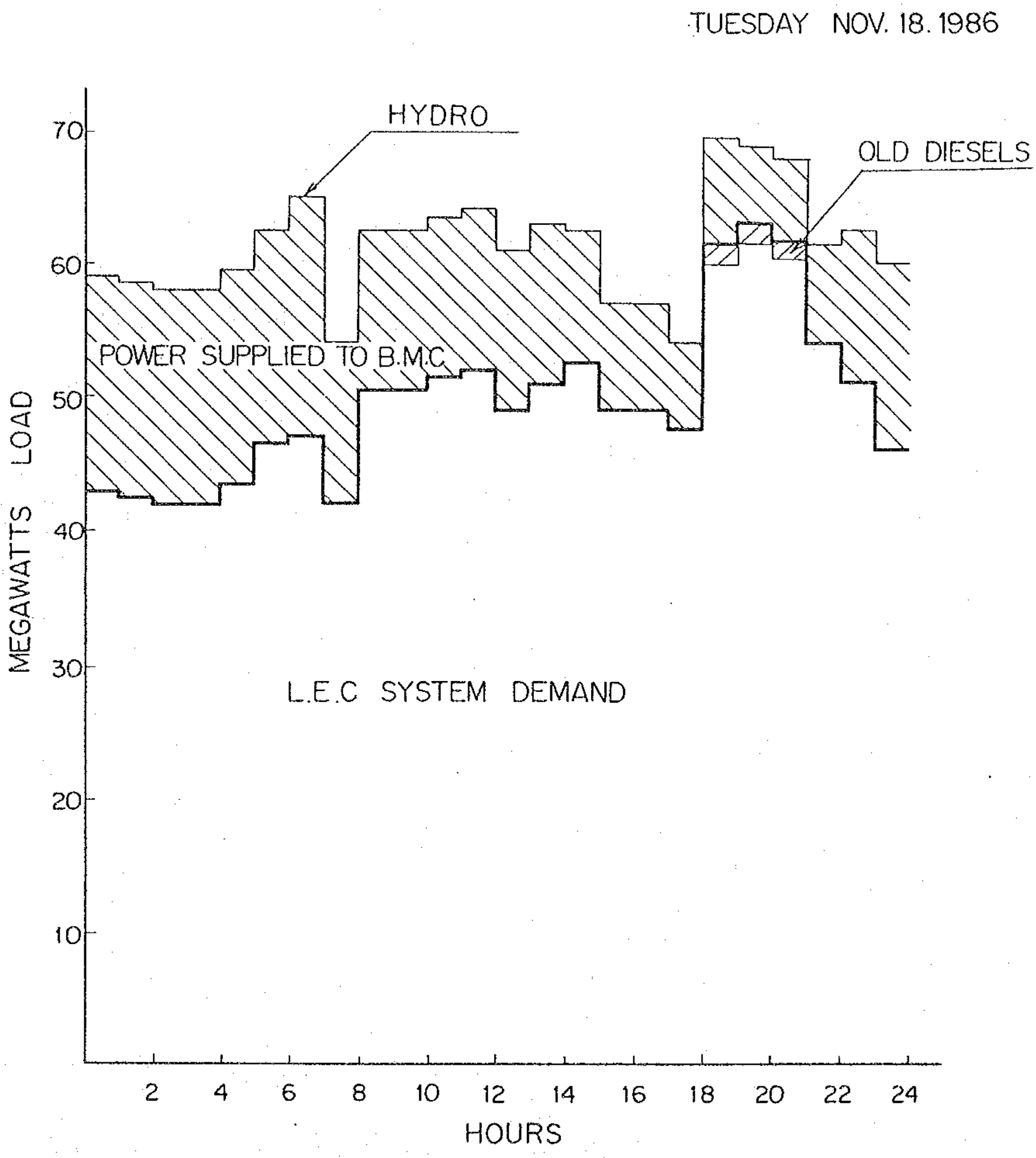
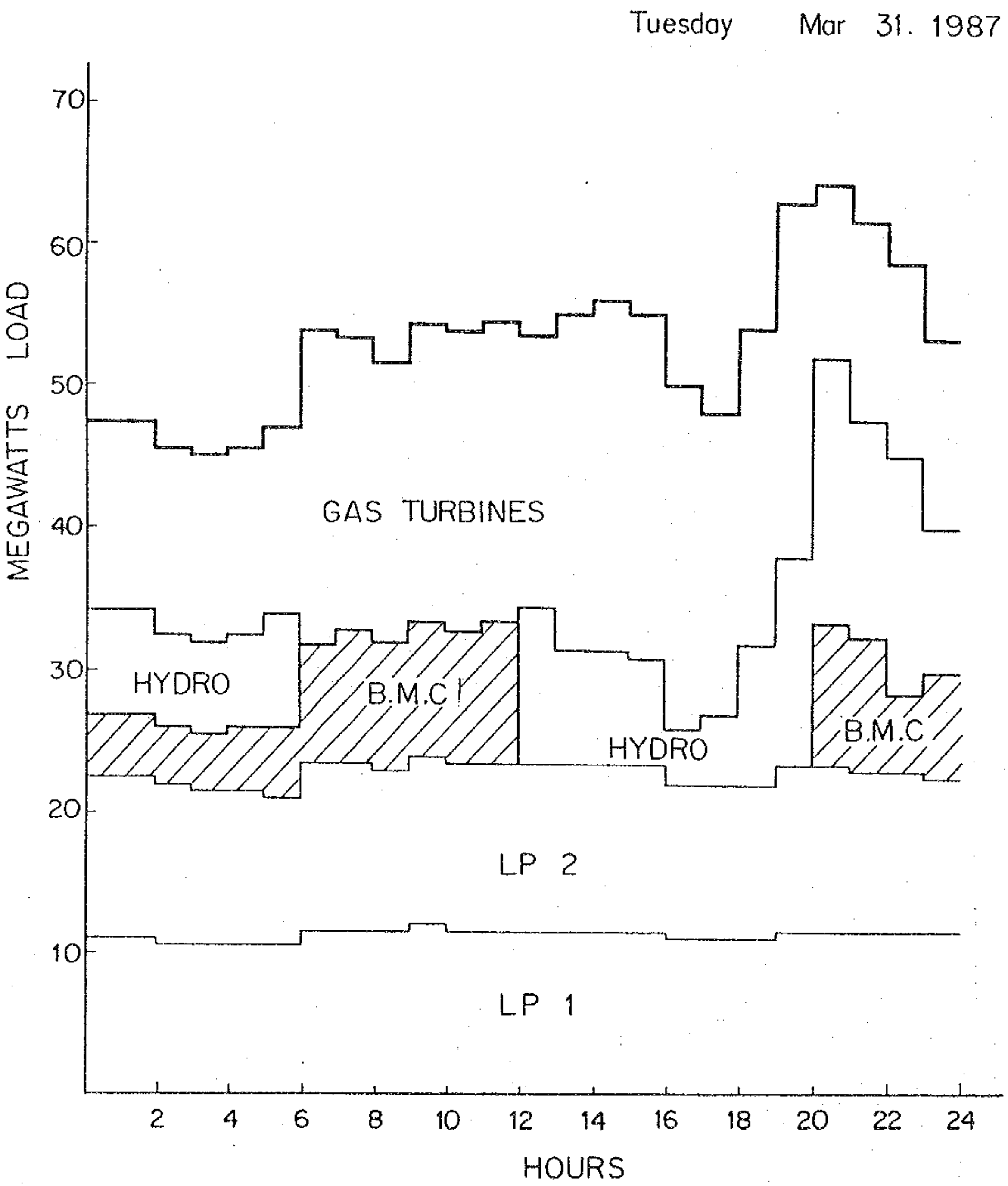


Fig. 2-6 SYSTEM LOAD CURVE
(DRY SEASON)



Priority 4: Embassies and high paying customers

Priority 5: General Users

Fig. 2-7 is a typical example of the power rationing implemented in 1986, compared with 1987 when no load sheddings were instituted.

The load sheddings implemented during the above-mentioned periods in the Monrovia Power System are classified by the substations and shown in attached Table 2-23 and Fig. 2-8.

As can be seen from those figures and table, the overall system resulted is as follows:

Number of load sheddings implemented	: approx.	6,100
Accumulated hours of load sheedings	: approx.	16,500 hours
Accumulated shedded energy	: approx.	19.4 GWh

Some feeders interrupted the service for 24 hours continuously, which reflects the seriousness of the problem.

In addition, in 1987 there has been a smaller number of load sheddings than the previous year.

(c) Composition of power demand

As shown in Table 2-24, the consumers of LEC in 1985 were general households (29.1%), Commercial users (32.9%), industrial users (24.1%) and government and other public users (13.9%). Although, residential accounted for almost 30% of major users, the growth of the general households was suppressed due to the load sheddings. BMC was a big customer of the industrial use, and the demand from the other manufacturers (e.g., timber processing, soap, rubber processing, textile, bottling industries and so on) was extremely small. Public use involved demand from the Executive Mansion and governmental offices, public organizations, etc., which have

Fig. 2-7 A Daily Load Curve During The Dry Season February 25

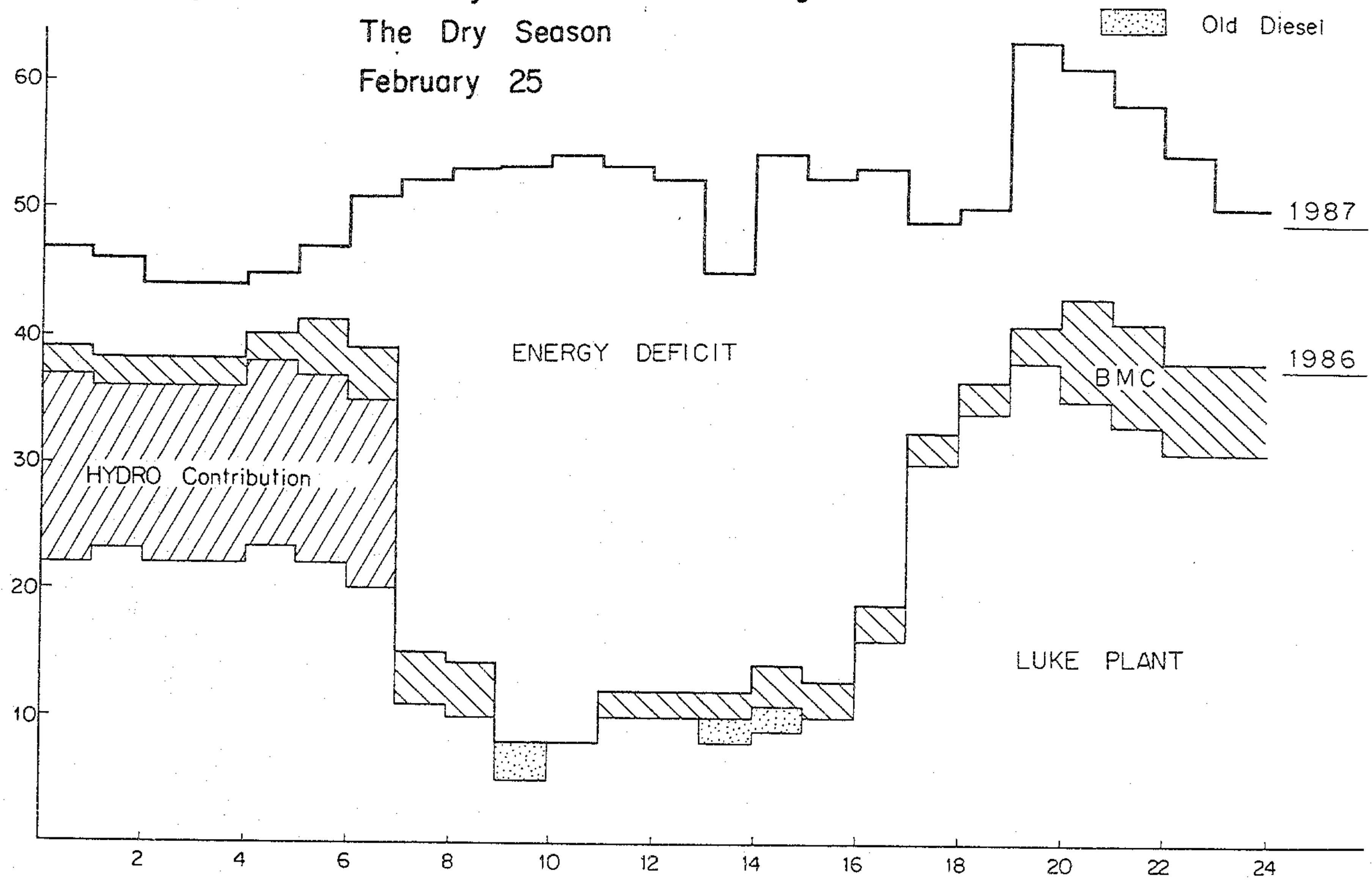


Table 2-24 Composition of Power Demand in Liberia (1977 - 1985)

Year	Residential Use		Commercial Use		Industrial Use						Government and Public Use		Total	
					BMC		Others		Total					
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
1977	75.5	27.1	76.4	27.4	60.4	21.7	43.3	15.5	103.7	37.2	23.1	8.3	278.8	(100)
1978	85.4	30.3	85.7	30.4	41.5	14.7	45.8	16.2	87.3	30.9	23.6	8.4	282.0	(100)
1979	90.8	31.8	94.4	33.1	32.1	11.3	44.3	15.5	76.4	26.8	23.9	8.3	285.3	(100)
1980	88.0	30.8	89.3	31.2	31.4	11.0	45.0	15.7	76.4	26.7	32.1	11.2	285.8	(100)
1981	88.0	32.1	89.8	32.7	20.5	7.5	42.2	15.4	62.7	22.9	33.8	12.3	274.3	(100)
1982	86.1	31.2	89.8	32.7	27.9	10.2	36.2	13.2	64.1	23.4	34.8	12.7	274.8	(100)
1983	89.7	33.0	86.0	31.6	32.3	11.9	30.1	11.1	62.4	23.0	33.9	12.5	272.0	(100)
1984	87.4	32.7	82.0	30.8	33.2	12.4	27.5	10.3	60.7	22.7	36.8	13.8	267.1	(100)
1985	73.3	29.1	83.0	32.9	38.5	15.3	22.6	8.8	61.1	24.1	35.2	13.9	252.0	(100)

Source: Five-Year Development Plan (1987-1991), LEC been growing constantly due to increased demand such as for air conditioners in offices.

It is considered that the growth in the future demand depends upon 1) the economic revival to be achieved by the improvement of international prices of Liberian primary commodities. 2) growth in other manufacturing sectors in place of the BMC, 3) a spread of electrical appliances for general households and 4) the state of implementation of development project after the government budgetary situations are reconstructed.

(2) Load forecast

The estimates of future demand for electric power in Liberia have so far been carried out by consultants, the AFDB, the World Bank, etc. As to the estimates made since 1980, the consulting company, C.T. Main of the United States estimated a growth rate of 5 - 7% annually; Sofrelec of France, 3.3 to 5.0%; and the AFDB, 5%. However, as shown, the growth of the demand for electric power of the LEC has declined lately. Therefore, the above-mentioned estimates can be defined as being a little too optimistic. It is nevertheless true that the growth in actual power consumption is being constrained because of the severe load sheddings which have been implemented.

	1978	1979	1980	1981	1982	1983	1984	1985
Growth rate of power generation (%)	1.4	6.9	-0.9	-5.3	1.2	-1.2	1.8	-0.2
Growth rate of power consumption (%)	1.1	1.2	0.2	-4.0	0.2	-1.0	-1.8	-5.7

The World Bank calculated the following estimated values based on the recent supply-demand situation:

	1984 - 1993	1994 - 2003
Estimated growth rate of power generation (%)	1.2	1.4
Estimated growth rate of power consumption (%)	3.0	2.8

On the other hand, since the growth in electric power consumption actually keeps declining and the load sheddings are carried out every year, the LEC has focused on maximum peak load to forecast the demand using the growth rates of the maximum load. It thus calculated demand to grow annually by 2.15%.

As a result, the future growth of the demand and energy requirements are estimated as shown in Table 2-25.

Table 2-25 Demand Estimates by LEC

	Peak Demand (MW)	Energy Requirements (GWh)
1986/87	66.6	432
1987/88	68.1	441
1988/89	69.6	451
1989/90	71.2	462
1990/91	72.9	473
1991/92	74.6	484
1992/93	76.3	495
1993/94	78.0	506
1994/95	79.8	517
1995/96	81.6	529
1996/97	83.5	541

Note: Average annual load factor are presumed to be 0.74%

2.4.5 Five-Year Development Plan

The LEC introduced the "Five-Year Development Plan: 1987 - 1991" in March 1987 as a medium-range electric power development plan for Liberia. This is an innovative plan to find positive solutions to the various problems faced by the LEC. The government has expressed its strong support of the plan.

The main objectives of this master plan are: (1) to implement measures to cope with demand by strengthening power generation capacities, (2) to increase revenues by reducing technical and non-technical losses,

(3) to improve the skills and ability of LEC technical staff and (4) to perform research and study activities for future long-term development plans.

The following are listed as a major projects to be undertaken by 1991.

(a) Thermal Plant Expansion (30 MW)
(b) Mt. Coffee Rehabilitation and Up-grading (2 x 5 MW)
(c) Luke Plant Rehabilitation
(d) Transmission and distribution improvement expansion
(e) Commercial Loss Reduction
(f) Mini Load Dispatch System

Investment programme

To implement the Five-Year Development Plan mentioned above, investment plan amounting to approximately 60 million dollars is prepared. The investment schedule for each programme is as shown in Table 2-26.

Table 2-26 Investment Projects for the LEC Five-Year Development Plan

(Unit: US$1,000)

	1987/88	1988/89	1989/90	1990/91	1991/92	Total
a. Diesel Plants (30 MW)		10,000	10,000	10,000		30,000
b. Mt. Coffee Rehab./ Uprating			3,600	3,600	3,600	10,800
c. Luke Plant Rehabilitation		1,617				1,617
d. Medium-Term Trans. & Improvement		1,600	1,500	200		3,300
e. Commercial Loss Reduction	2,300	400	976			3,676
f. Mini Load Dispatch System				950	680	1,630
g. Training Center		820	895	765	250	2,730
h. LEC Building Complex		1,625	2,222			3,847
i. Project Studies		1,500	1,000	750		3,250
Total	2,300	17,562	20,193	16,265	4,530	60,850

2.4.6 Bushrod Power Plant

Electric power to Monrovia is supplied from the Mt. Coffee Hydro-Power Plant during the rainy season and from the Bushrod Power Plant, a thermal-power generation facility, during the dry season. The Bushrod Power Plant is located at Bushrod Island adjoining the north side of the City of Monrovia, which is a large consuming region. It consists of the following power generation facilities and a substation.

- Bushrod Diesel Plant
- Gas Turbine Plant
- Luke Diesel Plant
- Step-up substation (69 kV)

The general layout and the main circuit single line diagram are shown in Figs. 2-9 and 2-10, and outlines of generators are shown in attached Table 2-27.

(1) Bushrod diesel plant

There are installation locations for six units; however, Unit 1 has been removed already. Units 2, 3 and 4 are now not in operation. Instead, they are used as sources of repair parts for Units 5 and 6 now in operation. Deterioration is intense in Units 5 and 6, so they are operated at a reduced output of 1.5 MW, as opposed to a rated output is 2.5 MW. They are scheduled to be retired in 1988.

Outline of the generator house is shown in attached Fig. 2-11.

(2) Gas turbine plant

Four gas turbine generators are installed. However, one of them has damaged turbine blade(s) and thus there is little prospect of resuming operation. Furthermore, another unit is now being prepared for repair because of a defective starting motor. In other words, there are only two operational units.

The operation and maintenance cost including fuel cost of gas turbine plant is expensive compared with diesel power generation (in the case of Bushrod, 2.36 times by LEC, survey team estimates 3.14 times as

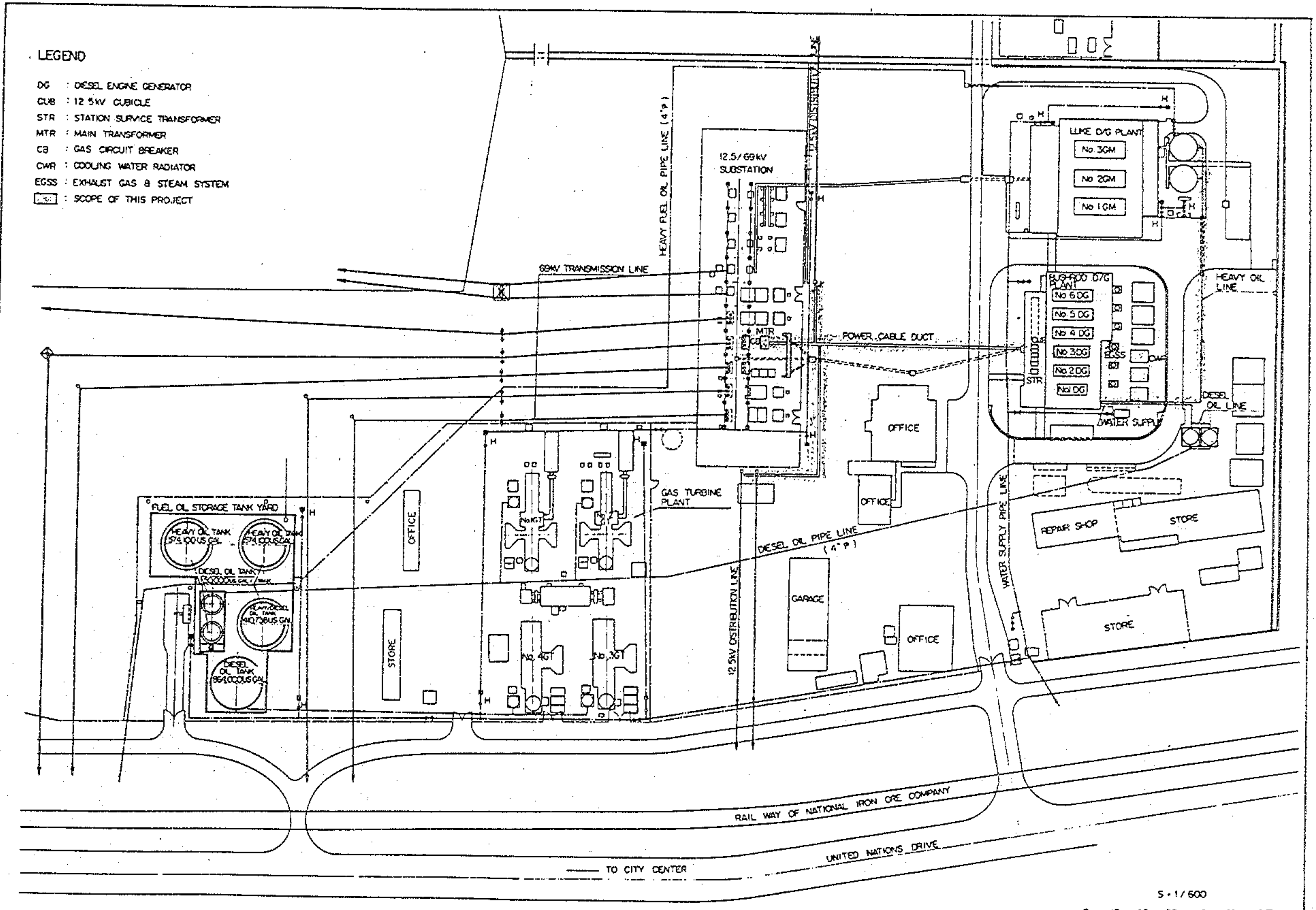


Fig. 2-9 GENERAL PLAN OF BUSHROD POWER STATION

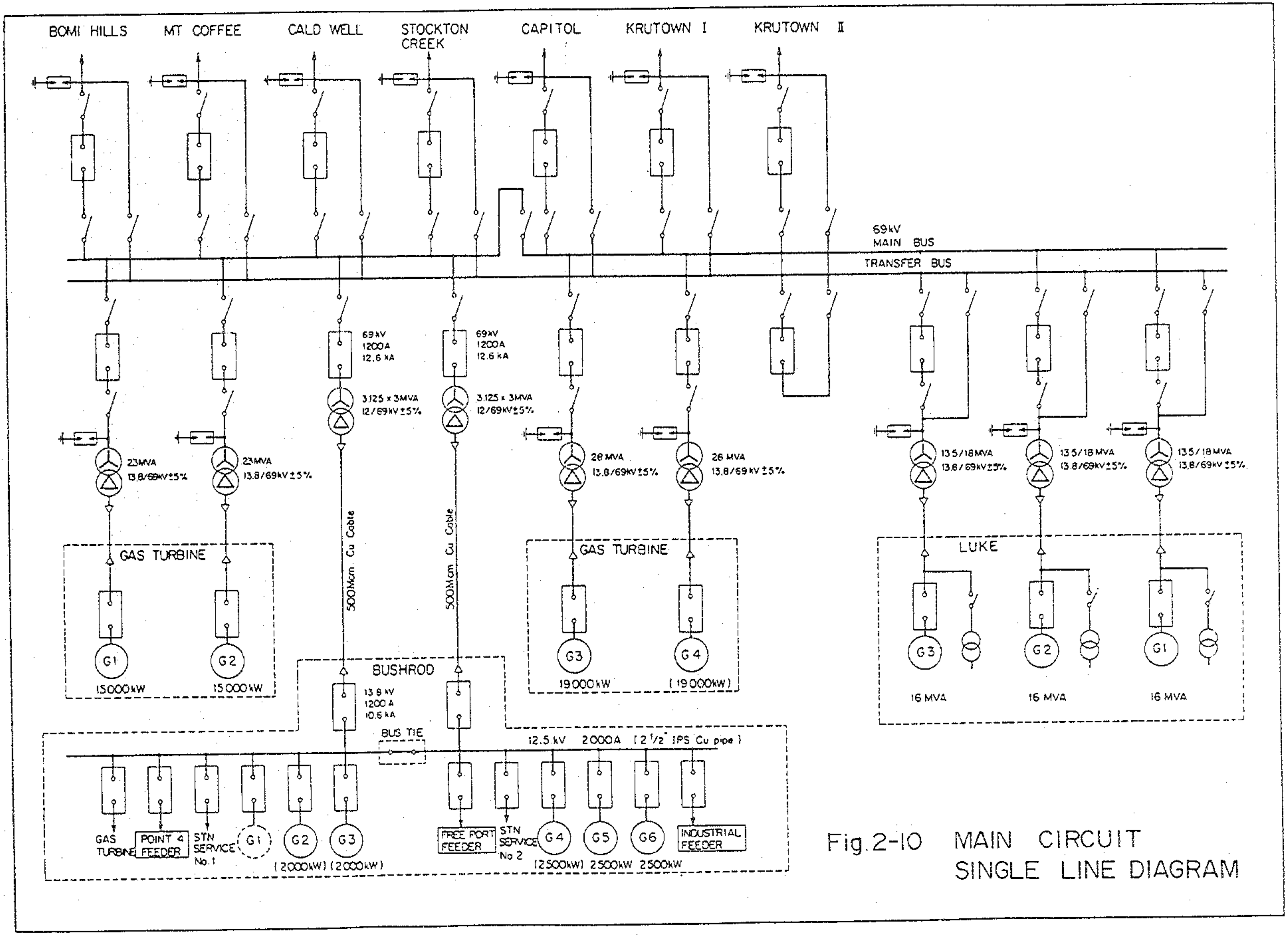


Fig.2-10 MAIN CIRCUIT SINGLE LINE DIAGRAM

much per kWh); therefore, it is an urgent task for the LEC to reduce the number of gas turbine operations.

(3) Luke diesel plant

These three (3) units, which are the main power source during the dry season have many troubles and then show the poor reliability. Although only several years have passed since the operation was commenced, the output has been reduced to 12 MW whereas the rated output is 13.6 MW. The LEC is planning the large-scale rehabilitation of the plant.

(4) Step-up substation

(a) Capacities of step-up transformers

For Bushrod plant:	
3.125 MVA x 3 phases x 2 banks	= 18.75 MVA
For gas-turbine plant:	
23 MVA x 2 banks	= 46 MVA
28 MVA x 2 banks	= 56 MVA
For Luke plant:	
18 MVA x 3 banks	= 54 MVA
Total	174.75 MVA

(b) Transmission lines installed

69-kV Transmission lines: 7 circuits
12.5 kV Transmission lines: 3 circuits

2.4.7 Request for the Project

The Government of Liberia faces a severe shortage of electric power during the dry season as mentioned in (1), 2.4.4. The government has planned the long-range plan and the medium-range Five-Year Development Plan to solve this problem. It is now making efforts to promote this plan.

The Government of Liberia therefore requested the Government of Japan for Grant Aid for urgently needed 10 MW facilities, of the 30 MW diesel power generation facilities being planned in the Five-Year Development Plan for improvement of electricity power supply.

2.5 MANAGEMENT OF LEC

2.5.1 Organization of LEC Personnel

The LEC has a staff of 1,327 as of the end of March 1987. The details are as follows:

Professionals & managers	60
Supervisory	154
Skilled	990
Unskilled	123
Total	1,327 people

As shown in the above, professionals account for a little less than 5%, so the shortage of qualified and experienced staff has been a major problem for the LEC management. Accordingly, with a view to training non-professional staff, the LEC Training Institute was established in 1987 with the initial aim of strengthening the training facilities to develop skilled Liberian staff.

2.5.2 Customers and Benefited Population

The LEC power-transmission/distribution network is limited within a 90 km radius around the capital Monrovia, i.e., the coastal main cities in the southwestern region, and excluding the isolated power system in rural areas. There were only about 39,300 customers as of March 1987, though this number includes large consumers such as government offices, manufacturers and commercial stores. Generally, in Liberia the size of a family is said to be 5 or 6 people on average in rural areas and 4 or 5 people in urban areas. Therefore the population benefiting from the electrification is estimated to be approximately 197,000 people, or 8.7% of the total population. Even when 40,000 people, the population benefiting from the isolated power system in agricultural areas, are added, only 10% or so of the total population is served electricity supply.

In addition, with regard to the number of customers' account, growth rates of more than 10% have been recorded every year since 1982. The trend in recent years is shown as follows.

	1981	1982	1983	1984	1985	1986	1987
Number of customers' accounts	20,200	23,800	27,200	34,900	35,300	37,800	39,300
Growth rate (%)	-	17.8	14.3	28.3	1.1	7.1	4.0

2.5.3 LEC Financial Situation

(1) Power tariffs

The LEC's power tariffs, thus far, were revised as the cost of fuel increased. The current power rates are set by a uniform tariff, no matter whether it is for public use or for industry. The fuel adjustment charge is added to the uniform tariff.

Uniform tariff:	11.5 cents/kWh
Fuel adjustment charge:	5 cents/kWh

The changes of power rates are shown as follows:

Customer classification		Revised in 1979	Revised in 1982	Revised in 1984	Revised in 1985
Households	0 - 400 kWh				
	401 - 1,500 kWh	10.1c	10.1c	11.6c	
	1,500 kWh or more	9.4c			11.5
Industry/ commerce	0 - 2,000 kWh	10.0c	10.0c	11.5c	
	2,000 kWh or more	8.1c			

On the other hand, when average power unit cost is calculated with revenues from power rates and amounts of power sales, the results are shown as follows:

	1984/85	1985/86
Electric power revenue (dollars)	36,290,000	35,289,000
Amount of electric power sales (kWh)	224,500,000	212,700,000
Average unit cost of electric power (cents/kWh)	16.16	16.6

Note: Since 1984, the fiscal year of the LEC has been July to June; therefore, there are statistical differences between the years before and after 1984. In addition, the amount of electric power supplied does not include the amount supplied by the BMC.

Therefore, as far as the average unit cost of power is concerned, it is getting difficult to cover the cost adequately at the tariff rate, 16.5 cents/kWh.

It should be noted in addition, that the indirect expenditures such as non-technical losses of power transmission and distribution, uncollected electricity bills and interest payment are not included in these calculations.

(2) Financial revenue

LEC's revenue comes mostly from electricity supply. As stated before, LEC customers are classified into general households, commercial stores, industries and government agencies. The government agencies are further classified into government offices and public organizations. The public organizations include the water and sewerage corporation, a broadcasting station, national hospital, etc. When this classification is used to examine how electricity bills are collected, general households account for more than 40% of the amount billed, followed by business, government, public corporations and industry. Particularly, the government offices and public corporations have almost 30% in all, unexpectedly high proportion.

LEC Colection Performance by Consumer Category (1985/86)

	Billings (10^3 dollars)	Billing Rate (%)	Collections (10^3 dollars)	Collection Rate (%)
Residential	15,216	43.1	9,991	65.7
Commercial	7,902	22.4	7,718	97.7
Industrial	2,418	6.9	2,866	118.3
Public corporations	4,020	11.4	1,108	27.6
Government	5,733	16.2	1,422	24.8
Total	35,289	100.0	23,105	65.5

However, with regard to collecting bills, energy sales do not equal revenue; only 65% or so of the amount billed is collected.

Especially, the collection rates of the government offices and public corporations are less than 30%. This reflects the financial difficulties facing the government. Moreover, collection periods are frequently delayed, and a several-month delay in payment is common.

	1982/83	1983/84	1984/85	1985/86
Energy Sales (1,000 dollars)	34,991	34,195	36,290	35,289
Collection (1,000 dollars)	26,665	23,629	21,360	23,105
Collection rate (%)	76.2	69.1	58.9	65.5

Uncollected electricity revenue is a serious problem facing the LEC. This is a major problem to be overcome if the sound liquidity of the LEC is to be ensured. There have been no fundamental solutions except an offset arrangement with the government and public corporations.

(3) Financial expenditure

LEC's main expenditures are on fuel, operation and maintenance, wages and debt repayments. The cost of fuel is for the purchase of heavy oil and diesel oil and accounts for about 20% of total outlays every year. Since the power generation system of the LEC consists chiefly of petroleum thermal-power generation, especially during the dry season, the burden of the fuel costs is not small to the LEC by any means. The load shedding have been implemented recently partly because the fuel cannot be provided sufficiently due to the financial difficulties in purchasing fuel.

The operation and maintenance expenses account for more than 30% of the total expenditure and continue to increase because the existing facilities are becoming old. With regard to the personnel expenses, the LEC once made efforts to cut personnel in compliance with a request from the World Bank. However, the number of full-time personnel increased, thereafter, and thus expenses have increased. Debts repayment is mainly payment of interest to foreign governments and international agencies. Thus far, the construction of the main electric power facilities have been financed by loans from abroad. For this reason, repayments are a substantial burden to LEC finances, amounting to more than 10% every year.

LEC Expenditure (1984/85)

	(Unit: $1,000)
Fuel cost	5,193 (13%)
Operation and maitnenance expenses	12,962 (31%)
Wages	6,454 (16%)
Depreciation	6,859 (17%)
Provision of Bad Debts	3,472 (9%)
Interest on Loans	5,200 (13%)
Others	450 (1%)
Total	40,581(100%)

As a result, it comes to a deficit of approximately 5 million U.S. dollars on LEC income and expense statement in 1984.

Financial Revenue	35,590	(Unit: $1,000)
Financial Expenditure	40,581	
Balance (Deficit)	4,991	

Note: Revenue included other than the electric power revenue.

2.5.4 Foreign Experts

The LEC has a short history of receiving foreign experts. It was a recommendation in the Fourth Loan from the World Bank that made the LEC accept foreign experts. With a view to improving the LEC's management, operation and maintenance, a Tata consultant from India was assigned as a management support team under a logn of the World Bank. It took one year for the Tata consultant to make a general assessment of the LEC management and submit recommendations. To implement in accordance with the recommendations, Indian experts are stationed for a long-term at the LEC. Then, various problems arose after the construction of the Luke Plant, so experts were recruited from B & W and Asea, Scandinavian companies, suppliers of the machinery. Recently, three Egyptian engineers were stationed as part of technical cooperation. Also, in the LEC Training Institute completed this year, an Indian instructor has been hired under a short-term contract.

These foreign experts are in charge of the technical areas of operation in each LEC section. The LEC is trying to strengthen the on-the-job training and is aiming at direct operation by local technical staff.

The details of foreign experts currently working for LEC are shown in attached Table 2-28.

2.5.5 Operation and Maintenance Organization

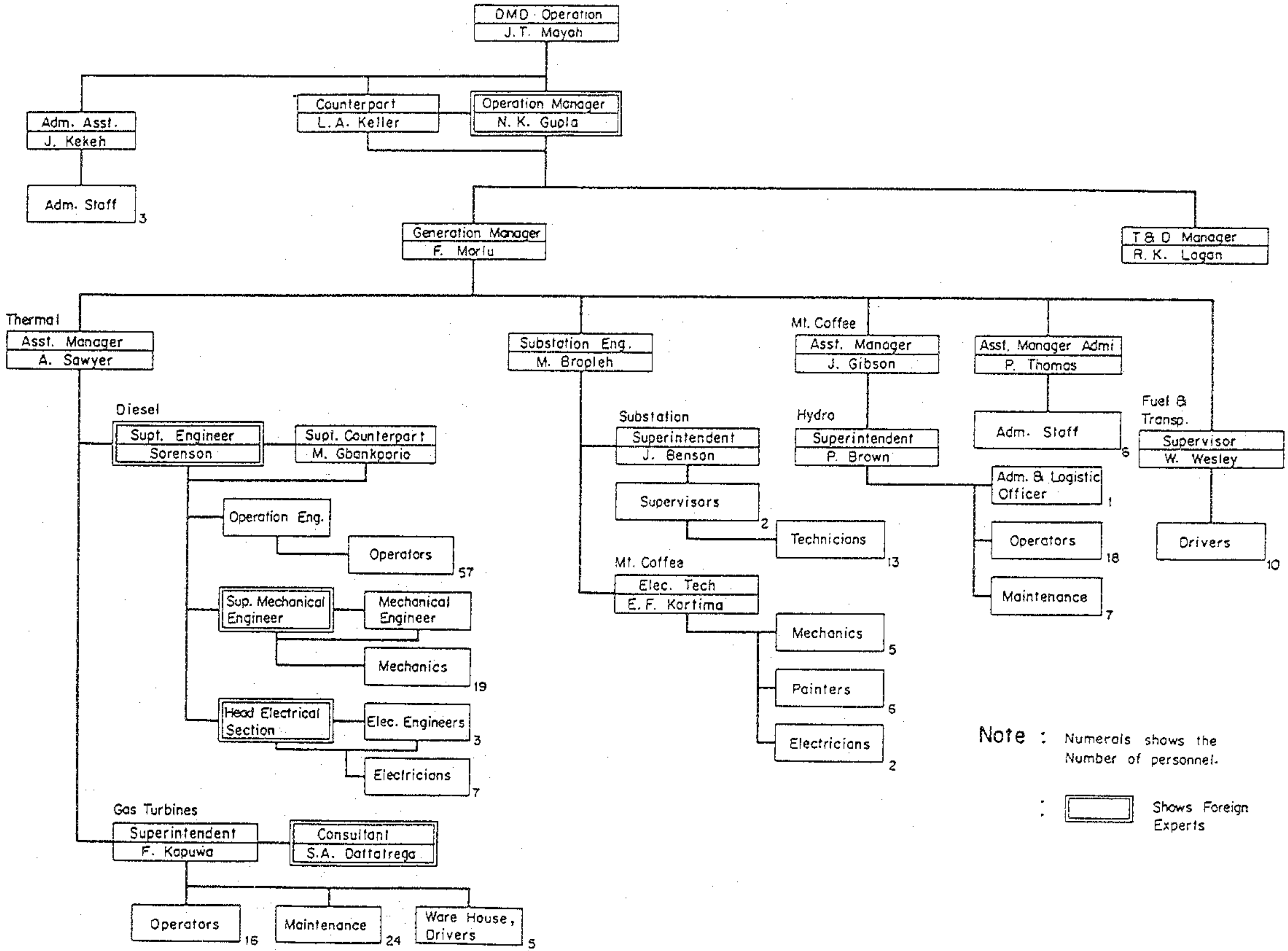
LEC's labour force ranking system is devided into four ranks, which are further classified according to experience and qualification, as follows.

1. Professional (60 people)
   - Managing Director
   - Deputy Managing Director
   - Manager
   - Assistant Manager
2. Supervisory (154 people)
   - Supervisory A3
   - " A2
   - " A1
   - " B2
   - " B1
   - " C2
   - " C1
3. Skilled (990 people)
   - Highly Skilled 2
   - " 1
   - Skilled A
   - " B
   - Semi-Skilled
4. Unskilled (123 people)

The organization of the LEC Operation Department is shown in the Fig. 2-12.

The LEC operation of the power generation facilities is normally organized with, of the above-mentioned personnel, chief operators from supervisors in the Highly Skilled 2 and, under their command, several skilled workers in the skilled B. Accordingly, the standard operation organization system in each plant is shown as follows:

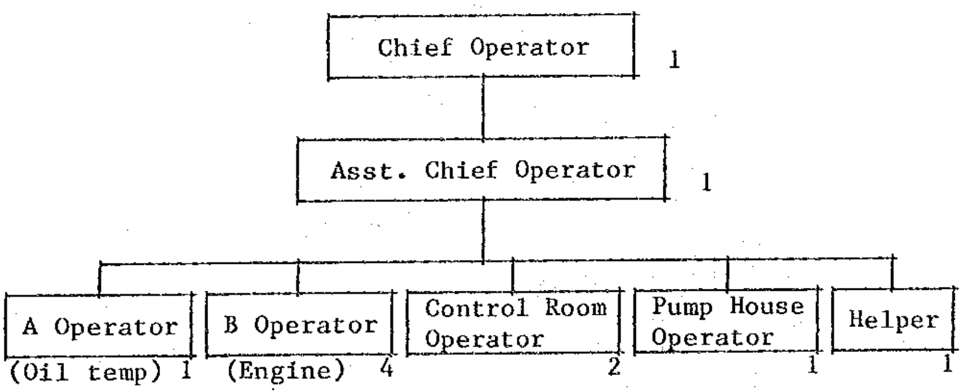
Fig. 2-12 ORGANIZATION OF OPERATIONS (Generation Department)



Bushrod Plant	--	4 people/team;	Shift system;	12 people
Luke Plant	--	11 people/team;	Shift system;	33 people
Gas Turbine Plant	--	4 people/team;	Shift system;	12 people
Mt. Coffee Plant	--	4 people/team;	Shift system;	12 people

The organization of operators at the Luke Plant is shown in Fig. 2-13.

Fig. 2-13 Organization of Operators at Luke Plant (per team)



Note: Figures stand for the number of staffs

On the other hand, within the maintenance oranization the personnel system differs according to job such as maintenance and inspection, minor repair, major repair, etc. Nevertheless, the maintenance team is usually organized with a leader from the Highly Skilled 2 and three or four skilled workers from the skilled B. In the case of the recently implemented major-repair works of the Luke Plant, the team consists of 9 to 11 people: a foreman (Supervisor A2), one assistant foreman (Supervisor B2), two highly skilled workers (Highly Skilled 2), three or four highly skilled workers (Highly Skilled 1) and two or three skilled workers (Skilled B).

However, in any operation and maintenance works, the foreign experts' instructions and assistance are being received; thus it is an urgent proposal to establish a consistent operation and maintenance system run by Liberian staff.

2.5.6 Problems and Issues on LEC Management

(1) Collection of electricity bills

One of the largest problems facing LEC management is the efficient collection of electricity bills. The revenue loss as a result of non-technical (commercial) losses of the total power generated has reached more than 30% in the past 10 years. But still this has not been improved. Moreover, because the collection rate of electricity bills remains at 77%, the LEC recovers merely 50% or less as electric power sales when the above-mentioned losses and the low collection rate are combined. In the medium-term plan the LEC plans to improve these figures to 20% and 87%, respectively; however, heavy deficits now require urgent measures. The measures being considered are:

(a) Thorough patrolling and investigation of contractors' meters and their use, and disconnection of illegal users (Block-Mapping Project)

(b) Thorough implementation of service and installation of watthour meters

(c) Prosecutions of illegal consumers (e.g., fines, additional impositions, power disconnection and so on)

These should be strengthened and be fully implemented.

(2) Effective and efficient management

Through this study, it was found that various data on technical and financial statistics are imcomplete. When the data are examined, it seems that there is lack of coordination and adjustment between sections. It represents big hurdles in the planning of the management policy and strategies. The LEC has been examining the introduction of a integrated computer system to perform collection, assessment and retrieval of data efficiently. Indeed, immediate practice of the above-mentioned point is important. With regard to the collection of bills, the problems of incorrect bills have been pointed out by the users, so making the office work effective and efficient can restore public confidence in the LEC. In this connection, it's worth mentioning that the LEC does not delay wages compared to the other public corporations in Liberia whereas, for instance, most other agencies deliver delay wages by 3 or 4 months. The LEC is reputed to be excellent in its management and recently has won official commendation from a group of German societies.

(3) Training and manpower planning

Of the LEC personnel, professionals account for less than 5% of the total. Aiming to improve this situation, the LEC has been actively carrying out personnel-training programme.

In Liberia:

(a) Sending students to educational institutions (e.g., University of Liberia)

(b) Training students at Monrovia Vocational School

(c) Establishing the LEC Training Institute (training institute)

Abroad:

(a) Sending students to overseas universities
(b) Dispatching students to research institutions

The LEC appropriated 350,000 dollars in the 1985 budget and has sent 192 people domestically and abroad over the past 6 years.

	1981	1982	1983	1984	1985	1986	Total
Domestic training	16	14	33	18	11	11	103
Overseas training	27	22	14	7	9	10	89
Total	43	36	47	25	20	21	192

Electrical engineering was once the main field of these studies and training; however, these diversified into mechanics, civil engineering, computer science, finance, business administration, accounting, etc.

In the future, besides the above-mentioned education and training, the on-the-job trainings with which the staff can benefit from practical knowledge and experience are expected to be increased and strengthened.

(4) Shift to hydroelectric power generation

The LEC is trying to cope with the immediate demand for electric power by using diesel generation. However, in the long term, the transition has to be made to hydroelectric power generation with its low operation and maintenance costs. The hydroelectric power projects proposed thus far are the Mano River Hydroelectric Power Generation Project (180 MW, 360 million dollars, 1981) and the St. Paul River Hydroelectric Power Generation Project (546 MW, 1,461 million dollars, 1982). Nevertheless, due to the government's financial problems, it is presently considered to be difficult to build such large-scale power-generation plants.

Accordingly, the project now being examined is the Via River Storage Dam Project, which involves building a storage reservoir in the upper stream of the Via River as an expansion of the existing Mt. Coffee Dam so that year-round generation will be possible. This project will result in reservoir capacity of 1,400 MCM and generating capacity of 20 MW. As a result, power generation of 155 GWh will be able to be supplied all year around.

In addition, with regard to the isolated power system in rural areas, a small hydroelectric power generation project to produce 500 kW -- 5,000 kW is planned to effectively utilize small to medium-sized rivers without depending on the conventional diesel generation.

Thus, for future power supplies, the long-term development plan has been designed for the conversion of the main power source from a petroleum thermal-power system to a hydroelectric power generation system. It is strongly suggested that the project can be implemented as soon as funds are available.

CHAPTER 3 CONTENTS OF THE PROJECT

CHAPTER 3 CONTENTS OF THE PROJECT

3.1 OBJECTIVE OF THE PROJECT

The objective of the Project is to provide the necessary equipment for the Monrovia Power System to urgently increase its power generating capacity in order to moderate the intensive power load sheddings currently in practice.

More specifically, the Project is intended to rehabilitate the existing generating equipment of the Bushrod Power Plant in order to increase its generating capacity, and thereby to contribute to the improvement in the economic and industrial functions of Monrovia, the stability of the life of the citizens, and the revitalization of industry.

3.2 EXAMINATION OF THE REQUEST

The request of the Government of the Republic of Liberia has been examined and confirmed for appropriateness, and a suitable scale is decided for the Project. Also, basic policies covering the scope of the supply in grant form of diesel engine power generating facilities and auxiliary equipment has been decided.

(1) Scale of the generating facilities

As described in 2.4.7, "Request for the Project", the grant for 10-MW diesel engine power generating facilities is requested by the Government of the Republic of Liberia as an immediate measure to relieve the intensive load shedding in the dry season. The propriety of the scale of the request is discussed as follows.

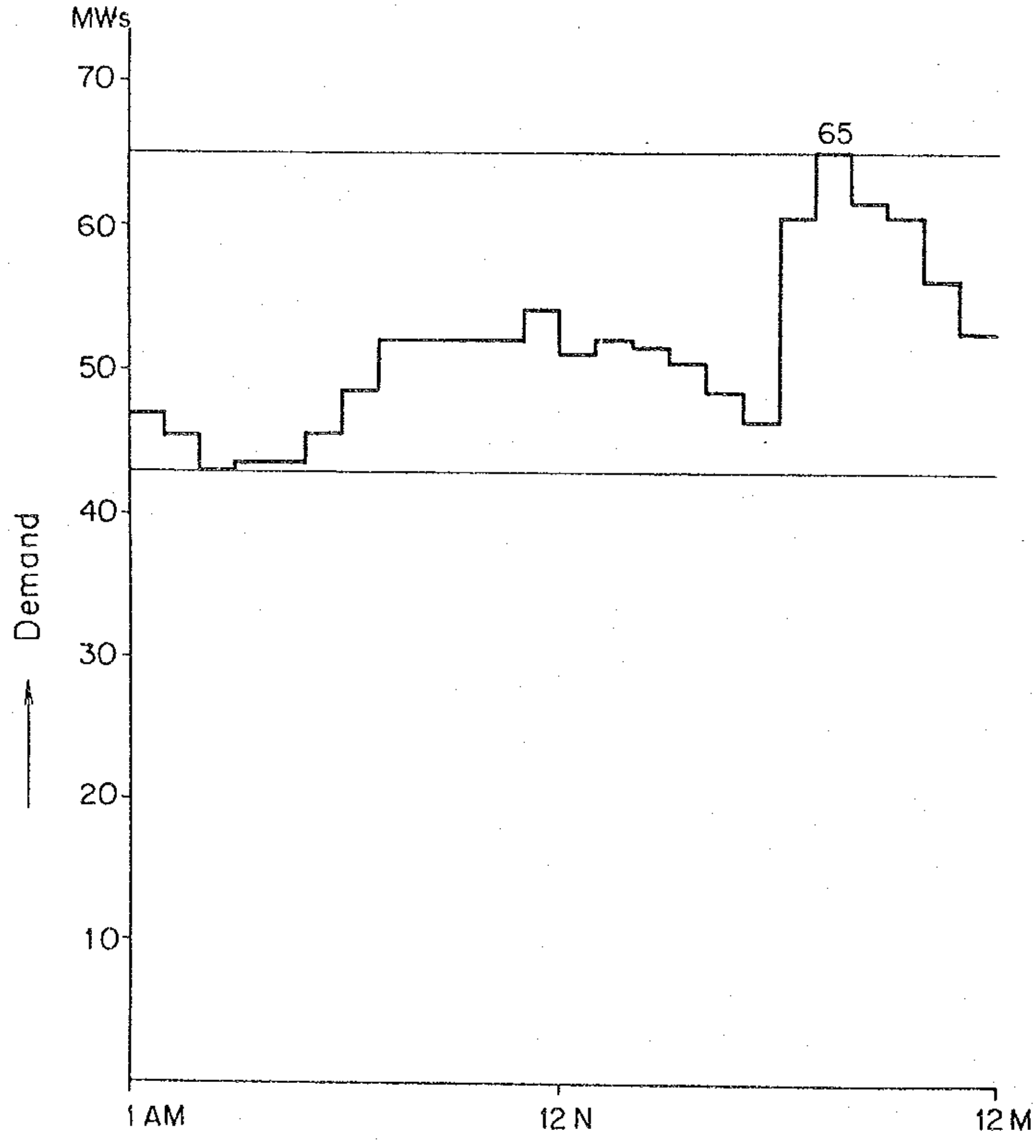
Fig. 3-1 shows the actual daily load curve, and Fig. 3-2 daily load duration curve, of the Monrovia power system in 1985. Based on these curves, a daily load duration curve in 1989/90 is estimated in Fig. 3-3.

In the dry season in 1989/90, the reliable total power supply available will be 55 MW, comprising a total of 24 MW by 2 generators

Fig. 3-1 TYPICAL DAILY LOAD CURVE

As of 1985

LIBERIA ELECTRICITY CORPORATION
CORPORATE PLANNING DEPARTMENT
SYSTEM STUDY SECTION.



IN THE "MONROVIA GRID", THE DAILY "PEAK LOAD" ORDINARILY OCCURS IN THE EARLY EVENING (20 HR). THE ANNUAL PEAK LOAD FOR THE YEAR 1985 OCCURED ON JANUARY 10 (DRY SEASON PERIOD)

Fig. 3-2 DAILY LOAD DURATION CURVE

As of 1985

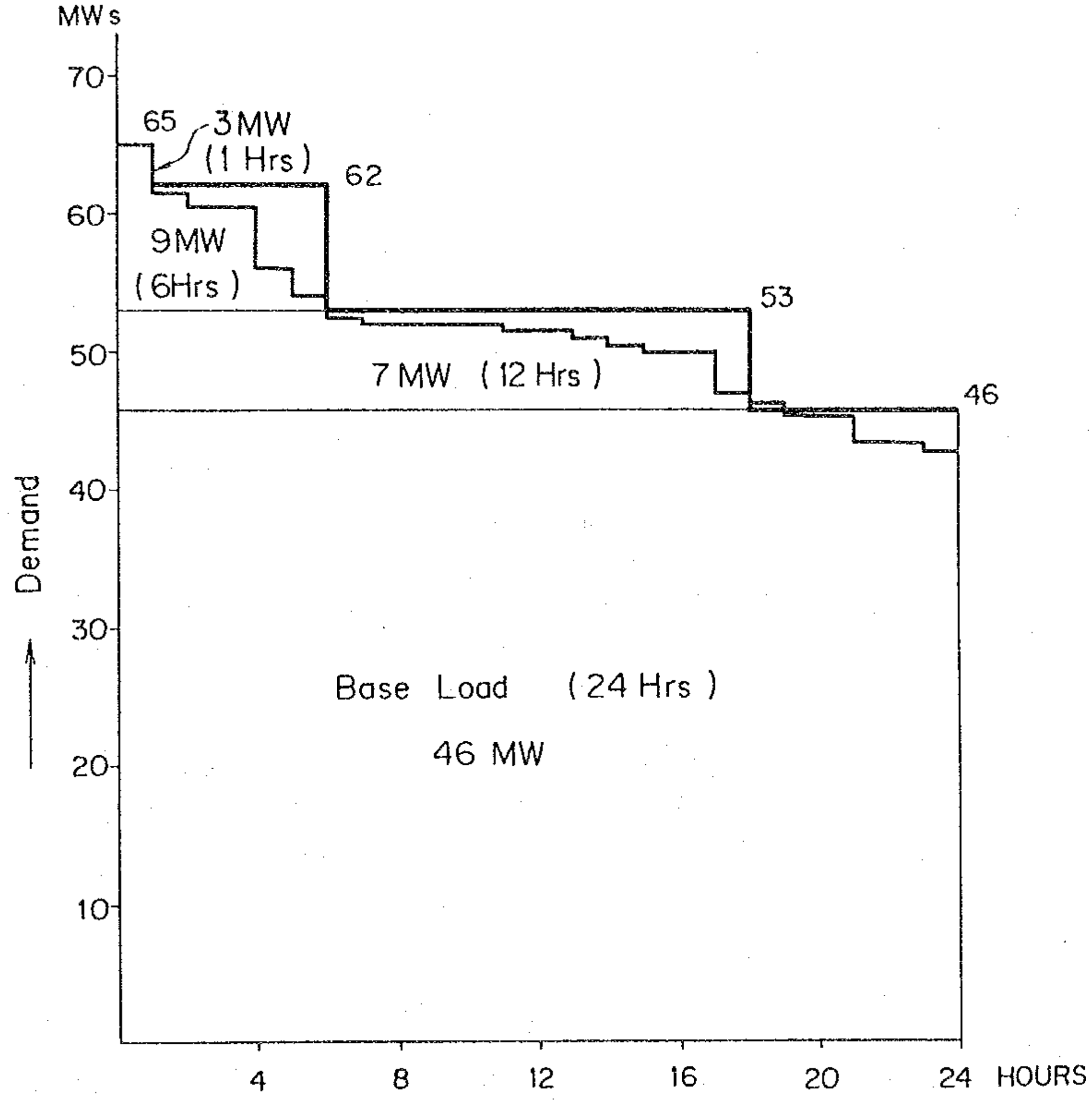
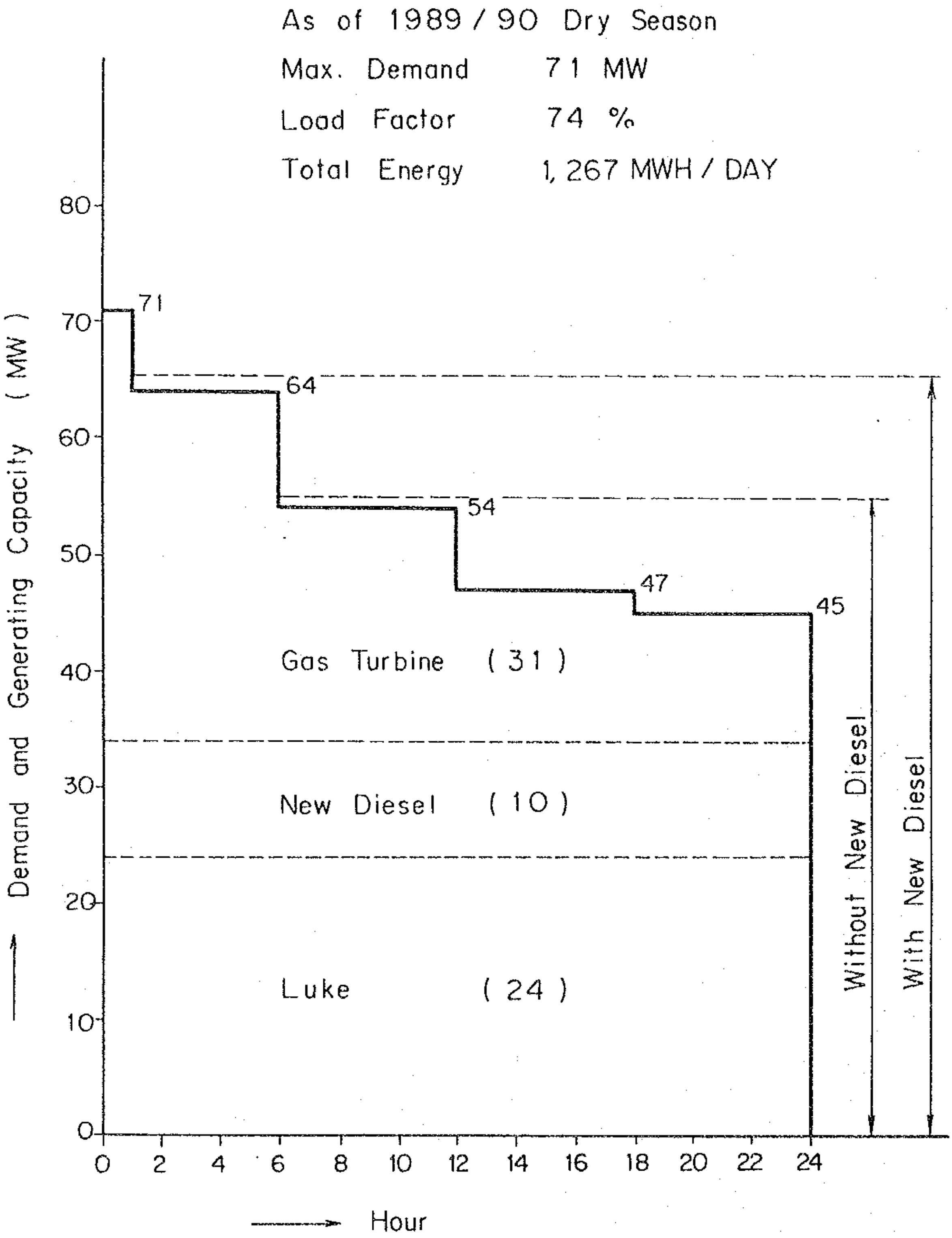


Fig. 3-3 DAILY LOAD DURATION CURVE



at Luke Plant, and a total of 31 MW by 2 generators at Gas Turbine Plant.

Note) As Luke plant shows low reliability, one of the three generators has to be allocated for reserve.

This means that power shortage will occur for 6 hours a day. The power sources that may be used to offset this shortage are:

- Reserved generator at Luke (12 MW)
- Hydroelectric units at Mt. Coffee
- Bong Mining Company

However, the generator at Luke Plant is not a reliable source of power supply because of its unsatisfactory operation. The hydroelectric power source depends on rainfall, and the power supply from BMC at a level higher than the agreement cannot be hoped for. All things being considered, load sheddings may still be unavoidable.

The additional 10-MW power supply under this Project could greatly reduce the power supply shortage time to only one hour, and the operation of diesel units instead of the high-running-cost gas turbines could reduce fuel costs by about US$2.0 million per dry season. The implementation of this Project is therefore considered viable for improving the power supply reliability as well as for reducing power plant operating costs.

Fig. 3-4 shows estimated daily duration curve as of 1992/93. According to Fig. 3-4, further improvement in the reliability will be attainable by the addition of 20-MW diesel units as planned by LEC.

For the reason described above, the 10-MW scale under this Project is considered feasible.

Figs. 3-5 and 3-6 show the expected peak demands and dependable generating capacities of each Plant in the dry and rainy seasons over the next 5 years. They indicate the necessity of installing additional 30-MW diesel engine generators for the dry seasons as planned by LEC.

Fig. 3-4 DAILY LOAD DURATION CURVE

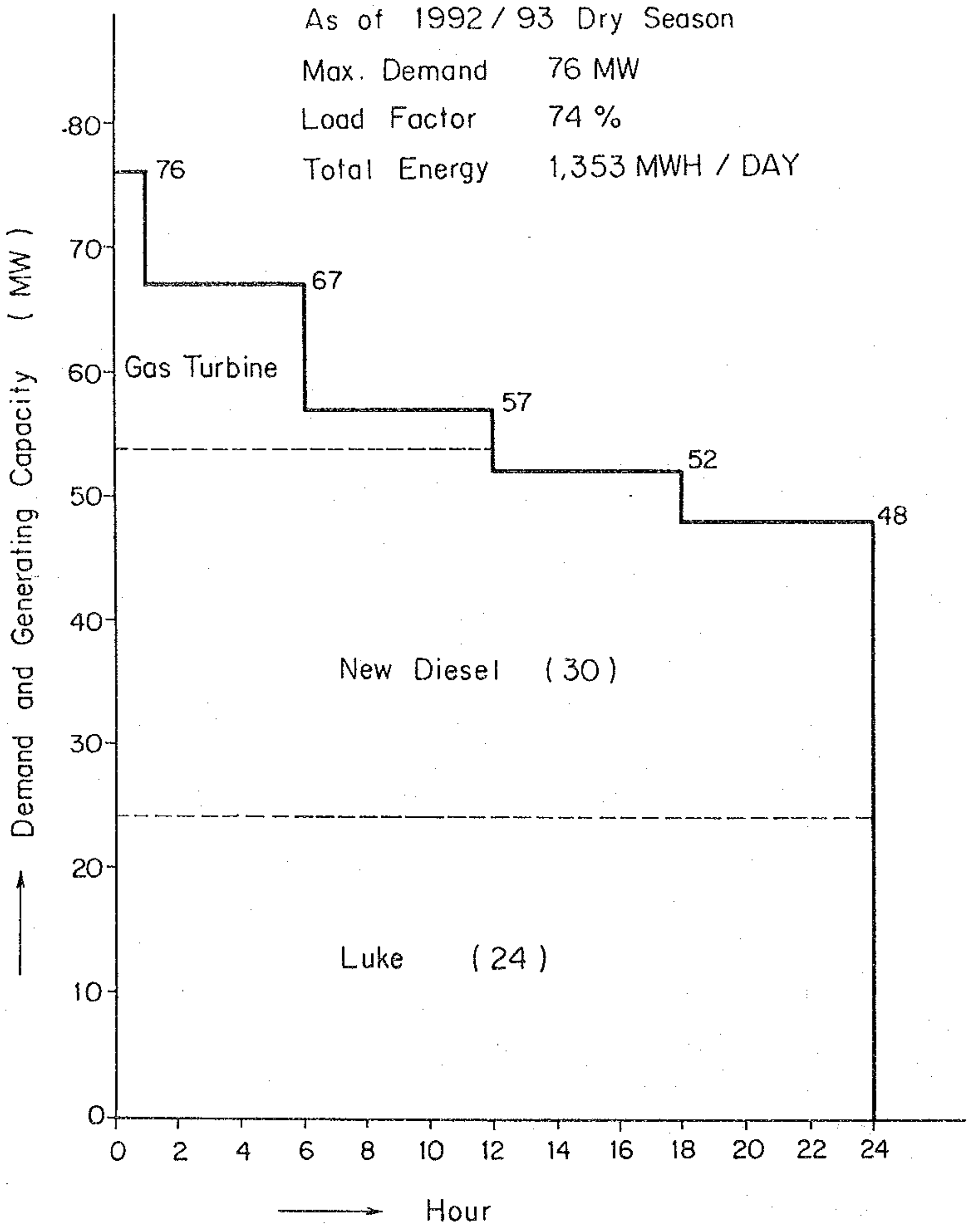


Fig. 3-5 PEAK DEMAND AND GENERATING CAPACITY

(Dry Season - Forecast)

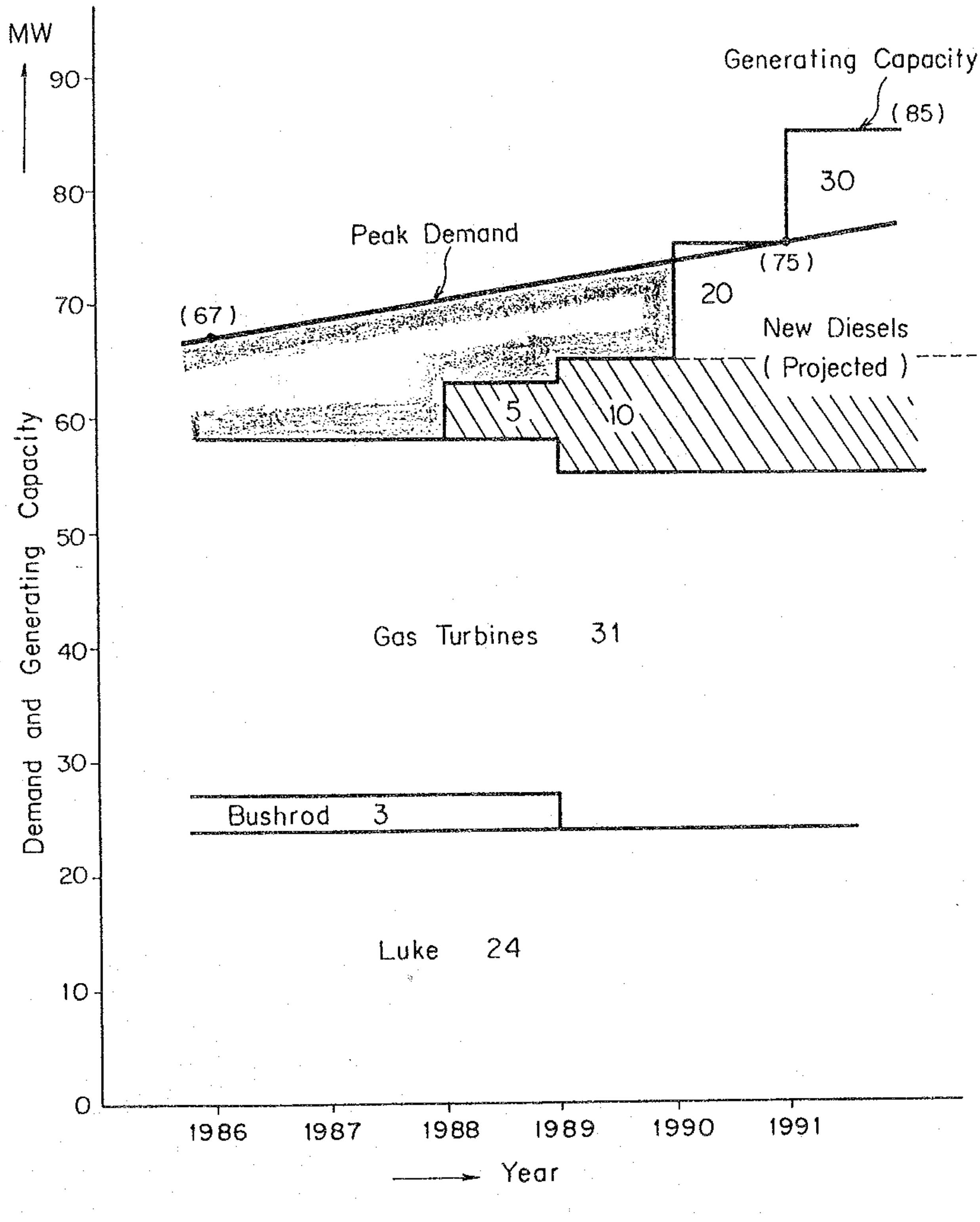
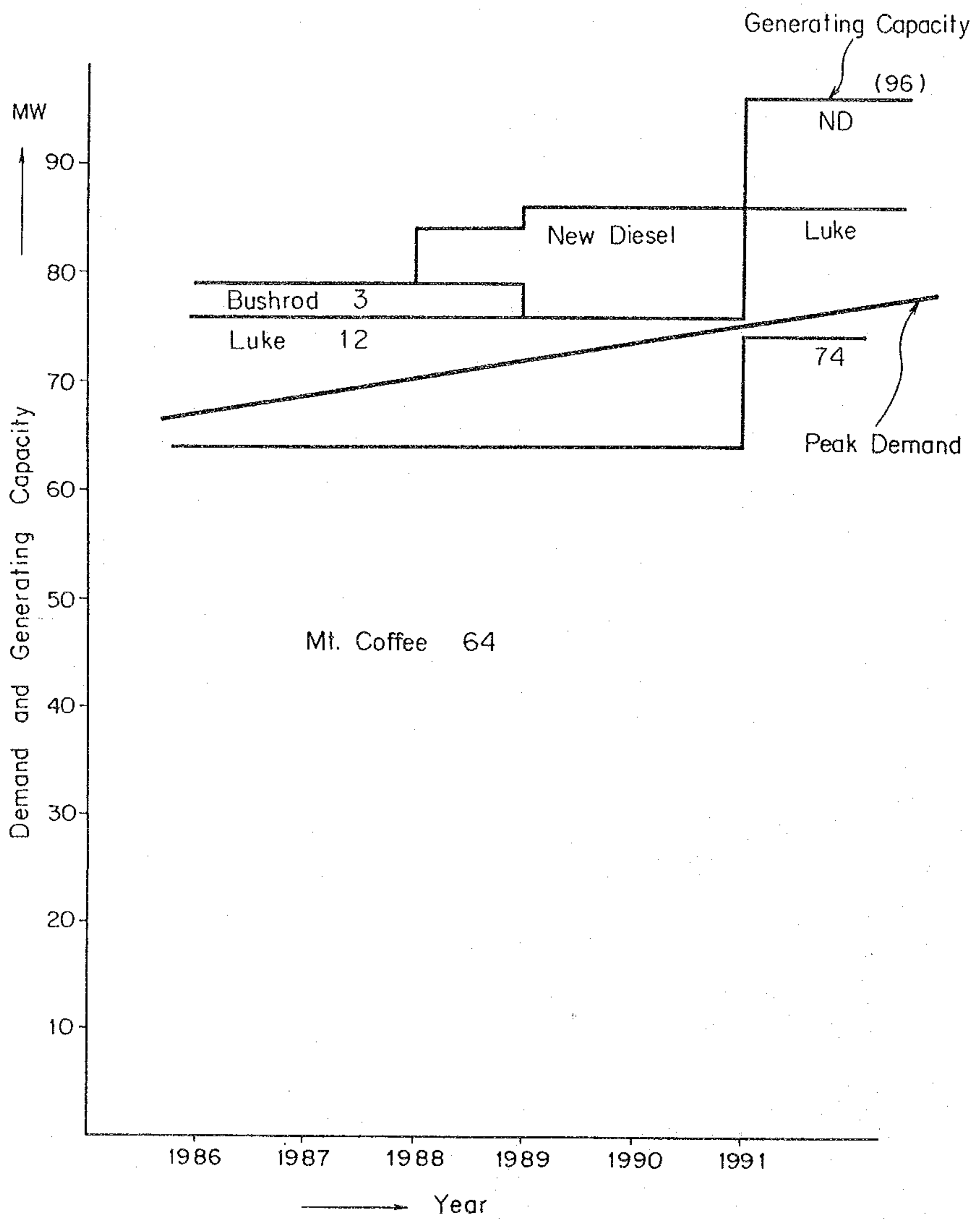


Fig. 3-6 PEAK DEMAND AND GENERATING CAPACITY
(Rainy Season - Forecast)



(2) Selection of generating system

For the 10-MW power generating system, a gas turbine generating system and a diesel engine generating system are possible alternatives in view of the urgency. Since operation and maintenance costs for the gas turbine generating system are expensive, and since LEC regards the alternative as questionable, the selection of a diesel engine generating system is considered appropriate.

(3) Type of engine

Diesel engine for power generation with a running speed of less than 500 rpm are usually called low-speed engines, and those having a running speed between 500 and 1,000 rpm are called medium-speed engines. In terms of their operation cycles, they can be classified into a two-stroke cycle (two cycle) and four-stroke cycle (four cycle) types; and in terms of the arrangement of their cylinders, they can be classified into In-line engine (L type) and Vee engine (V type).

The diesel engines currently operated by LEC are the 277-rpm facility in Bushrod Plant and the 150-rpm engine in Luke Plant. Two low-speed 5-MW units, 2-cycle L-type engines of 150-rpm class, have been requested for the Project by LEC.

Based on the LEC's request for these two units, some major requirements, such as when existing building and foundations will be utilized, or they will not be utilized, are compared in Table 3-1 based on medium-speed 5 MW engine.

When the existing building and foundations are used, the effective use of the existing facilities lisited below will be considered.

(i) Existing building
(ii) Existing foundation
(iii) Existing overhead crane
(iv) The fuel now used at the present Luke Diesel plant will be used.

As for the existing foundations No. 1 through No. 6 at Bushrod Diesel Plant, the No. 2 and No. 3 foundations will be utilized for this Project for the following reasons.

No. 1 Foundation: This foundation should be kept as an installation work area and as a future operations, maintenance and overhaul space, and will not therefore be used as a foundation for this Project.

No. 4 Foundation: This foundation must continue to be used for the supply of parts to the No. 5 and No. 6 Units now in operation. In addition, it is located adjacent to the operating units, and its utilization should therefore be avoided to ensure work safety.

No. 5 and No. 6 Foundations : Although these units are to be retired in 1988, they cannot be removed before the start of operation of the facilities to be installed under this Project.

No. 2 and No. 3 Foundations : These units have already been dismantled and the foundations are free of particular problems.

As can be seen from Table 3-1, low-speed units are physically larger and consequently more expensive than medium-speed units. Newly constructed building and foundations for low-speed units require a large outlay and long-term work beyond the allowable limits of funds and time for this Project. Also, low-speed units are too large to be installed on existing foundations and in the existing building. For

Table 3-1. Comparison between Low-Speed and Medium-Speed Units (2x5-MW Units)

No.		Construction of new building	Utilization of existing building	Utilization of existing building and foundations
1	Output per unit (MW) x number of units	5 x 2	5 x 2	5 x 2
2	Running speed	Low-speed	Low-speed	Medium-speed
3	Estimated efficiency	45%	45%	44%
4	Service life (years)	20	20	20
5	Running costs	100	100	100
6	Whether LEC has experienced or not	Experienced	Experienced	No-experience
7	Construction expences			
	(1) From Grant aid (%)	180	180	100
	(2) At LEC's account (%)	500	200	100
8	Building	To be built	Large scale modification of the existing	Modification of the existing
9	Foundations for engine(s)	To be constructed	Large-scale modification of existing	Modification of the existing
10	Entrance for carry-in the equipment	To be built	Modification	Modification
11	Overhead traveling crane	To be installed	Modification	Modification
12	Term of installation (%)	200	150	100

these reasons, the installation of low-speed 5-MW units is impracticable.

A generating unit with an output capacity can be reduced in size if it can run faster with the same output capacity. Table 3-2 shows a comparison result of some units having a different speed and consequently a different possible application size for the existing building.

Engine of 300 to 400-rpm class are not included in Table 3-2 above, because they are not produced in Japan.

Low-speed engines will be two-cycle, and medium-speed engine will be four-cycle, in consideration of operation and combustion efficiencies. As for the cylinder arrangement, low-speed engines will be L-type, and medium-speed engines will be either L-type or V-type.

The contents of Table 3-2 are summarized as follows.

Low-Speed Engine : Output capacity of about 3 MW. Needs to be disassembled for transportation. Methods of assembling and installation must be considered.

Medium-Speed Engine: Output capacity of about 5 MW. For Type L, assembling and installation practicability must be considered.

Thus, 5-MW engines of medium-speed class (500 to 700 rpm) can be employed.

(4) Output per unit and the number of units

Considering the limitations of use of the existing foundations, the maximum output of a medium-speed engine is approximately 5 MW. The advantages of the FOB price of 2 medium-speed (V) 5-MW engines compared with that of 3 medium-speed (L) 3.5-MW engines and 3 low-speed (L) 3.5-MW engines, all to attain the output of 10-MW level, can be seen in the following table.

Table 3-2. Comparison of Low-Speed and Medium-Speed Units (For installation on existing foundations)

No.	Item \ Running Speed Class (rpm)	150	300 to 400 *	500 to 600	700
1	Cylinder arrangement	L	-	L	V
2	Cycles	2	-	4	4
3	Applicable output (MW)	3	-	5	5
4	Estimated efficiency (%)	45	-	43	44
5	Overhaul cycle (during continuous service) (years)	1	-	1	1
6	General inspection (during continuous service) (months)	4	-	4	4
7	Operation and maintenance cost (%)	100	-	100	100
	1) Number of parts	Small	-	Large	Large
	2) Weight of parts	Heavy	-	Light	Light
	3) Days required for inspection	Many	-	Not	Not
	4) Inspection cost	Hight	-	Low	Low
8	Machine weight (tons)	180	-	110	65
9	Transportation of engine **	Knockdown	-	Knockdown	Assembled
10	Construction cost (%/KW)	200	-	140	100
11	Utilization of existing foundation	Over-weight and over-width		Over-width	No problem

* Running speed class between 300 and 400 rpm is not available in Japan
** In case of approxi. 40 tons trailer will be used

	Medium-speed (V) 5-MW x 2	Medium-speed (L) 3.5-MW x 3	Low-speed 3.5-MW x 3
Electrical	100%	155%	210%
Mechanical	100%	140%	170%
Average	100%	150%	170%

(5) Limitations on individual generator output

The output of individual generators operated in a series in a power supply system is normally limited, depending on the scale of the power supply system, in order to reduce the effection system in the event of a failure of any of the generators.

Generally, the output of an individual unit is limited to 10% or less of the output capacity of the system, though this percentage varies depending on the size of the system. By this limitation, system frequency drop in the event of a failure of a unit is controlled to within 1.5 Hz.

Ten per cent of the system capacity in Monrovia in 1988 amounts to 70 MW x 10% = 7 MW. The 5-MW output of an individual unit is therefore acceptable.

(6) Comparisons of operation and maintenance

LEC has experience in the operation of large, low-speed (150-rpm, 277-rpm) units. Low-speed units are desirable for this reason, though, there is actually little difference in the technical difficulty of operation and maintenance between low-speed and medium-speed units.

Rather, the components of a medium-speed unit weight less and are easier to disassemble and inspect than a low-speed unit having the same output capacity. This applies also to Type-L and Type-V medium-speed units; that is, a Type-V unit has more cylinders but its parts weight less and are smaller in size than a Type-L unit. Consequently, they differ little as far as maintenance is concerned.

As regards the fuel supply system, no problems should arise provided the same fuel system used at the Luke Diesel Plant is employed.

The cooling system to be used in this Project can be simplified relative to that used at the Luke Plant. Whereas seawater is used as the primary cooling water and tap water as the secondary cooling water at the Luke Plant, only tap water will be used with radiators for the cooling system under this Project to simplify maintenance.

Whatever the type of units actually employed, personnel training and instruction in installation, test runs, and operation and maintenance of the units are extreme importance and therefore due consideration must be given during implementation of the Project.

(7) Summary

The above studies on the engines are summarized as follows,

i)	Installation location	:	In the building at Bushrod Plant
ii)	Engine foundations	:	Existing No. 2 and 3 Foundations
iii)	Type of generation	:	Diesel engine generators
iv)	Output/unit x number of units	:	5 MW x 2 units
v)	Running speed of units	:	Medium-speed

The advantages of the Type-V cylinder arrangement can be seen from Table 3-2.

The results of the comprehensive studies with due consideration given to the operating conditions at site are shown in ANNEX-6.

3.3 OUTLINE OF THE PROJECT

3.3.1 Operation and Maintenance Organization

Operation and maintenance organization of the existing Bushrod Diesel Power Plant is currently operated under the same administration system of Luke Diesel Power Plant as outlined in 2.5.5. This administrative dependence of Bushrod Plant on Luke Plant seems to be due to its small generating capacity and its comparatively short operating time. The operation and maintenance system of the Bushrod Plant, however, will need to be reassessed because the power generating facilities, once put in operation under this Project, will have an important role to play in the power supply system.

In fact, LEC now plans to reorganize the Bushrod Plant administration system so that the new Bushrod Diesel Power Plant, equipped with the generating facilities under this Project, may be operated and maintained independently of Luke Plant.

It will be necessary, therefore, to assign the administration, operation and maintenance staff in charge of the new facilities with on-the-job training so that they can acquire the sufficient knowledge and skills, and also necessary to provide them technical instruction from Japanese experts for some time following the commencement of the operation of the facilities as presently practiced in Luke Diesel Plant.

3.3.2 Outline of Equipment to be Provided

The particulars of the equipment to be provided in grant form are as outlined below.

		1st Phase	2nd Phase	Total
(1)	Diesel engine	1 unit	1 unit	2 units
(2)	Engine control device	1 unit	1 unit	2 units
(3)	Air compressor	1 set	1 set	2 sets
(4)	Fuel feeder	1 set	1 set	2 sets
(5)	Cooling system	1 set	1 set	2 sets
(6)	Exhaust system	1 set	1 set	2 sets
(7)	Generator	1 unit	1 unit	2 units
(8)	Exciter	1 unit	1 unit	2 units
(9)	Switchboard for monitor and control panel	1 set	1 set	2 sets
(10)	Step up transformer	-	1 unit	1 unit
(11)	Station service transformer	1 unit	-	1 unit
(12)	Station service equipment	1 set	1 set	2 sets
(13)	DC power equipment for controls	1 set	-	1 set
(14)	15 kV switchgear	5 units	1 unit	6 units
(15)	72 kV circuit breaker	-	1 unit	1 unit
(16)	Power cable and fittings	1 set	1 set	2 sets
(17)	Spares, tools, etc.	1 set	1 set	2 sets
(18)	Control room air conditioner	-	1 set	1 set

The project incorporates the plant for utilizing the following existing equipment.

(1) Generator house (including control room)

(2) Overhead traveling crane

(3) Fuel storage tank

(4) Cooling water (tap water)

The locations of the existing equipment relevant to this Project and the layout of the facilities provided under this Project are shown in Fig. 2-9.

A fuel oil piping diagram and a cooling water piping diagram of the existing power plant, and the locations where branching from these pipings can be made for facilities provided under this Project, are shown in attached Fig. 3-7 and 3-8.

3.3.3 Outline of the Site

(1) Bushrod power plant

The Bushrod Power Plant in which the facilities are to be installed under this Project, is located on Bushrod Island to the north of central Monrovia. The Station site has residental quarters on its east and north sides, an industrial area on its south side, and the Atlantic Ocean on the west. The Bushrod Power Plant includes thermal power plants to supply power during dry seasons, the Bushrod Diesel Plant, the Luke Power Plant, and a Gas Turbine Plant, all located in one central area. The power generated by these plants are transmitted through the 69 kV step up transformers and the Monrovia power supply network.

The Power Plant, having its customers in nearby districts, is located about 3 km from the Monrovia Port, from which heavy articles can be easily transported to the Power Plant. The Plant has an area wide enough to keep the completely free from environmental problems such as noise, vibration and exhaust gases. The Plant is thus ideally placed.

(2) Monrovia Port

The Monrovia Port, where materials supplied under the Project will be landed, is situated adjacent to the urban districts of Monrovia. The port, the largest one in Liberia, serves as the main entrance port for foods, general commodities, machines and other imports from overseas. It is also the export port for iron ore produced in the country. The port facilities are under the control of the National Port Authority of Liberia.

(3) Roads

The roads from the Monrovia Port to the Bushrod Power Plant are fully paved and 4-lane. There are no bridges along the course except one point the road runs beneath a railway bridge (vehicle height limit: approx. 5.4 meters). However for the transportation of heavy equipment, this bridge will not be an obstacle because a bypass is available.

3.3.4 Transfer of Technology

The staff to operate and maintain the facilities provided under this Project are required to have adequate technical knowledge, skills and experience. The technical training of the staff, therefore, is indispensable. During the term of the construction work, the Liberian technical staff will need to be given on-the-job training for routine operation and maintenance of the facilities by the engineers of the contractor.

When the Basic Design Study Team visited the Republic of Liberia, the latter expressed its desire to have Japanese experts sent from Japan and to have their Liberian counterparts trained in Japan. Implementation of this type of cooperation might not be completed within the term specified by E/N. Therefore, it will be necessary to take appropriate measures to meet the requests of the Republic of Liberia.

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4.1 BASIC DESIGN CONCEPT

4.1.1 Basic Design Concept

Through the basic design work for the Project, the basic policy shall be to set up an economical plan by removing the existing ancillary facilities as far as practicable, and by utilizing the present foundations from which the above-mentioned facilities are removed to install new generating units within the existing generator house while taking into consideration refitting and renewal plans to be set up in the future.

The Principal items to be utilized for this Project from among the existing facilities are listed as follows:

(1) Concrete foundations for engines and generators

The installation of a medium-speed 5-MW diesel generating units on existing foundations involves the two choices as shown below:

- Medium-speed, V-type engine (class of 720 rpm)
- Medium-speed, L-type engine (class of 500 to 600 rpm)

If these engines are installed on the existing foundations, the weight and dimensions of the V-type engine will not cause any problems. However, the L-type engine may be installed, provided its weight is within the upper weight limit. But, it will have some problems because of its overall dimensions. (See the ANNEX-7)

(2) Generator house (including control room)

Since this Project is rehabilitation and reinforcement of obsolate Fairbanks-Morse generators (installed in 1961), it is important to determine the most practicable method of delivering the generators to the site for this Project.

Ideally, the diesel engines should be delivered to the site with all the necessary accessories equipped, without being disassembled after they have been subjected to performance tests at the manufacturer's factory.

This will mean assembling and installation work must be carried out at the said factory. It will also shorten the adjustment and testing period, and minimize the occurrence of the initial troubles which sometimes occur immediately after commissioning.

Since it is expected that 5-MW medium-speed V-type engines will be employed in this Project, it will be possible to transport the equipment by separating it into three sections, namely, the diesel engine main body, generator, and common frame.

It is impossible to deliver the diesel engine main body, the largest of the three, through the existing entrance of the generator house (see the attached Fig. 2-11) and so it is necessary to provide a new entrance.

As described in the Minutes of Discussion, the preparation of the entrance and its recovery to its original state are regarded as undertakings and responsibilities of Liberian authorities. Concrete procedures include removal of the side walls in the suction and discharge sides of the engines No. 2 and 3 when delivering a new engine No. 3 and recovery of them after completion of the delivery.

A new No. 2 engine shall be delivered through the side wall between the existing engines No. 1 and 2. The dimensions of the entrance which is required for delivering the new diesel generator into the generator house should be 3.5 m wide and 5.0 m high. The generator should be so designed to utilize the existing anchor bolts, but minor renovation may be made if required.

Arrangement of equipment and instruments in the control room should be determined by taking the possibility for future development into full consideration.

(3) 10-ton overhead traveling crane

An existing overhead traveling crane with a lifting load of 10 tons and a hook-lifting height of approximately 6 m from the floor surface should be used for assembling and inspecting the grant-aid facilities. It is necessary, therefore, to ensure smooth operation and maintenance of these when designing them.

This crane may be used for overhauling, inspection, and maintenance of a 5-MW medium-speed diesel engine. It should have no problems after commissioning. If an L-type medium-speed diesel engine is chosen, however, the main part of the engine cannot be transported in a fully equipped state, and it will be necessary to use a larger crane for assembling it on site because the existing crane does not meet the requirements of allowable load and allowable hook moving distances.

Moreover, some of the electric parts of the existing crane which was installed 25 years ago should be replaced to ensure safe operation during the overhauling and maintenance of the engine after commencement of running as well as during the installation of the engines.

(4) Fuel storage tank

The equipment supplied by the grant aid involve a change from the existing diesel oil-firing type to the heavy oil-firing type now in use in the Luke Diesel Plant.

Both heavy oil and diesel oil should be stored in the following storage tanks which are also presently used for the Luke Diesel Plant and the Gas Turbine Plant.

Heavy oil tank	:	574,100 U.S.Gal.	(approx. 2,173 kl)	x 2
Diesel oil tank	:	50,000 U.S.Gal.	(approx. 189 kl)	x 2
Diesel oil tank	:	864,000 U.S.Gal.	(approx. 3,270 kl)	x 1
Reserve tank	:	410,738 U.S.Gal.	(approx. 1,554 kl)	x 1

Even assuming that hydraulic and thermal power plants share an estimated power demand of 473 GWh in 1990 (as per the LEC's 5-year plan report), there will be no need to construct a new storage tank. This is because the capacity of the heavy oil tank meets about one month's demand and that of the diesel oil tanks meets about 2.5-month's demand. An added reason is that the tanks of the Liberia Petroleum Refining Company are installed adjacent to the Port of Monrovia.

(5) Ancillary facilities

The existing Bushrod diesel plant was built between 1961 and 1963. The ancillary facilities are so obsolete that it is difficult to keep the required reliability of the generating facilities.

Therefore, following facilities should be newly provided as the power source for auxiliary units, DC control power, 12.5 kV switchboard for AC power system, and step up transformers, and so on.

Since the Project involves the renewal of the Fairbanks-Morse units, the generating system, the connections to the power system, and other installations remain virtually the same as those of the existing units, as illustrated in Fig. 2-10 and Fig. 4-1.

4.1.2 Design Conditions

(1) Climatic conditions (Monrovia City)

Atmospheric temperature:

Max. temperature	42°C
Mean value of max. temperature	30°C
Min. temperature	21°C

Relative humidity:

Max. humidity	100%
Min. humidity	70%
Mean value	74%

Atmospheric pressure

Altitude = EL 3 m	1,013 mb

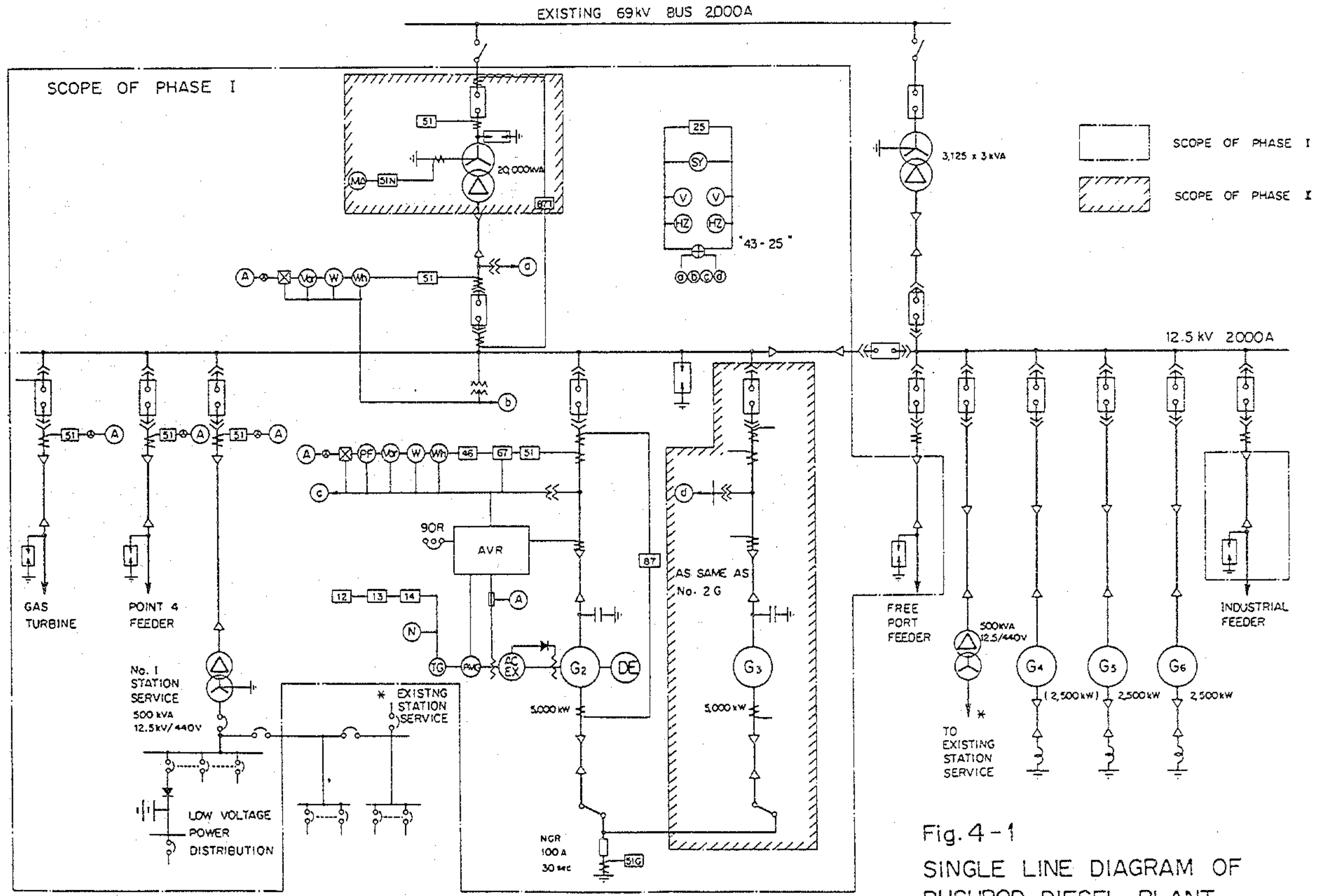


Fig. 4-1
SINGLE LINE DIAGRAM OF
BUSHROD DIESEL PLANT

Precipitation

Max. during a year	950 mm
Max. during a month	620 mm
Max. during an hour	50 mm
Wet season	May to October

Winds

Wind direction (dry season)	East
Wind direction (wet season)	North
Max. velocity	34 m

There is no need to consider seismic factors in designing the facilities.

It is necessary to take measures to protect the facilities from damage by salty wind, when designing.

(2) Fuel composition

The fuel composition presently adopted in the Bushrod Powr Plant is shown below:

a) Diesel oil (equivalent to JIS heavy oil A)

Specific gravity, A.P.I.	82 - 41
Viscosity, SUS at 100 F	32 - 45
Flash point, °C	> 66
Sulfur content, %wt	< 1.0
Water content, %vol	< 0.05
Sediments, %wt	< 0.01
Calorific value, kcal/kg	10,200
Cetane number	> 45%

b) Heavy oil (equivalent to JIS heavy oil C)

Specific gravity, at 15°C	0.965
Viscosity, CTS/50°C	130 - 160
Flash point, °C	> 60
Sulfur content, %wt	< 4.0

Water content, %wt	< 1.0
Ash content, %wt	< 0.12
Vanadium, ppm	< 150
Sodium (natrium), ppm	< 25
Asphalt, %wt	< 3
Aluminium, ppm	< 30

(3) Composition of cooling water

The cooling water presently used in the Bushrod Diesel Power Plant is supplied from the Liberia Water and Sewerage Corporation. The analytical data of the water are shown below:

pH at 25°C	8.2
M alkalinity	20.0 ppm
Electric conductivity	81.7 micro mho/cm
Chloride	10.0 ppm
Total hardness	26 ppm
Water temperature	29°C
Water pressure (at Bushrod)	1.0 - 2.0 kg/cm^2

(4) Applicable standards

The below-mentioned Japanese standards should be applied mainly when designing the grant-aid equipment:

Japanese Industrial Standards (JIS)
Japanese Electro-technical Committee Standards (JEC)
Japanese Electrical Manufacturer Association (JEM)
Japan Cable Maker's Association Standards (JCS)

4.2 BASIC DESIGN

4.2.1 Engine Output and Generator Capacity

Based on the rated output of 5 MW of the generator, the required engine output and rated capacity of the generator are calculated as follows: